The Construction Model of "Virtual-Real Integration" and Operational Effectiveness Evaluation of Practical Training Bases in Vocational Undergraduate Education

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Abstract: *As a key carrier connecting higher education and vocational education, the core competitiveness of vocational undergraduate education is mainly embodied in practice teaching ability, and its training bases are the core support for implementing practice teaching. Conventional entity-based training bases face some problems such as low resource utilization rate, difficulty in simulating high-risk scenarios, and insufficient inter-disciplinary collaboration. The model of "virtual-real integration" provides feasible solutions to these problems through the deep integration of virtual simulation technology and entity-based training resources. This paper departs from the "high-skilled and high-level" talent development objectives in vocational undergraduate education, analyzes the construction logic of the training bases of "virtual-real integration", constructs a three-level construction model of "resource level-teaching level-collaboration level", and explores the evaluation system of its operational effectiveness from three dimensions: teaching adaptability, resource utilization rate, and skill transformation effect, aiming to provide theoretical reference and practical paradigms for the high-quality construction of training bases in vocational undergraduate education.*

Keywords: *Vocational Undergraduate Education; Practical Training Bases; Virtual-Real Integration; Construction Model; Operational Effectiveness Evaluation*

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1.Introduction

Vocational undergraduate education aims to develop high-level technical talents with solid theoretical foundation, exquisite professional skills and strong innovation ability. Its essential characteristics determine that practice teaching needs to break the conventional model of "theory + simple operation" and move towards an advanced stage of "complex scene simulation, integrated skill application and vocational competency rehearsal". As the "first classroom" of practice teaching, the construction quality of training bases directly affects the quality of talent development. However, at present, most training bases in vocational colleges and universities still mainly rely on entity-based resources and are confronted with practical predicaments, for example, updating of high-cost equipment lags behind industrial technology iteration, the training scenarios of high-risk industries cannot be truly reproduced, and it is difficult to share cross-regional and inter-disciplinary training resources.

2.The Construction Logic in the Practical Training Bases of "Virtual- Real Integration" in Vocational Undergraduate Education

The talent development objectives in vocational undergraduate education determine that the construction of training bases needs to take into account both "theoretical depth" and "skill precision". The main logic of the model of "virtual-real integration" lies in achieving seamless connection between practical training teaching and job demand through the bidirectional interaction of "the virtual complementing the real and the real verifying the virtual".

From the demand side, industrial upgrading has given rise to the demand for talents that can solve complex technical problems and adapt to rapid technology iteration. For instance, in the field of intelligent manufacturing, the operation and maintenance of industrial robots require students not only to grasp solid theoretical knowledge about mechanical structures and control systems, but also to have hands-on ability in fault diagnosis and programming debugging. However, in entity-based training, the high-load operation and complex fault simulation of robots are not only costly but also pose safety risk. Virtual simulation can create "whole-scene, risk-free, and repeatable" training environment, and allow students to repeatedly practice the troubleshooting process of complex faults in the simulation, and then verify the accuracy of the operation through entity-based training, forming a complete learning closed loop of "cognition-simulation-practical operation-internalization" [1].

From the supply side, there is a dual contradiction of "insufficient total quantity" and "unbalanced structure" in the training resources of vocational colleges and universities. On the one hand, training equipment for some majors is high in unit price and is updated frequently, making it difficult for colleges and universities to bear the cost of large-scale procurement. On the other hand, conventional entity-based training bases are mostly divided by majors, with obvious resource barriers, making it difficult to carry out inter-disciplinary synergistic training. The model of "virtual-real integration" can reduce the reliance on physical devices through the "infinite replicability" of virtual resources, and break down resource barriers through the "inter-disciplinary integration capability" of virtual platforms to achieve the linkage of training scenarios of different majors and developing students' systematic thinking and collaborative ability. From the perspective of teaching, practice teaching in vocational undergraduate education needs to break the conventional "teacher-centered and operation-oriented" model, and shift towards high-level teaching that is "student-centered and problem-solving-oriented" [2]. Virtual simulation technology can transform abstract theoretical knowledge into concrete training tasks through "contextual design". For instance, students majoring in in engineering cost can build three-dimensional building models through virtual platforms to simulate cost accounting and progress control management under different construction schemes, and independently identify and resolve technical conflicts during construction. Entity-based training can focus on "precision verification", enable students to implement the virtual design schemes into physical models, compare the deviations between the virtual models and the physical models, and deepen their understanding of theoretical knowledge and precise control of skills.

3.The Three-Level Construction Model of "Virtual-Real Integration" for the Practical Training Bases in Vocational Undergraduate Education

3.1 *Resource Level: Building a "Virtual-Real Complementary, and Dynamically Adaptive" Resource System*

The resource level is the foundation of training bases of "virtual-real integration". Its core lies in achieving exact match and dynamic update between virtual resources and physical resources, and avoiding formal construction of "virtual for the sake of the virtual". In the construction of virtual resources, it is necessary to follow the "industry-oriented and problem-driven" principle, and focus on "high-risk, high-cost, and high-complexity" scenarios that physical resources cannot cover [3]. For instance, the school of automotive maintenance & detection can develop a virtual module for "Fault Diagnosis of Engine Electronic Control System" to simulate over 20 complex fault scenarios such as sensor failure and line short. Students can read fault code, analyze data streams, and make maintenance plans through virtual operation. The school of architectural engineering technology can construct a virtual scene of "whole-process high-rise building construction" to cover key links such as retaining and protection of foundation excavation, pouring of concrete, and installation of steel structures. Students can observe the construction process from a "God's perspective" or switch to a "worker's perspective" to complete specific operation.

3.2 *Teaching Level: Establishing a Teaching System with "Virtual-Real Interaction, and Progressive Ability Development"*

Teaching level is the core of training bases of "virtual-real integration". It is necessary to break the status quo where "virtual training is divorced from entity-based training", and build a teaching process based on "progressive ability development" to achieve a teaching closed-loop of "virtual preview-entity-based operation-virtual review". In the design of learning objectives, it is necessary to divide the practical training objectives into three levels: "basic skills-integrated skills innovation skills" in accordance with the "hierarchical requirements" for the development of vocational talents. The basic skills level centers on "transforming theory into operation", and enabling students to master normative operation procedures through virtual training. For instance, students majoring in mechatronics can learn the basic instructions of PLC programming through virtual platforms and complete simple motor control tasks. Entity-based training verifies the correctness of programming logic and develops normative operation. The integrated skills level centers on "solving complex problems", and enables students to tackle tasks with multiple factors of interference through the interaction of "virtual scenarios + physical verification". The innovation skills level centers on "technological improvement and scheme optimization", and enables students to conduct innovative experiments through the "parameter adjustability" of virtual platforms [4].

In the teaching implementation process, it is necessary to adhere to the "student-centered" philosophy and employ the "task-driven" teaching method. Before class, teachers arrange "preview tasks" through virtual platforms. Students independently study the theoretical knowledge related to practical training and complete the basic operation of virtual simulation. The platforms automatically record students' learning data, and teachers adjust the focus of classroom teaching based on the data. During the class, students are divided into groups based on "real job tasks". They first fulfil the "scheme design" (such as making equipment maintenance plans and construction schemes) on the virtual platforms, and then evaluate each other's schemes among the groups. Then, in the entity-based practical training, the schemes are implemented, and teachers provide guidance on the problems encountered in the practical operation. Finally, they return to the virtual platforms for a "review and summary". By replaying the comparison videos between virtual operation and entity-operation, they can analyze the reasons for the deviations and optimize the operation procedures. After class, the virtual platforms open up "extension tasks". Students can independently choose complex scenarios for intensive training. The entity-based training bases offer "appointment-based" practical operation services to meet students' personalized learning needs.

3.3 *Collaboration Level: Constructing a Guarantee System Featuring "Symbiosis Between Schools and Enterprises, and Multi-Stakeholder Participation"*

Collaboration level serves as the support for the training bases of "virtual-real integration". It is necessary to break the construction model of "fighting alone" and establish a multi-stakeholder synergistic guarantee mechanism involving "schools, enterprises, and industry associations" to ensure that the construction direction of the training bases is consistent with industry demand and its operational effectiveness continuously improves.

In terms of the synergy among construction main bodies, it is necessary to clarify the authority and responsibility of all stakeholders and build a "co-construction and sharing" mechanism. Colleges and universities are responsible for the site construction, teaching management and talent development of the training bases, while enterprises provide authentic industrial cases, technical norms and equipment support. For instance, the training bases of intelligent manufacturing can cooperate with local leading manufacturing enterprises to transform the production line data of the enterprises into virtual training scenarios, and enterprise engineers can participate in the development of virtual resources and practical training teaching. Industry associations are responsible for making the construction standards and evaluation criterion for the training bases of "virtual-real integration". For instance, they should set technical indicators for virtual training modules and configuration standards for entity-based training equipment to prevent "homogeneous" and "low-level" construction in educational institutions. In terms of operational management collaboration, it is necessary to establish a "School-Enterprise Joint Management Committee" to be responsible for the daily operation and resource allocation of the training bases. The committee is composed of college teachers, enterprise engineers and industry experts. It holds regular meetings to discuss the update demand of practical training resources and the optimization directions of teaching schemes. Meanwhile, it is necessary to establish "resource sharing platforms" to connect virtual training resources with the technical training resources of cooperative enterprises. Students from colleges and universities can learn the pre-job training courses of enterprises, and employees of enterprises can also use the entity-based training equipment of colleges and universities to carry out skills improvement training, achieving the bidirectional flow of "teaching-training" resources and improving the utilization rate of training bases. In terms of the synergy of talent development, it is necessary to implement a “dual-mentor system”, meaning that each student is assigned both a “school mentor” and an “enterprise mentor”. School mentors are responsible for theory teaching and virtual training guidance, while enterprise mentors design training tasks and guide physical operation based on the job demand in the industry.

4.The Operational Effectiveness Evaluation System for the Practical Training Bases of “Virtual-Real Integration” in Vocational Undergraduate Education

4.1 *Focusing on the “Matching Degree Among Practical Training, Learning Objectives, and Industry Demand”*

Teaching adaptability is the key to evaluating whether a training base can support the talent development objectives. It should be evaluated from two aspects: “the matching degree of teaching objectives” and “the matching degree of industry demand”.

In the evaluation on the matching degree of teaching objectives, it is necessary to employ a combination of the “course benchmarking method” and the “student feedback method”. The “course benchmarking method” assesses whether virtual and entity-based practical training can cover the core knowledge points and skill points of the course by analyzing the corresponding relation between practical training modules and the course syllabus. For instance, in the school of Mechanical Design, Manufacturing and Automation, it evaluates whether the practical training of “Mechanical CAD virtual design + physical model making” can cover core content such as “part design and assembly technology”. The “Student feedback Method” collects students’ evaluations on the correlation between practical training content and theoretical knowledge of the course through questionnaires and group interviews, such as “whether practical training tasks can help students understand the theoretical knowledge learned in class” and “whether the alignment is smooth between virtual and entity-based practical training”, and determines the matching degree between practical training content and learning objectives through qualitative analysis.

4.2 *Focusing on the “Optimal Allocation Effect of Virtual and Physical Resources”*

Resource utilization rate is the key to evaluating the economic efficiency of training bases, and it should be evaluated from three aspects: “frequency of resource utilization”, “resource sharing rate”, and “cost saving rate”. In terms of the evaluation on resource utilization frequency, the operation data on virtual platforms and the appointment records in the entity-based training bases are collected to analyze the utilization of resources. The utilization frequency of virtual resources can be measured by indicators such as “module visit times” and “average usage time per person”. In the evaluation on the resource sharing rate, the focus is on assessing the effect of inter-disciplinary and cross-subject resource sharing. The inter-disciplinary resource sharing rate is measured by “the proportion of different majors to use the same virtual/physical resources”, for example, “the usage proportion of the intelligent manufacturing virtual platform among the mechanical, electrical, and software majors”. The cross-subject resource sharing rate is measured by “the usage proportion of practical training resources between enterprises and other institutions”. In the evaluation on cost-saving rate, the economic efficiency of resource allocation is assessed by comparing the input cost of the model of “virtual-real integration” with that of the conventional physical model. Cost saving is mainly embodied in three aspects: “equipment procurement cost”, “equipment maintenance cost”, and “practical training consumables cost”.

4.3 *Focusing on “Students’ Ability to Transfer Skills from Practical Training into Job Positions”*

The effect of skills transformation is the core for evaluating the quality of talent development in training bases, and it needs to be evaluated from three aspects: “skills mastery”, “skills application ability”, and “employment competitiveness”. In terms of the evaluation on the mastery of skills, it is necessary to adopt a combination of practical operation assessment and virtual assessment. Practical operation assessment evaluates the standardization, accuracy and efficiency of students’ operation by having them finish designated entity-based training tasks, such as “completing the troubleshooting and repair of industrial robots within the prescribed time”. Virtual assessment evaluates students’ ability to tackle complex scenarios through “contextual assessment” on virtual platforms. For instance, “In a virtual intelligent manufacturing production line failure scenario, assessment can be conducted on whether they can quickly locate the problem and make a solution”. By combining quantitative scoring with qualitative evaluation (such as the rationality of the solution), it comprehensively assesses students’ skills mastery. In terms of the evaluation on skills application ability, it is assessed through “project practice + enterprise internship”. In the project practice, students are asked to complete comprehensive practical training projects in groups. The evaluation can be conducted on whether they can combine the design competency they have mastered in virtual training with the operational skills they have acquired in entity-based training to complete project development. During the enterprise internship, the evaluation of enterprise mentors can let teachers know whether students can apply the practical training skills to actual work.

5.Conclusion

The construction model of “virtual-real integration” for the training bases in vocational undergraduate education can effectively breaks through the resource bottleneck and teaching limitations of conventional entity-based training bases through a three-level framework of “complementary resource level, interaction of teaching level, and guarantee of collaboration level” to provide strong support for the development of high-level technical talents. Their operational effectiveness evaluation system departs from three dimensions: “teaching adaptability, resource utilization rate, and skills transformation effect”, achieve comprehensive and precise evaluation on the construction quality of the training bases, and avoid the misunderstanding of “emphasizing construction over evaluation”.

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