Current Status, Challenges, and Optimization Strategies for the Application of Virtual Interactive Classrooms in Vocational and Technical Education

HU Minmin[1], ZHENG Shiliang[2]
[1],[2](Department of Vocational and Technical Education, Shanghai Polytechnic University, China)

ABSTRACT :*Against the backdrop of the ongoing digital transformation of vocational education and the deepening integration of industry and education, virtual interactive classrooms have emerged as a crucial approach to addressing the challenges associated with practical training instruction in vocational institutions—namely, high investment requirements, high resource consumption, high risks, difficulties in implementation, difficulty in observation, and challenges in replicating such training experiences—while also serving as an important tool for enhancing the quality of technical and skilled talent development. This paper employs literature analysis and case study methods to clarify the connotation and characteristics of virtual interactive classrooms in vocational and technical education. Based on this understanding, it systematically examines the current state of their application across three dimensions—practical training instruction, theoretical course teaching, and skill assessment and evaluation—and identifies prominent issues in their current implementation across four dimensions: technology, resources, faculty, and mechanisms. Subsequently, the paper proposes targeted optimization strategies—such as refining technical standards, deepening the co-construction and sharing of educational resources, enhancing teachers' digital teaching capabilities, and strengthening evaluation and collaboration mechanisms—aiming to provide a reference for vocational institutions in advancing the development of virtual interactive classrooms and deepening their teaching reforms.*

KEYWORDS: *Vocational and technical education; Virtual interactive classrooms; Current application status; Optimization strategies*

I. INTRODUCTION

As the educational sector most closely linked to economic and social development, vocational education bears the important mission of cultivating a large number of high-quality technical and skilled professionals, skilled artisans, and master craftsmen for society. Practical training constitutes the core component that distinguishes vocational education from general education, and it serves as a key pillar in determining the quality of technical and skilled talent development. Only through hands-on training conducted in real-world production settings can students internalize theoretical knowledge into practical operational skills, thereby achieving the transition from "knowing" to "being able to perform."

However, for a long time, practical training programs in vocational institutions have commonly faced the practical dilemma of "high investment, high wear and tear, high risk, as well as difficulties in implementation, observation, and replication." On one hand, the procurement and maintenance costs for practical training equipment in fields such as CNC machining, automotive repair, chemical production, power system operation and maintenance, and aviation maintenance are prohibitively high—often requiring investments amounting to millions or even tens of millions of yuan; as a result, certain high-risk, high-precision, or high-value training projects—such as live-high-voltage work, emergency response to chemical accidents, or the disassembly and assembly of large-scale equipment—prove difficult to conduct repeatedly in real-world settings due to their significant safety risks and high maintenance costs. On the other hand, constrained by limitations regarding available space, the number of equipment units, and safety management requirements, students' opportunities to engage in hands-on practice with actual equipment are often very limited; for complex process flows or accident scenarios, students "can only listen but not observe, or can only observe but not act." This creates a gap between teaching effectiveness and actual industry demands, which in turn hinders the further improvement of the quality of technical and skilled talent cultivation in vocational institutions.

In response to this practical challenge, the rapid advancement of next-generation information technologies—such as virtual reality (VR), augmented reality (AR), digital twins, and artificial intelligence—has opened up new technological pathways and enabled the implementation of reforms in vocational education's practical training programs. In recent years, the Chinese government has continuously strengthened its policy support for the digital transformation of vocational education. The "Opinions on Deepening the Reform of the Modern Vocational Education System Construction," issued by the General Office of the Communist Party of China Central Committee and the General Office of the State Council, explicitly calls for enhancing the core operational capabilities of vocational schools and launching key projects, including the establishment of virtual simulation training bases for vocational education. Similarly, the "Action Plan for the Integrated Development of Virtual Reality and Industrial Applications (2022–2026)," jointly issued by five government departments—including the Ministry of Industry and Information Technology and the Ministry of Education—clearly mandates the establishment of a number of virtual reality classrooms, teaching and research offices, laboratories, and virtual simulation training bases across primary and secondary schools, higher education institutions, and vocational schools, while also supporting the development of key virtual simulation experiment and training projects. Since the launch of the 2021 Pilot Project for the Development of Exemplary Virtual Simulation Training Bases in Vocational Education in 2021, a large number of vocational institutions across China have actively engaged in the construction and deployment of virtual simulation training bases and virtual interactive classrooms**Error! Reference source not found.**.

Against this backdrop, virtual interactive classrooms—constructed using technologies such as virtual reality, digital twin, and human–machine interaction—are gradually evolving from simple simulations of practical training scenarios into comprehensive educational environments that encompass theoretical instruction, classroom interaction, and formative assessment and evaluation; this trend has become a focal point in current research and practice within the field of vocational education informatization**Error! Reference source not found.Error! Unknown switch argument.** . However, it is also important to recognize that the actual deployment and implementation of virtual interactive classrooms face a range of practical challenges, including inconsistent technical standards, limited availability of high-quality educational resources, insufficient teacher competency in utilizing these tools, and inadequate evaluation mechanisms; these issues urgently require theoretical clarification and practical resolution.

This study focuses on the virtual interactive classroom framework within vocational and technical education as its research subject. Employing a literature analysis approach, it systematically reviews relevant policy documents and academic research findings, while also drawing upon case studies of exemplary institutions and representative academic programs. The analysis is conducted across three dimensions—current application status, practical challenges, and optimization strategies—aiming to ensure that the problem identification and corresponding policy recommendations are logically coherent and mutually supportive, thereby providing a valuable reference for the implementation of related initiatives and for future research in vocational education institutions.

II. THE CONNOTATION AND CHARACTERISTICS OF VIRTUAL INTERACTIVE CLASSROOM IN VOCATIONAL AND TECHNICAL EDUCATION

(1) Conceptual Definition

The Vocational and Technical Education Virtual Interactive Classroom is a novel instructional space created by leveraging information technology—including virtual reality, augmented reality, 3D modeling, and human–computer interaction—to transform real-world vocational scenarios, production processes, equipment structures, and operational procedures into digital, interactive virtual teaching resources, and by systematically integrating these resources into classroom teaching, practical training sessions, and skill assessment activities. Unlike traditional multimedia courseware-based teaching or one-way virtual simulation demonstrations, the Virtual Interactive Classroom places greater emphasis on the two-way interaction between learners and the virtual teaching environment; learners can perform autonomous operations within the virtual environment, receive real-time feedback, and engage in repeated practice, thereby gaining a practice experience that closely mirrors real-world scenarios**Error! Reference source not found.Error! Reference source not found.**.

It is important to note that the virtual interactive classroom and virtual simulation-based training are both related and distinct: virtual simulation-based training places greater emphasis on the high-fidelity reproduction of real-world production processes and operational procedures, focusing on addressing safety risks and capital cost concerns in practical training instruction; in contrast, the scope of the virtual interactive classroom is broader—it encompasses not only virtual simulation scenarios designed for practical training activities but also a variety of interactive digital resources intended for introducing theoretical teaching, facilitating classroom interactive discussions, and conducting formative assessment and evaluation. This model represents the result of the deep integration of virtual simulation technology with classroom teaching practices; essentially, it constitutes a reconfiguration and extension of vocational education instructional spaces in the digital age.

(2) Technical Composition

From a technical implementation perspective, current virtual interactive classrooms for vocational and technical education are primarily built upon the following technologies: First, immersive virtual reality technology utilizing head-mounted display devices, which provides learners with a highly immersive three-dimensional operational environment and is commonly employed for high-risk, high-value practical training projects; Second, augmented reality technology leveraging mobile terminals, which overlays virtual information onto physical equipment to deliver integrated virtual-and-physical operational guidance; Third, digital twin technology tailored for real-world equipment and production lines, which creates a digital replica of the equipment to enable synchronous mapping between the virtual environment and the actual operational state of the production line; Fourth, the Cloud VR model, which leverages cloud computing and cloud rendering technologies to reduce the computational resource requirements of end-user devices, facilitating the widespread adoption of virtual interactive resources within vocational institutions.

(3) Main Characteristics

Building upon existing research and practical explorations, the virtual interactive classroom in vocational and technical education primarily exhibits the following four characteristics:

First, contextual relevance: Virtual interactive classrooms can accurately replicate real-world industrial scenarios and workplace contexts, enabling students to gain an intuitive understanding of production processes and operational procedures within a virtual environment. This helps bridge the psychological and cognitive gap between theoretical learning and practical workplace experience, thereby enhancing students' adaptability to future professional roles.

Second, interactivity. Unlike traditional one-way instructional demonstrations, the Virtual Interactive Classroom enables students to engage in real-time interaction with virtual environments using controllers, motion-sensing devices, touch-based terminals, or other interfaces, and to receive immediate feedback on their actions.

This feature represents the core characteristic that distinguishes the Virtual Interactive Classroom from conventional multimedia teaching resources, and it is also the key factor that sets the "Virtual Interactive Classroom" apart from "Virtual Simulation Demonstrations" **Error! Reference source not found.**.

Third, openness and repeatability: Students can engage in repeated practical exercises without being constrained by time, space, or the number of available devices or setups; this approach is particularly well-suited for high-risk, high-value, or irreversible practical training projects, as it effectively reduces teaching costs, improves the utilization rate of teaching resources, and provides strong support for blended online-offline teaching.

Fourth, transferability and shareability. Well-designed virtual interactive classrooms can accommodate diverse teaching scenarios, facilitating students' understanding and application of similar knowledge and skills, as well as enabling the cross-platform sharing of high-quality educational resources across different institutions and disciplines—thereby expanding the reach of these premium teaching resources.

III. CURRENT APPLICATION STATUS OF VIRTUAL INTERACTIVE CLASSROOMS IN VOCATIONAL AND TECHNICAL EDUCATION

In recent years, with the ongoing advancement of the Demonstration Virtual Simulation Training Base Development Project for Vocational Education and the thorough implementation of the Vocational Education Digitalization Strategy Initiative, virtual interactive classrooms have been widely adopted across various aspects of vocational institutions—including practical training sessions, theoretical course instruction, and skill assessment and evaluation—yielding significant phased achievements.

(1) Current Application Status in Practical Training Teaching

Practical training education represents the field where virtual interactive classroom applications are most extensively deployed and where their effectiveness is most pronounced. In specialized sectors—such as equipment manufacturing, transportation, energy and chemical engineering, pharmaceuticals and healthcare, and modern agriculture—where training costs are high and safety risks are significant, numerous vocational institutions have established a number of virtual simulation training centers that possess considerable scale and influence.

In the field of finance and business-related disciplines, some higher vocational institutions have leveraged virtual interaction technology to develop comprehensive virtual simulation training platforms tailored to specific job scenarios—such as accounting, financial services, and marketing—converting real-world corporate financial operation scenarios, which would otherwise be challenging to replicate on campus, into reusable virtual environments, thereby providing students with practical training opportunities that closely mirror real-world workplace conditions **Error! Reference source not found.**. In the context of specialized training programs for cross-border e-commerce, certain institutions have utilized virtual simulation technology to establish integrated training systems covering various stages—including platform operations, order processing, international logistics, and payment settlement—addressing the limitations of traditional training approaches, such as the difficulty in accessing authentic transaction scenarios and the narrow scope of training projects; this enables students to fully experience the entire business process—from product selection and listing to order fulfillment—within a virtual platform**Error! Reference source not found.**. In the teaching of international freight forwarding programs, research has also explored the use of virtual simulation technology to allow students to repeatedly practice operational procedures—such as customs declaration and inspection, document preparation, and goods inspection—within virtual environments, thereby enhancing the relevance and effectiveness of the practical training instruction **Error! Reference source not found.**.

In the field of equipment manufacturing disciplines, the application of virtual interactive classrooms increasingly serves as a viable alternative to high-risk, high-value practical training programs. Some studies have conducted systematic explorations into script design strategies for virtual simulation teaching resources, emphasizing the need to closely integrate real-world production processes with instructional objectives by presenting operational steps, fault scenarios, and assessment criteria through scripted approaches, thereby enhancing the teaching suitability and usability of virtual simulation resources**Error! Reference source not**

found.. Additionally, other studies, based on a systematic review of the development of national exemplary virtual simulation training base projects for vocational education, have highlighted the positive role played by these bases in expanding the supply capacity of practical training resources and diversifying practical training methodologies**Error! Reference source not found.**.

(2) Current Application Status in Theoretical Course Teaching

In addition to practical training components, virtual interactive classrooms are increasingly being integrated into theoretical course instruction, giving rise to a new blended learning model characterized by "online theoretical learning + virtual interactive practice." Some institutions have combined virtual interactive resources with online teaching tools such as MOOCs; by presenting abstract process principles, equipment internal structures, and production workflows through three-dimensional visualization and interactive interfaces, they help students gain a more intuitive understanding of the key and challenging aspects of the course material. This approach overcomes the limitations of traditional classroom teaching—where instructors can only lecture while students have limited opportunities to observe—and effectively enhances the appeal and instructional effectiveness of classroom instruction**Error! Reference source not found.**.

Meanwhile, a study conducted through a questionnaire survey among students majoring in relevant fields found that the introduction of virtual interactive resources can help enhance students' learning interest and classroom engagement. Students generally perceive the learning experience in virtual interactive environments as superior to that offered by traditional text-based instruction; however, their actual instructional effectiveness is simultaneously influenced by multiple factors—such as the quality of the resource content, the rationality of the interactive design, and the classroom organization methods—rather than being solely determined by the technology itself**Error! Reference source not found.**. This suggests that the application of virtual interactive resources in theoretical course instruction should be seamlessly integrated into the overall course teaching design, rather than being treated as a mere technological overlay.

(3) Current Application Status in Skill Assessment and Evaluation

During the skill assessment and evaluation phase, some vocational institutions utilize virtual interactive platforms to conduct formative assessments. By systematically recording data such as students' operational steps, processing time, compliance with standards, and accuracy rates within virtual scenarios, these platforms provide a more objective, traceable, and quantifiable basis for skill assessment—thereby partially mitigating the limitations of traditional skill assessment methods, which primarily rely on on-site scoring by examiners, are subject to significant subjectivity, and have limited coverage. Additionally, virtual interactive platforms can offer a low-cost, repeatable simulated environment for pre-competition training and referee training for skill competitions, further expanding the range of application scenarios for virtual interactive technology in the vocational education evaluation process.

(4) Summary of Implementation Outcomes

From an overall development perspective, the establishment of vocational education virtual simulation training bases and virtual interactive classrooms has yielded phased achievements. One study conducted a relatively systematic review of the development and implementation of the National Vocational Education Exemplary Virtual Simulation Training Base Cultivation Project; by integrating annual performance data with findings from both online and offline surveys, the study revealed that these projects have played a positive role in expanding the supply of practical training teaching resources and innovating practical training teaching models, while simultaneously highlighting several issues that require urgent attention [4]. In recent years, related review studies have also noted that, against the backdrop of the ongoing advancement of the National Education Digitalization Strategy Initiative, virtual simulation-based digitalization and intelligence have become one of the key directions for exploring digital transformation in vocational education. Although research on the digitalization of practical training accounts for a relatively small proportion of the literature on vocational education digitalization, it is increasingly showing a trend of rapid integration with emerging technologies such as artificial intelligence and the metaverse **Error! Unknown switch argument.**.

Overall, the adoption of virtual interactive classrooms has effectively alleviated the tension between the shortage of practical training resources in vocational institutions and the difficulty of implementing certain high-risk, high-value training projects, while also providing students with safer, more cost-effective, and repeatable practical training opportunities. However, across China, there remain significant disparities in the level of adoption of virtual interactive classrooms among different regions, institutions, and academic disciplines; furthermore, there is considerable room for enhancing both the overall depth of implementation and the actual effectiveness of these systems – a issue that this paper aims to further analyze.

IV. CHALLENGES IN THE IMPLEMENTATION OF VIRTUAL INTERACTIVE CLASSROOM APPLICATIONS IN VOCATIONAL AND TECHNICAL EDUCATION

Although the application of virtual interactive classrooms in the field of vocational education has yielded certain positive outcomes, existing research and practical cases reveal that these classrooms still face several pressing practical challenges—particularly regarding technology, resources, faculty, and institutional mechanisms—that hinder the full realization of their potential.

(1) Technical aspect: The interactive experience and system compatibility require improvement.

From a technical implementation perspective, the immersive quality and interactive experience of certain current virtual interactive classroom resources remain inadequate; some virtual simulation resources are still limited to simple, component-or tool-level displays—their primary function being the static presentation of device appearances and basic operational steps—without achieving deep integration with the core elements of practical training instruction—such as specific teaching objectives, tiered learning tasks, and formative operational feedback. As a result, these resources struggle to fully support the dual demands of "teaching" and "learning" during practical training sessions, nor can they provide differentiated interactive experiences tailored to students with varying competency levels **Error! Reference source not found.**.

Meanwhile, the lack of unified technical standards—particularly regarding data formats, system interfaces, and communication protocols—among virtual simulation systems developed by different manufacturers has resulted in poor compatibility between various platforms. As a consequence, virtual interactive resources extensively invested in by one institution often cannot be directly reused on the platforms of another institution; consequently, it is difficult to achieve flexible cross-platform and cross-terminal access to these resources. This situation objectively exacerbates the "information silo" phenomenon and, to some extent, increases the system operation, maintenance, and upkeep costs for vocational institutions**Error! Reference source not found.Error! Reference source not found.**. Additionally, certain virtual interactive systems impose high computational resource requirements on end-user devices, which objectively hinders their widespread adoption and deployment in institutions with relatively limited technological infrastructure.

(2) Resource Level: Limited coverage of high-quality resources and inadequate co-construction and sharing

The development of virtual interactive teaching resources typically involves multiple specialized stages—including 3D modeling, animation rendering, interactive script design, and software development—characterized by lengthy development cycles, high technical barriers, and substantial financial investment. Creating a high-quality set of virtual simulation training resources often requires an interdisciplinary team to dedicate several months or even longer to the development process. As a result, the development of such high-quality virtual interactive resources is predominantly concentrated among a small number of institutions with strong academic capabilities or specialized technology firms; consequently, the range of disciplines covered by these resources remains relatively limited. For emerging disciplines or disciplines with distinctive regional characteristics, it is often challenging to secure virtual interactive resources that align with their specific teaching requirements**Error! Reference source not found.Error! Reference source not found.**.

Meanwhile, due to the absence of effective mechanisms for cross-institutional and cross-regional collaborative development and resource sharing, there is a degree of redundant investment in the development of virtual interactive resources across different higher education institutions; virtual simulation resources for similar academic programs or training projects are often developed independently by various institutions, leaving room for improvement in resource utilization efficiency; furthermore, some existing resources, owing to the lack of a sustainable updating mechanism, fail to promptly reflect advancements in industrial technologies or changes in manufacturing standards, posing a risk of the virtual teaching content gradually becoming disconnected from actual industry practices**Error! Reference source not found.**.Additionally, issues such as intellectual property ownership, cost allocation, and revenue distribution in the development of virtual interactive resources have not yet been addressed through clear and actionable institutional frameworks—this, in turn, dampens the willingness of higher education institutions to engage in collaborative resource development and sharing.

(3) Faculty Level: Teachers' digital teaching competencies require further enhancement.

The effective implementation of virtual interactive classrooms imposes new and higher demands on teachers' capabilities in digital instructional design: teachers are not only required to possess solid professional knowledge and extensive practical experience but also to master the criteria for selecting virtual interactive resources, methods for adapting instruction to virtual environments, and the relevant skills needed to organize classroom activities and conduct formative assessment using virtual interactive platforms. However, in practice, some teachers at vocational institutions—particularly older "dual-qualified" teachers who have long been engaged in traditional practical training instruction—still lack systematic training in areas such as selecting virtual teaching resources, designing instructional sequences, and organizing classroom sessions. Their understanding and practical experience regarding how to seamlessly integrate virtual interactive resources with traditional teaching methods, or how to utilize virtual interactive platforms to conduct precise, personalized formative assessment, remain limited; in some cases, these teachers even exhibit a degree of apprehension or resistance toward such approaches. This, to some extent, hinders the full realization of the effectiveness of virtual interactive classroom teaching **Error! Unknown switch argument.**.

Furthermore, current information technology-based teaching competency training programs offered to teachers in vocational institutions still predominantly focus on general IT application training; a dedicated training framework specifically designed for the development of virtual interactive classroom teaching methods remains underdeveloped, and there is also a certain degree of misalignment between the training content and the actual teaching requirements of teachers' respective disciplines.

(4) Institutional Level: The evaluation system and collaborative mechanisms remain inadequate.

From the perspective of support mechanisms, the development of virtual interactive classrooms in vocational education currently lacks unified, scientifically grounded construction standards and an effective performance evaluation system. The methods used to assess the effectiveness of virtual interactive classroom applications—particularly the impact on students 'skill acquisition and transfer—remain predominantly reliant on qualitative descriptions and subjective judgments. There is a lack of a data-driven learning process evaluation mechanism capable of implementing a closed-loop feedback system; furthermore, the vast amount of operational data generated by students within virtual environments has not been fully mined or utilized, making it difficult to establish an effective closed-loop for students' self-regulated learning on this basis**Error! Reference source not found.**.

Furthermore, the collaborative mechanism between vocational institutions and industry enterprises in the development and application of virtual interactive resources remains underdeveloped; the creation of certain virtual interactive resources is primarily led by vocational institutions or third-party technology companies, without fully aligning them with enterprises' actual production processes, equipment parameters, or workforce requirements; thus, the depth of industry-education integration requires further enhancement**Error! Reference source not found.Error! Reference source not found.**. At the institutional level, the effectiveness of virtual interactive classroom initiatives has not yet been fully incorporated into relevant indicator systems—such as those used for assessing teaching quality or evaluating the development level of academic programs—within vocational institutions, which to some extent undermines their intrinsic motivation to continue investing in such initiatives.

V. OPTIMIZATION STRATEGIES FOR VIRTUAL INTERACTIVE CLASSROOM SETTINGS IN VOCATIONAL AND TECHNICAL EDUCATION

To address the practical challenges encountered at the four levels—technology, resources, faculty, and mechanisms—it is essential to adopt a problem-oriented approach and systematically advance the development of virtual interactive classrooms for vocational and technical education, thereby effectively enhancing their practical effectiveness.

(1) Technical Level: Enhance the interactive experience and advance standardization efforts

On one hand, emphasis should be placed on designing virtual interactive resources based on the internal components of the teaching system, moving away from the traditional resource development approach that "prioritizes display over interaction." Instead, virtual simulation technology should be closely integrated with specific teaching objectives, tiered learning tasks, and formative feedback mechanisms. This approach will drive the evolution of virtual interactive resources—from simple component-or tool-level displays—to solutions capable of fully supporting an integrated "teaching–learning–assessment" framework, while providing adaptive interaction pathways tailored to students 'varying competency levels, thereby effectively enhancing students' sense of immersion and interactive experience within virtual environments**Error! Reference source not found.Error! Reference source not found.**.

On the other hand, active efforts should be made to promote the establishment of unified industry-wide virtual simulation technology standards, clearly defining technical specifications—including data formats, system interfaces, and communication protocols—to enhance compatibility and interoperability among various virtual interaction systems and create the necessary technical foundation for the cross-platform and cross-device application and sharing of virtual interaction resources; simultaneously, by leveraging technical approaches such as cloud rendering, the computational resource requirements for end-user devices can be reduced, thereby improving the accessibility of virtual interaction resources in institutions with relatively limited educational infrastructure**Error! Reference source not found.Error! Reference source not found.**.

(2) Resource Level: Deepen university–industry collaboration and enhance resource-sharing mechanisms.

The synergistic role of school-enterprise collaboration in the development of virtual interactive educational resources should be fully leveraged. Vocational institutions should be encouraged to collaborate with leading industry enterprises in co-developing virtual interactive teaching resources, transforming real-world industrial production processes, equipment parameters, and operational procedures into instructional materials. This approach enhances the alignment between virtual interactive resources and actual industry practices, while simultaneously providing enterprises with practical application scenarios for targeted skilled talent development and employee training, thereby achieving mutual benefit and win-win outcomes for both schools and enterprises **Error! Reference source not found.**.

Meanwhile, by leveraging regional and industry-specific vocational education resource-sharing platforms, efforts should be made to promote the joint development and shared utilization of virtual interactive resources across similar disciplines and across different institutions. Through the implementation of unified resource-sharing standards, appropriate cost allocation mechanisms, and robust intellectual property protection frameworks, redundant resource development can be minimized and resource utilization efficiency can be enhanced; furthermore, a dynamic resource update mechanism should be established, clearly defining the responsible entities and update cycles for resource maintenance, ensuring that virtual interactive resources promptly reflect the latest developments in industrial technologies and process standards, thereby preventing any disconnection between virtual teaching content and actual industry practices**Error! Reference source not found.Error! Reference source not found.**.

(3) Faculty Level: Strengthen training for teachers' digital instructional competencies

The ability to design instructional materials for virtual interactive classrooms should be integrated as a key component of the teacher training system for vocational institutions. Through various approaches—such as school-based professional development, enterprise-based practical training, and cross-institutional experience-sharing initiatives—teachers can be supported in mastering the criteria for selecting virtual interactive resources, the methods for designing instructional activities, and the fundamental skills required for conducting formative assessment using virtual interactive platforms, thereby effectively enhancing their capacity to seamlessly integrate virtual interactive resources into traditional classroom teaching **Error! Unknown switch argument.Error! Reference source not found.**.

Meanwhile, training content should be designed in a categorized manner to meet the specific needs of teachers across different disciplines and age groups, thereby avoiding a "one-size-fits-all" approach to general education training; alternatively, collaborative teaching teams composed of "renowned educators, technical experts, and industry professionals" can be established to leverage the complementary strengths within these teams, addressing the technical application competency gaps among some teachers; furthermore, the design and application of virtual interactive classroom teaching should be gradually integrated into the assessment systems governing teachers 'professional development and recognition initiatives, thereby stimulating teachers' intrinsic motivation for proactive learning and application.

(4) Institutional Level: Strengthen the evaluation system and deepen industry–education collaboration.

It is essential to accelerate the development of construction standards and teaching effectiveness evaluation systems tailored for virtual interactive classrooms. By leveraging virtual interactive platforms to collect students 'behavioral data during instructional activities and comprehensively applying technologies such as learning analytics and artificial intelligence, a data-driven learning process evaluation mechanism can be established. This enables dynamic monitoring and precise diagnosis of students' skill acquisition, provides data support for teachers to optimize instructional design and for students to engage in self-regulated learning, thereby creating a closed-loop teaching evaluation process encompassing "data collection – analysis – feedback – improvement" **Error! Reference source not found.**.

Furthermore, it is essential to further strengthen the collaborative mechanism between vocational institutions and industry enterprises in the development of virtual interactive classrooms, fostering deeper cooperation between schools and enterprises across various aspects—including the design of talent development programs, the creation of practical training projects, and the evaluation of teaching effectiveness—while exploring ways to promptly integrate new technologies, innovative processes, and updated industry standards into the development of virtual interactive classrooms, thereby effectively enhancing their alignment with industrial demands**Error! Reference source not found.**. Additionally, it is recommended that the competent authorities incorporate the effectiveness of virtual interactive classroom development into the teaching quality assessment and program development evaluation indicator systems for vocational institutions, providing institutional incentives and safeguards to encourage sustained investment in this area.

VI. CONCLUSION

The virtual interactive classroom, as a novel teaching approach emerging amid the digital transformation of vocational education, provides an effective solution to the practical challenges faced by vocational institutions in practical training—namely, high investment requirements, high resource consumption, high risks, as well as difficulties in implementation, observation, and replication. Its application in areas such as practical training, theoretical course instruction, and skill assessment and evaluation has already yielded positive results, making it a vital support for enhancing the quality of technical and skilled talent development.

At the same time, it is important to recognize that the development of virtual interactive classrooms in vocational and technical education still faces a range of practical challenges—such as insufficient technological compatibility, limited coverage of high-quality educational resources, the need to enhance teachers' digital teaching capabilities, and inadequate evaluation and collaboration mechanisms. These issues are interwoven and collectively hinder the full realization of the potential benefits of virtual interactive classroom applications**Error! Reference source not found.**. Vocational institutions should adopt a systems-thinking approach and take coordinated actions across multiple fronts—such as improving the interactive experience and advancing the development of standardized frameworks, deepening the joint development and sharing of school-enterprise resources, strengthening teacher capacity-building programs, and refining evaluation and collaboration mechanisms—to shift the focus of virtual interactive classroom development from "emphasizing construction" to "emphasizing application and effectiveness."

Looking ahead, as next-generation information technologies—such as artificial intelligence, digital twins, and large language models—become increasingly deeply integrated with virtual simulation environments, virtual interactive classrooms are poised to achieve new breakthroughs in areas including multimodal data acquisition, personalized learning support, and intelligent teaching assessment. This will provide more robust and precise technological support for the high-quality development of vocational education and the cultivation of technical and skilled talent, while also contributing positively to enabling vocational education to better serve national industrial transformation and upgrading as well as the building of a skilled workforce society**Error! Reference source not found.Error! Reference source not found.**.

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