Implementation Pathways for Virtual Simulation Technology in Vocational Bachelor's Mechanical Engineering Courses

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Abstract: Vocational bachelor's education aims to cultivate high-caliber technical talent. Mechanical Engineering, a theory-applied discipline, suffers from challenges, such as limited practical training scenarios, difficulty in conducting high-risk machine operation, and disconnection between theory and practice, in traditional course teaching, which hinders the quality improvement of talent cultivation. Virtual simulation technology provides effective support for addressing the aforementioned challenges with its merits of immersive experience, repeatable operation, zero risk and low cost. Based on the teaching characteristics and talent cultivation requirements of vocational bachelor's Mechanical Engineering courses, and aligned with the applied merits of virtual simulation technology, this paper deeply explores the specific implementation pathways of virtual simulation technology in Mechanical Engineering courses, optimizes the course teaching system, promotes the deep integration of theory teaching and practice teaching, and enhances students' engineering practical competencies, innovative thinking and position-fit competency, offering reference for the curriculum reform of vocational bachelor's Mechanical Engineering courses.

Keywords: Vocational Bachelor's Education; Mechanical Engineering; Virtual Simulation Technology; Implementation Pathways; Curriculum Reform

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1.Introduction

Virtual simulation technology, as an important support for promoting the reform in vocational bachelor's Mechanical Engineering courses and improving the quality of talent cultivation, aligns highly with the teaching characteristics and talent cultivation demands of vocational bachelor's Mechanical Engineering courses. At present, virtual simulation technology still faces challenges, such as inadequate resource alignment, monolithic teaching models, insufficient teaching competencies, and undeveloped evaluation systems, which restrict the full realization of its enabling value. By establishing a virtual simulation resource system that aligns with job requirements, innovating integrated teaching models, strengthening the construction of faculty teams, and refining the targeted evaluation system, etc., these implementation pathways can effectively solve teaching problems, promote the deep integration of virtual simulation technology and Mechanical Engineering courses, optimize the talent cultivation models, enhance students' engineering practical competencies, innovative thinking and position-fit competency, and catalyze vocational bachelor' Mechanical Engineering programs to cultivate more high-caliber technical talent that meets the high-quality development requirements of the manufacturing industry.

2.The Compatibility of Vocational Bachelor's Mechanical Engineering Courses with Virtual Simulation Technology

2.1 *Teaching Characteristics of Vocational Bachelor's Mechanical Engineering Courses*

Unlike regular bachelor's Mechanical Engineering courses that emphasize theoretical research, vocational bachelor's Mechanical Engineering courses are oriented by job requirements, and give priority to the teaching philosophy of "functional theory with practice immersion". The curriculum design aligns closely with the core competency requirements of mechanical manufacturing, equipment operations and maintenance, product design, and other positions. The course content integrates theory and practice. It not only includes fundamental theoretical knowledge, such as mechanical drawing, material mechanics, and mechanical design, but also covers practical competency training such as machining, equipment debugging, and fault diagnosis. During the teaching process, emphasis is placed on the practicality and operability of knowledge, with a focus on cultivating students' capability to apply theoretical knowledge to solve real-world engineering problems. Students are required to possess strong position-fit competency and professionalism. However, there are prominent problems, such as disconnection between theory and practice, insufficient practical training resources, and monolithic practical training models in current course teaching, failing to adequately meet the cultivation needs of applied talents.

2.2 *Applied Merits of Virtual Simulation Technology*

Virtual simulation technology relies on computer technology, 3D modeling technology, and interaction technology to create virtual practical training scenarios and operation objects. It can perfectly align with the teaching characteristics of vocational bachelor's Mechanical Engineering courses. Its core merits are manifested in three aspects. The first merit is security. It can simulate high-risk practical training scenarios, preventing equipment damage and personal safety risk that may occur due to improper operation by students, enabling students to conduct repeated trial-and-error training confidently. The second merit is economic efficiency. There is no need to invest a large amount of funds in purchasing large-scale practical training equipment or consuming practical training consumables, which effectively reduces the cost of practical training and solves the problem of insufficient practical training resources in vocational undergraduate institutions. The third merit is visual immediacy. It enables the visualization and concretization of abstract mechanical structures, transmission principles, processing procedures, etc., facilitating students to quickly understand difficult knowledge. At the same time, it can break through the limitations of time and space, enabling students to conduct practical training anytime and anywhere, thereby improving the efficiency and effectiveness of the practical training. Furthermore, virtual simulation technology can also enable personalized teaching. Based on students' learning progress and individual ability difference, it can customize tiered practical assignments, accounting for the learning needs of students at different level.

2.3 *Core Logic of Their Compatibility*

The core objective of vocational bachelor's Mechanical Engineering courses is to cultivate technical talent that meets the job requirements of enterprises. The core value of virtual simulation technology lies in breaking through the limitations of practice teaching and enhancing students' practical competencies [1]. The compatibility of the two lies in the precision demand-supply alignment. Virtual simulation technology can remedy the deficiencies—insufficient practical training resources and monotonous scenarios—in traditional courses, and convert the real-world job scenarios, operation procedures, and fault cases of enterprises into virtual practical training content, achieving seamless articulation between course teaching and post practice. Meanwhile, the immersive and interactive features of virtual simulation technology can ignite students' interest in learning and guide them to proactively participate in practical training. This aligns with the learning characteristics of vocational undergraduate students who are equipped with "strong hands-on competency and prominent concrete thinking". It catalyzes to achieve the learning objective of "learning by doing and doing by learning", and promotes the synchronous development of talent cultivation quality and corporate job requirements.

3.Current Challenges in Implementing Virtual Simulation Technology in Vocational Bachelor's Mechanical Engineering Courses

3.1 *Inadequate Resource Alignment*

Currently, the virtual simulation resources introduced by some vocational undergraduate institutions are general resources, failing to precisely align with the competency requirements of Mechanical Engineering positions. Moreover, their integration is not high with the course teaching content. Some virtual simulation resources focus on theory deduction and lack practical operability and specificity, failing to simulate the complex scenarios and unexpected failures that occur in real-world enterprise production, and struggling to meet the needs of students' job skill training. Furthermore, some virtual simulation resources are outdated, failing to keep up with the technological development trends in the mechanical industry. They are disconnected from the latest manufacturing techniques, device models, and operation specifications of enterprises, resulting in the skills mastered by students through virtual practical training failing to directly meet the job requirements, thereby affecting the application effect of virtual simulation technology.

3.2 ***Lack of Innovation in Teaching Models and Formalistic Technology Application***

When applying virtual simulation technology, certain educational institutions failed to transcend the constraints of the traditional teaching model and simply equated virtual simulation practical training with "online operation", lacking systematic teaching design and scientific teaching guidance. During the teaching process, teachers often adopt the "demonstration + imitation" model, and students passively follow and operate, and lack the space for proactive thinking and innovative exploration, failing to enable "learning-centered" teaching transformation [2]. Furthermore, some teachers have insufficient understanding of the application of virtual simulation technology. They merely use it as a supplement to traditional practical training, failing to deeply integrate virtual simulation technology with theory teaching, practice teaching, and on-the-job training. As a result, the application of virtual simulation technology becomes merely a formality, failing to fully leverage its core enabling teaching value.

3.3 ***The Comprehensive Capabilities of Faculty Teams Needs Improvement***

The application of virtual simulation technology in Mechanical Engineering courses requires teachers to not only possess solid theoretical knowledge in Mechanical Engineering and practical teaching competencies, but also to master the operation methods, resource development and teaching design capabilities of virtual simulation technology. However, currently, in some vocational undergraduate institutions, the majority of Mechanical Engineering teachers possess strong specialized theoretical knowledge and traditional practice teaching experience. However, they lack systematic learning and practical application of virtual simulation technology. As a result, they are unable to proficiently operate virtual simulation devices and platforms, fail to effectively guide students to conduct virtual practical training, and also have difficulty in developing appropriate virtual simulation resources that are tailored to the needs of course teaching. Meanwhile, the educational institutions lack special training on the application of virtual simulation technology, which results that teachers' comprehensive capabilities fail to meet the requirements of virtual simulation-based teaching. This, in turn, hinders the in-depth application of virtual simulation technology.

3.4 ***Undeveloped Evaluation Systems, Lack of Specificity***

Current teaching evaluation systems for vocational bachelor's Mechanical Engineering courses are still mainly centered on traditional theoretical exams and practical operation assessments, lacking targeted special evaluation content and scientific evaluation criterion for virtual simulation practical training. The evaluation methods are relatively monolithic, with a focus mainly on outcome-oriented assessment, while neglecting the evaluation of students' learning attitude, operational process, innovative thinking, and problem-solving capabilities during the virtual simulation practical training. The evaluation entities are relatively limited, mainly teachers. There is a lack of student self-evaluation, peer evaluation, and enterprise evaluation, failing to comprehensively and objectively reflect the practical training outcomes and position-fit competency of students. Furthermore, the evaluation results have a low correlation with students' course grades, awards and honors, and job recommendation, struggling to leverage the guiding role of the evaluation systems, which fails to effectively motivate students to proactively participate in virtual simulation practical training, and is not conducive to the quality improvement of virtual simulation-based teaching [3].

4.Pathways for Implementing Virtual Simulation Technology in Vocational Bachelor's Mechanical Engineering Courses

4.1 ***Building a Virtual Simulation Resource System That Aligns with the Job Requirements***

It is imperative to construct a triple virtual simulation resource system (Foundational + Specialized + Position-Specific) based on the job requirements and teaching content of vocational bachelor's Mechanical

Engineering programs to enhance the adaptability of the resources. The foundational resources focus on fundamental courses such as mechanical drawing and material mechanics to create virtual scenarios like three-dimensional models of mechanical structures and demonstrations of mechanical principles, helping students understand abstract theoretical knowledge. Specialized resources focus on core courses such as machining, equipment debugging, and fault diagnosis to create virtual practical training scenarios including machining process simulation, equipment overhaul simulation, and troubleshooting simulation in order to enhance students' professional skills training. Position-specific resources are aligned with the real-world positions of enterprises. Educational institutions should collaborate with industrial enterprises to develop resources, such as practical operation simulation, production flow simulation, and emergency handling simulation, to replicate the real-world work scenarios of enterprises, enhancing students' position-fit competency. At the same time, it is necessary to establish a mechanism for updating virtual simulation resources, keep pace with the technological development trends in the mechanical industry, and promptly update resources to guarantee the technological sophistication and practical applicability of the resources, and achieve precision alignment between the teaching content and the job requirements of enterprises.

4.2 *Innovating a Virtual Simulation-based Integrated Teaching Model*

It is imperative to transcend the constraints of the traditional teaching model and construct a "theory-virtual simulation-practical operation" triune integrated teaching model to promote the deep integration of virtual simulation technology and course teaching. In theory teaching, virtual simulation technology can be leveraged to concretize abstract mechanical principles and structural features. Three-dimensional demonstrations and dynamic simulation, etc. can catalyze students to quickly grasp difficult knowledge, enabling "concretization of theory". In practice teaching, the model of "virtual practical training first, actual operation later" should be adopted to enable students to first acquire basic operational skills and proficiency in the operation procedures through virtual simulation practical training, and then proceed to the authentic practical training sites to carry out hands-on training. This model reduces the operational risk and enhances the training effectiveness, and achieve "efficient practice". In the on-the-job training, virtual simulation technology should be used to simulate corporate work scenarios and job tasks, and carry out position-specific skill enhancement training and emergency handling drills to help students adapt to the job positions in advance and achieve "position alignment" [4]. In addition, project-based and group collaboration teaching methods should be employed to guide students to conduct proactive exploration and cooperative learning around the virtual simulation practical training projects, thereby cultivating their innovative thinking and teamwork skills.

4.3 *Strengthening the Comprehensive Capability Construction of Faculty Teams*

It is necessary to establish a "training-introduction-practice" triune faculty construction system to enhance the teachers' capability to apply virtual simulation technology. Firstly, vocational undergraduate institutions should carry out special training, invite experts in virtual simulation technology and corporate technicians to provide systematic training for mechanical professional teachers around the operation of virtual simulation platforms, resource development, and teaching design, etc. to enhance their technology application and teaching design capabilities. Secondly, they should engage versatile talent with virtual simulation technology application experience and an academic background in Mechanical Engineering to enhance the faculty teams and optimize the faculty structure, establish practice exchange platforms, organize teachers to conduct in-depth research and learning in industrial enterprises to understand the application status of virtual simulation technology, and job requirements of enterprises, and carry out on-campus virtual simulation-based teaching discussions and experience exchanges to promote mutual learning and common improvement among teachers. Furthermore, they should encourage teachers to collaborate with corporate technicians to develop appropriate virtual simulation resources based on the needs of course teaching, thereby enhancing teachers' resource development capability and providing faculty safeguards for the in-depth application of virtual simulation technology [5].

4.4 *Improving the Targeted Virtual Simulation-based Teaching Evaluation System*

It is imperative to establish a virtual simulation-based teaching evaluation system featuring “process + outcome + multi-stakeholders” to enhance the comprehensiveness and targeted applicability of the evaluations. In terms of evaluation content, it should account for both theoretical application capabilities, virtual operation skills, innovative thinking and problem-solving capabilities, include virtual practical training operation process, practical training reports, innovation schemes and other aspects of students in the evaluation scope, avoiding monolithic outcome-oriented evaluation. In terms of evaluation criteria, it is necessary to formulate scientific and detailed evaluation standards based on the learning objectives of the courses and the job requirements of enterprises to clearly define tiered evaluation requirements, and ensure the objectivity and fairness of the evaluations. In terms of the evaluation entities, it is necessary to establish a diversified evaluation entity system integrating teacher evaluation, student self-evaluation, peer evaluation and enterprise evaluation to fully leverage the evaluation role of all parties involved and comprehensively reflect the practical training outcomes and position-fit competency of students.

5.Conclusion

Virtual simulation technology, as an important support for promoting the reform in vocational bachelor’s Mechanical Engineering courses and improving the quality of talent cultivation, align highly with the teaching characteristics and talent cultivation requirements of vocational bachelor’s Mechanical Engineering courses. At present, during the implementation process of virtual simulation technology, there are problems, such as insufficient resource alignment, monotonous teaching models, insufficient faculty capabilities, and undeveloped evaluation systems, which restrict the full realization of its enabling value. By establishing a virtual simulation resource system that aligns with job requirements, innovating integrated teaching models, strengthening the construction of faculty teams, and refining the targeted evaluation system, etc., these implementation pathways can effectively solve teaching problems, promote the deep integration of virtual simulation technology and Mechanical Engineering courses, optimize the talent cultivation models, enhance students’ engineering practical competencies, innovative thinking and position-fit competency, and catalyze vocational bachelor’ Mechanical Engineering programs to cultivate more high-caliber technical talent that meets the high-quality development requirements of the manufacturing industry.

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