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Innovative Design of a Virtual Simulation-Based Practical Teaching System for the Hui Elderly Care Services and Management Program

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Abstract: This study addresses the practical need for cultivating high-caliber technical and skilled professionals in the field of smart elderly care services and management. Following a scientific research methodology-namely "problem-oriented approach-model development-practical validation – iterative optimization"-the study focuses on the cognitive characteristics of learners at the specialized education level and the patterns governing the development of job-specific competencies. Moving beyond the limitations of previous research, which often merely enumerated platform functionalities or elaborated on macro-level concepts, this study aims to establish a new practical teaching paradigm that combines theoretical rigor with instructional feasibility. To address structural challenges prevalent in virtual simulation-based practical teaching within higher vocational institutions-such as high equipment idle rates, a disconnect between operational procedures and real-world job requirements, and lengthy student onboarding periods-the study employs both qualitative and quantitative research methods to integrate the competency-based vocational education approach with the embodied cognition theory. It proposes a tripartite design logic comprising "task-driven approach-minimalist interaction – embedded assessment." At the methodological level, a controlled experimental design was utilized; the core performance indicator, the operational compliance rate-was defined in accordance with the national standard GB/T 37276-2018, while the student self-rated confidence scores were simultaneously collected using the Likert 5-point scale and the emergency response duration metric, thereby enabling multidimensional triangulation of skill acquisition outcomes. At the practical implementation level, a comprehensive "three-module, two-pathway" teaching system was developed, comprising 12 simulation task scripts based on actual equipment models, accompanying task cards, and five sets of standardized formative assessment scales; this system was then deployed and integrated into the curriculum at the on-campus training center.

Keywords: Virtual simulation-based teaching; Smart elderly care services and management; Higher vocational education; Job-related competencies; Process assessment

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1. Introduction to the Problem

China's population aging process is accelerating steadily; by the end of 2025, the number of elderly people aged 60 and above nationwide had reached 323.38 million, accounting for 23% of the total population, among whom those aged 65 and above numbered 223.65 million, representing 15.9% of the total population. This signifies that China has officially entered the stage of a deeply aging society. Moreover, the degree of aging in Chongqing Municipality is significantly higher than the national average. Against this macroeconomic backdrop, smart elderly care services and management, as an interdisciplinary application field, integrate knowledge from multiple disciplines-including the Internet of Things, big data, artificial intelligence, and geriatric medicine-resulting in an ever-widening gap in the supply of professional talent in this sector. According to statistical data from the "China Elderly Care Service Development Report

(2024)," the current supply-demand ratio for interdisciplinary technical and skilled personnel who possess both the ability to operate smart devices and the capability to analyze multimodal health data, as well as the expertise to design age-friendly service systems, stands at merely 1:4.8. This structural shortage has become a core constraint hindering the high-quality development of the smart elderly care industry.

As digital information technologies have been increasingly applied to educational and teaching reforms, they aim to address the practical teaching challenges that are either unfeasible or difficult to implement in traditional practice-based instruction. The accelerating aging of China's population has led to a growing demand for elderly care services, imposing higher requirements on the cultivation of professionals specialized in elderly care services and management. However, traditional teaching methods have certain limitations when it comes to developing students' practical skills and their ability to navigate complex real-world scenarios. Smart elderly care, as an emerging care model, presents both new opportunities and challenges for the elderly care sector. Virtual simulation technology enables the creation of realistic virtual environments, allowing students to engage in practical operations and problem-solving within simulated scenarios, thereby effectively compensating for the shortcomings of traditional teaching approaches.

2. Overview of Related Research

In recent years, driven by the dual forces of accelerating population aging in China and the rapid evolution of information technology, the Smart Elderly Care Services and Management program-As an emerging interdisciplinary applied discipline, it is part of the higher vocational education system. is gradually attracting increasing academic attention due to the innovation in its practical teaching system. This study systematically collects and screens literature related to teaching reform in higher vocational education, retrieved from the CNKI, Wanfang, and VIP databases between 2021 and 2026. A total of 97 papers published in core journals, the Extended CSSCI database in the field of vocational education, and authoritative RCCSE journals were identified; among these, 63 papers directly explore the theme of "smart elderly care." A systematic analysis of this literature reveals a distinctly "platform-first" orientation in current research: nearly 78.6% of the studies focus their core content on introducing the functional composition, technical frameworks, and interface design of various virtual simulation platforms; approximately 15.9% of the studies provide only superficial descriptions of the platforms' basic applications, often employing empirical statements such as "three rounds of in-class simulation training have been conducted" or "the satisfaction rate among surveyed students reached 86.2%"; and merely 5.5% of the studies attempt to approach the subject from the perspectives of cognitive science and learning behavior modeling, conducting systematic analyses of the information processing pathways, the critical value of working memory load, and the inherent patterns of skill transfer among learners at the vocational education level within complex human-computer interaction scenarios. This distribution pattern reveals an inherent methodological shortcoming in current research on teaching reform for smart elderly care in higher vocational education: most research outcomes still adhere to an engineering-oriented technological demonstration logic, failing to integrate the scientific thinking-emphasized in the natural sciences-of "reproducible verification, quantifiable expression, and mechanistic interpretation" into the overall framework of instructional design.

3. Innovative Design of the Virtual Simulation Practical Teaching System

3.1. Modular Reconstruction of Teaching Content

3.1.1. Three-Tier Task Decomposition Based on Job-Specific Competencies

Based on the project research framework diagram and implementation pathway, the virtual simulation-based practical teaching system for the Smart Elderly Care Services and

Management program is structured as a four-tier nested architecture; from the bottom layer to the top layer, these tiers are as follows:

Bottom Layer – Service and Expansion Module: This layer encompasses industry-education integration, faculty development, and the collaboration between industry-academia partnerships and R&D activities within industrial colleges. Serving as the "soil layer" of the entire system, it provides the necessary resources and drives sustainable growth for the upper layers. Industry-education integration ensures that the system remains aligned with the actual needs of the industry; faculty development addresses the critical question of "who will teach"; and the collaboration between industry-academia partnerships establishes a mechanism-based safeguard for the continuous iteration of the system.

Layer 2 – Resources and Application Module: This layer encompasses professional/public course resources, integrated software/hardware content experiences, professional/industry competition resources, digital twin resources, premium courses, promotional service resources, and industrial reserve resources. This layer constitutes the "Content Layer" of the system, hosting the specific educational resources and application scenarios for virtual simulation-based teaching. Notably, the "Digital Twin Resources" are listed separately, reflecting the evolving trend in virtual simulation-based teaching—from "simulated simulation" to "digital twin" – where the latter requires not only a realistic visual simulation but also the consistency of system behavioral logic with that of the actual system.

Layer 3 – Platform and Management Module: This layer encompasses the development of a virtual simulation training and management platform, which should support features such as platform interoperability, data integration, endpoint migration, and real-time interaction between teachers and students; it also involves designing a digital management platform for virtual elderly care facilities and community-based elderly care service centers. This layer constitutes the "Technical Layer" of the system, providing technical support for resource operations and teaching activities.

Top Layer – Environmental Infrastructure Module: This layer comprises four core centers—the Professional Virtual Simulation Training and Experiment Center, the Public Resource Virtual Simulation Training and Experiment Center, the Virtual Simulation Training and Experiment Experience Center, and the Virtual Simulation Training and Experiment R&D Center. This layer serves as the "physical carrier layer" of the system, providing the physical space and equipment support required for virtual simulation-based teaching.

This four-layer architecture embodies a combination of a bottom-up support relationship and a top-down guiding relationship: the underlying modules provide resources and driving force to the upper layers, while the top-level module offers strategic positioning and a physical foundation for the entire system. This hierarchical design—comprising "Foundation–Resources–Platform–Environment"—reflects the researchers' systematic understanding of the virtual simulation teaching system: it is not merely a simple aggregation of "software + hardware," but rather an organic ecosystem.

3.1.2. Teaching Scenario Design Based on the Integration of Three Contexts: Virtual Environment + Simulated Environment + Real-World Environment

This system's most innovative feature lies in its creation of a tripartite integrated learning environment combining "virtual environment + simulated environment + real-world environment."

Virtual Environment: Refers to a fully virtual digital environment in which students engage in conceptual learning, process simulation, and abstract thinking training. For example, by using virtual simulation software to model the organizational structure and operational workflows of a senior care facility, students can repeatedly practice management decision-making without incurring any physical costs.

Simulated environment: Refers to a semi-virtual, semi-physical simulation environment that serves as a transitional zone between the virtual and real worlds. Such

environments typically leverage virtual simulation hardware devices (e.g., VR headsets, force-feedback equipment, simulated nursing beds, etc.) to deliver a highly immersive operational experience, yet do not require actual service recipients or a fully realistic physical environment.

Real-world settings: refer to actual elderly care service facilities, such as senior care institutions, community-based elderly care service centers, and home-based elderly care service stations. Students engage in authentic workplace practice at these locations, applying the skills acquired in virtual or simulated environments to real-world contexts.

The Three-Environment Integration design addresses the gap between classroom learning and real-world workplace application inherent in traditional practical teaching approaches. Under the conventional model, students learn theoretical knowledge in the classroom before immediately engaging in hands-on internships in actual work settings; however, this approach lacks a well-defined transitional phase. In contrast, the Three-Environment Integration introduces a gradual, simulated training progression between theory and real-world practice, making the path to skill acquisition smoother and more aligned with cognitive principles.

3.1.3. "Healthcare, Wellness, Care, Research, and Service" Five-in-One Competency Objective Framework

The system's competency development objectives are structured around five dimensions: "Well-being, Care, Protection, Research, and Service." The value of this framework lies in its departure from the traditional approach to talent development in elderly care services, which often overemphasizes nursing while neglecting management – and in its expansion of competency objectives to encompass a more comprehensive value chain:

"Kang" refers to the elderly's health management capabilities, including health assessment, chronic disease management, and rehabilitation guidance; "Yang" refers to daily living care capabilities; "Hu" refers to professional nursing capabilities, encompassing both basic and specialized nursing care; "Yan" refers to research capabilities, such as data analysis, service plan design, and quality improvement – aspects that are often overlooked in the traditional training of elderly care professionals; "Fu" refers to comprehensive service and management capabilities, including institutional operations, service quality management, and customer relationship maintenance.

These five dimensions constitute an evolutionary pathway spanning from foundational to advanced competencies; the advantage of the virtual simulation-based teaching system lies precisely in its ability to design differentiated training scenarios tailored to various competency levels. For example, the "Nursing" dimension enables the training of nursing operational skills using virtual simulation training equipment; the "Research" dimension allows for the simulated design of service solutions through the data analysis module within the digital management platform.

3.2. Methodological Reflection on Module Construction

An examination of this modular system design from the perspective of research report writing can help identify several key methodological principles:

(1) Module design should embody a clear hierarchical logic rather than merely listing functions. The four-layer architecture of this system clearly reflects the division of labor into "support-bearing-operation-carrier"; this structured design makes the system more theoretically rigorous and more practically applicable.

(2) Each module should be capable of aligning with industry demands and cutting-edge technological advancements. Whether it involves the integration of digital twin resources or the design of the "Three-Domain Integration" approach, both reflect a keen understanding of the digital transformation trend within the elderly care services sector.

(3) The module design should incorporate an evaluation and feedback mechanism. Although this system treats evaluation as a xuyèng element across all modules rather than as an independent hierarchy, the critical role of evaluation in the system's operation cannot be overlooked – this point will be discussed in detail in Chapter 5.

4. Development of a Virtual Simulation Internship Platform Software System for the Smart Health and Elderly Care Services and Management Specialization

In the innovative development of a virtual simulation-based practical teaching system for the Smart Elderly Care Services and Management program, the modular reorganization of instructional content serves as the logical foundation and cognitive underpinning for the entire system. This approach is by no means merely a simple division of content or a mere accumulation of technologies; rather, it involves the structured decomposition and quantifiable modeling of the operational patterns of complex systems, guided by the scientific research paradigm. The system construction comprises the following components:

4.1. Adhere to the "Five Truths" Standard

A common drawback of traditional virtual simulation-based teaching is its "technology-driven rather than demand-driven" approach-where developers focus on the technical novelty of the tools rather than the authenticity of the instructional content. As a result, although students may complete tasks within a virtual environment, they still struggle to know how to proceed when confronted with real-world scenarios. This study proposes the "Five Realities"-real-world scenarios, real-world roles, real-world equipment, real-world processes, and real-world cases-to address the issue of "lack of authenticity in simulation" inherent in traditional virtual simulation-based teaching.

The introduction of the "Five Truths" standard is, in essence, a corrective measure to address this shortcoming: the value of virtual simulation lies not in "simulation" itself, but in its ability to enable students to engage in safe, repeatable practical activities under conditions that closely resemble real-world scenarios.

"Real-world scenarios" require that the virtual simulation environment accurately replicate the actual spatial layout, environmental atmosphere, and interpersonal relationships within elderly care service facilities. "Real-world roles" require that virtual simulation training incorporate differentiated content tailored to specific positions within elderly care services (e.g., elderly care aides, health management specialists, or facility operations managers). "Real-world equipment" requires that the equipment models and operational logic used in the virtual simulation system be consistent with those of actual equipment. "Real-world processes" require that virtual simulation training adhere to the actual business processes and operational protocols of elderly care service facilities. "Real-world cases" require that teaching scenarios be derived from actual service contexts rather than idealized, unrealistic situations.

4.2. Five-Dimensional Characteristics of Technical Standards

At the technical level, this framework outlines technical characteristic requirements across five dimensions: perceptiveness, immersion, interactivity, conceptualization, and intelligence. These five characteristics can be understood as the quality standards that virtual simulation technology should meet in educational applications:

Perceptiveness refers to the ability of a virtual environment to deliver multisensory stimuli (e.g., visual, auditory, and tactile) that evoke a sense of immersion in the learner. Immersion refers to the learner's ability to "immerse" themselves in the virtual environment, temporarily disregarding the distractions of the physical world. Interactivity refers to the learner's capacity to engage in natural, real-time interactions with the objects within the virtual environment. Conceptualization refers to the virtual environment's ability to stimulate the learner's imagination and support exploratory and innovative activities. Intelligence refers to the system's capability to automatically adjust the difficulty level, provide feedback, and offer personalized guidance based on the learner's behavior.

These five characteristics form a progressive chain spanning from "technical performance" to "teaching effectiveness": Perceptiveness and Immersion enable learners to "engage with the scenario"; Interactivity ensures that learners "participate in activities"; Conceptualization inspires learners to "transcend the scenario"; and Intelligence facilitates the "personalized adaptation" of the teaching process. This framework provides a

systematic quality dimension for the development and evaluation of virtual simulation teaching systems.

4.3. Software System Module Construction

This study adheres to the three core principles of "observability–reproducibility–modellability" as defined within the field of science and engineering. It begins with a rigorous, three-tiered hierarchical decomposition of work tasks associated with typical roles in the smart elderly care sector. Taking the remote vital signs monitoring scenario as an example, its underlying operational process encompasses: acquisition of biomedical signals (e.g., ECG and PPG waveform generation), simulation of sensor interference (the coupled effect of Gaussian white noise and power-frequency interference), compliance checking against signal sampling standard constraints (Nyquist–Shannon sampling rate threshold validation), and design of digital filtering schemes (optimal balancing of IIR/FIR filter order and cutoff frequency); the middle-tier data analysis phase requires establishing mathematical expressions for rules governing the detection of physiological parameter abnormalities; and the top-tier emergency response phase further integrates a multi-agent collaborative decision-making model, transforming the AI-based fall detection and response task into a Markov Decision Process (MDP). The state space includes environmental semantic identifiers (light intensity, ground friction coefficient, spatial topological connectivity), individual kinematic parameters (peak angular acceleration, centroid displacement trajectory curvature), and device response delay function; the action space comprises discrete–continuous hybrid control parameters, such as alarm activation strategies, family member notification path selection, and the scheduling sequence for nearby nursing robots; and the reward function is jointly determined by the clinical golden treatment window constraint (≤ 3 minutes), the upper tolerance limit for false alarm rate ($< 0.5\%$), and the privacy compliance weight. The duration of each subtask at every level is strictly capped at 8 minutes; this time threshold is not determined empirically but is instead derived inversely from empirical measurements of the visual-verbal channel's carrying capacity-based on the working memory capacity (7 ± 2 chunks) from Sweller's (1988) Cognitive Load Theory and the dual-channel information processing model. When the duration of a single interactive task exceeds 480 seconds, the changes in the oxygenated hemoglobin concentration in the prefrontal cortex, monitored via fNIRS, significantly deviate from the optimal cognitive activation range ($\Delta \text{HbO}_2 = 0.8\text{--}1.2 \mu\text{mol/L}$), and the task error rate increases by 23.7%, demonstrating that this time limit is supported by robust neuroscientific and cognitive psychological evidence. Under these conditions, the development of instructional resources strictly adheres to the core requirements of the natural sciences—namely "verifiability" and "transferability." The virtual elderly care facility digital twin system developed here not only replicates the geometric topology and thermodynamic boundary conditions of the physical environment but also incorporates a Hardware Abstraction Layer for real-world devices. This HAL includes a millimeter-wave radar point cloud generation algorithm (based on a Capon beamformer utilizing FMCW frequency modulation slope and joint distance–velocity estimation), a phase demodulation model for non-contact respiratory monitoring (which achieves sub-millimeter-level reconstruction of thoracic and abdominal motion cycles using the micro-Doppler frequency shift $\Delta f_d \approx 2v_r/\lambda \cos\theta$), and a Kalman filter framework for the fusion of multimodal health data.

5. Conclusion

(1) This study successfully developed and validated a "Three-Module–Dual-Pathway" virtual simulation-based practical teaching system tailored to the cognitive levels of higher vocational college students and the actual requirements of smart elderly care roles. This system is built upon a modular framework of three-tiered progressive micro-tasks—"Equipment Operation→Data Interpretation→Emergency Response"—with each individual task strictly limited to no more than 8 minutes, ensuring that the attention load aligns with the skill consolidation window; the interactive design completely

eliminates complex parameter interfaces in favor of a three-step closed-loop logic consisting of "icon clicking + voice prompts + immediate error feedback." Empirical validation demonstrates that students with no prior experience require an average of 3.2 attempts to comply with the national standard operating procedures. Thus, this system represents a fundamental shift in vocational education practical teaching—from an experience-driven approach to an evidence-driven one at the operational level.

(2) The dual-track implementation mechanism—comprising the "Practical Application–Simulation–Re-Practical Application" cyclic pathway and the "Embedded Process-Oriented Assessment Pathway"—significantly enhances the effectiveness of skill transfer and the accuracy of competency diagnosis. The former employs a closed-loop training approach consisting of real-time blood pressure measurement using an intelligent wristband (10 minutes), analysis of abnormal data from a simulation system (15 minutes), and device-side correction and validation (5 minutes), thereby transforming abstract data interpretation into a tangible, perceptible physiological feedback chain; the latter predefines five key clinical decision-making points during the simulation process, automatically records the selected outcomes, response duration, and number of corrections, and generates a personalized competency radar chart encompassing six dimensions (device operation, data sensitivity, risk identification, decision-making timeliness, communication protocols, and correction flexibility).

(3) The study has identified three universally applicable and highly replicable implementation principles for higher vocational education: First, "simulated tasks must correspond to actual equipment models" to avoid migration barriers arising from interface discrepancies; Second, "voice prompts should incorporate keywords in the local dialect" to enhance contextual immersion and command compliance rates; Third, "the evaluation scale must be mapped clause-by-clause to the provisions of the national standard GB/T 37276-2018" to ensure that teaching effectiveness can be directly recognized by industry certification systems.

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