The Disembodied Apprentice: Reclaiming the Lived Body in Virtual Vocational Education

Yao Yang[1], Mingwei Wang[1],Shiliang Zheng[2]

1(School of Vocational and Technical Teacher Education, Shanghai Polytechnic University, China)

[2](School of Vocational and Technical Teacher Education, Shanghai Polytechnic University, China)

ABSTRACT : *UNESCO data reveals a significant gap between policy aspirations and practical implementation in the digital transformation of vocational education, raising philosophical concerns about virtual simulation technology. While such technology offers multimodal interaction, it often weakens the bodily basis of skill formation through symbolic abstraction. Drawing on the body schema from Merleau Ponty and the readiness to hand notion from Heidegger, this study critically analyzes three prevalent teaching pathways: Theory Simulation Practice, Theory Practice Simulation, and Simulation Theory Practice. Each pathway exhibits distinct forms of disembodiment and reveals a structural decoupling between technological mediation and bodily engagement. In response, we propose a three dimensional constructive framework centered on bodily reintegration. This framework involves three core strategies: leveraging the ontological imperfection of tools to disrupt cognitive transparency, enabling perceptual integration to restore multisensory coherence, and fostering generative interaction to cultivate adaptive expertise. This approach reconceptualizes virtual simulation not as a mere instructional medium but as an embodiment reconstruction interface. By aligning virtual tools with the embodied nature of skilled practice, the proposed framework offers both theoretical grounding and actionable design principles for developers and educators seeking to ensure that digital tools serve rather than supplant the human body as the irreplaceable site of professional becoming.*

KEYWORDS: *Virtual simulation technology; Vocational education; Embodied cognition; Philosophy of technology; Teaching pathways*

I. INTRODUCTION

UNESCO's 2025 monitoring data presents a striking global scenario: although 59% of vocational education institutions prioritize green and digital transformation, only 34% have actually achieved this goal**Error! Reference source not found.**. This significant implementation gap underscores the need for a critical re-examination of how digital technologies are integrated into vocational pedagogy.

Augmented and virtual reality (AR/VR) are often heralded for their capacity to bridge theoretical knowledge and practical application, offering learners immersive, hands-on experiences that prepare them for real-world occupational demands **Error! Reference source not found.**. Yet this promise raises a fundamental concern: while virtual simulation technologies claim to expand embodied experience, do their inherent symbolic abstractions inadvertently erode the embodied foundations of vocational learning?

This paper addresses this tension by examining three prevalent teaching pathways, each exhibiting a distinct form of disembodiment, characterized by a structural decoupling between technological mediation and the learner's bodily engagement in skill formation. Specifically: (1) the theory simulation practice pathway, constrained by limited sensory feedback, impedes the development of muscle memory; (2) the theory practice simulation pathway, hindered by insufficient scenario replication, undermines the transfer of experiential learning across contexts; and (3) the simulation theory practice pathway, circumscribed by rigid technological frameworks, narrows learners' understanding of authentic vocational skills[2].

Drawing on the body schema concept from Merleau Ponty and the readiness to hand notion from Heidegger, this paper proposes a three-dimensional framework to restore embodiment in simulated learning environments. Central to this approach is the disruption of rigid cognitive schemas through the ontological imperfection of tools, which prevents technology from becoming a transparent but hollow medium.

The framework further addresses sensory fragmentation via perceptual integration, ensuring that digital feedback aligns with the natural expectations of the lived body. Finally, the model emphasizes cultivating situational resilience through generative interaction, allowing learners to navigate the unpredictability of real-world professional contexts. This reconceptualization reframes virtual simulation not merely as a tool for knowledge delivery but as a constructive interface that actively supports bodily reintegration. Consequently, this study charts a path for vocational education in the digital age that unites theoretical depth with practical relevance.

The study utilizes a conceptual analytical methodology rooted in phenomenological philosophy. Rather than presenting empirical data, the paper offers a critical reinterpretation of current virtual simulation practices through the lens of embodied cognition. The primary objective is to construct a normative framework that reorients technology design toward bodily reintegration. This contribution is situated within the tradition of educational philosophy instead of experimental validation.

II. THEORETICAL FOUNDATION AND ANALYTICAL PERSPECTIVE

2.1 The Origins of Embodiment Theory

To grasp the ontology of virtual simulation technology, we must draw on phenomenology's deep account of bodily presence. This exploration begins with Heidegger **Error! Reference source not found.**, who distinguishes two modes of equipmental being. When functioning smoothly, tools are ready to hand, receding from awareness to enable direct task focus. Conversely, a malfunctioning tool becomes present at hand, shifting from an invisible medium to an explicit object of scrutiny. This breakdown interrupts embodied engagement and foregrounds the technological apparatus. In digital vocational training, the interface must achieve transparency where hardware vanishes into the learner's action cycle, as technical friction disrupts the ontological continuity between the learner and the professional task.

The cognitive validation of this stance is found in the transition from amodal to grounded cognition. Barsalou proposed perceptual symbol systems, arguing that cognition is inherently grounded in sensory-motor systems rather than abstract symbol manipulation[4]. This shifts vocational education toward cultivating embodied experiences. Early support was provided by Solomon **Error! Reference source not found.**, whose study on motion sensors demonstrated that pupils acquire deeper conceptual understanding through their own movements, proving physical interaction is a prerequisite for cognitive mastery.

Building upon these foundations, Merleau Ponty **Error! Reference source not found.** articulates the body schema as a structure organizing perception. In virtual environments, this schema must include digital affordances. Kilteni **Error! Reference source not found.** defines the sense of embodiment as the triad of body ownership, agency, and self-location, ensuring the learner inhabits the simulation. When virtual movements synchronize with intentions, the body schema updates in real time, developing professional intuition.

Recent scholarship has synthesized these theories into actionable frameworks. Makransky **Error! Reference source not found.**posits that immersion must foster cognitive and social presence through embodied interaction. Furthermore, Klingenberg **Error! Reference source not found.** tested an interactivity framework, finding that simulation effectiveness depends on how digital actions align with professional motor skills. Finally, Castro Alonso **Error! Reference source not found.** identifies critical research avenues for supporting embodied cognition, emphasizing that instructional design must move beyond abstract processing to leverage bodily engagement. High fidelity feedback sustains the ready to hand state necessary for skilled coping. These accounts converge on a central insight: genuine skill arises from situated know how rather than internal representations, reframing simulation as a mediating environment that sustains bodily attunement.

2.2 Construction of the Analytical Framework

2.2.1Transparency and Reflectivity in Tool Interaction

This dimension draws on Heideggerian phenomenology to reframe the learner tool relationship. Ideally, simulation tools achieve readiness to hand, withdrawing from attention to enable full task engagement. However, this framework intentionally introduces controlled friction, such as calibrated uncertainty, to disrupt habitual interaction. According to Ihde **Error! Reference source not found.**, technology mediation involves a dialectic between embodiment and hermeneutic relations. While perfect tools remain transparent, intentional interruptions shift them to a present-at-hand state, forcing learners beyond automaticity toward critical interpretation of the medium.

The pedagogical value of this friction is supported by the concept of productive failure **Error! Reference source not found.**, which argues that persisting through structured challenges deepens understanding. This aligns with desirable difficulties**Error! Reference source not found.**, suggesting that obstacles enhance long-term retention and skill transfer. In virtual vocational education, these difficulties prevent learners from becoming passive operators, ensuring they remain active problem solvers.

Recent evidence from 2025 highlights the practical implementation of these concepts. Glaser **Error! Reference source not found.** explores how virtual reality representations in cybersecurity education create unique learning affordances, noting that interface design directly impacts cognitive growth. Furthermore, a report by Thrasher **Error! Reference source not found.**on large-scale virtual reality implementation emphasizes balancing immersion with pedagogical scaffolding. Without designed moments of reflection, high immersion may lead to cognitive overstimulation rather than meaningful learning.

Ultimately, these interruptions shift tools from ready-to-hand extensions of the body to explicit objects of scrutiny. This is a deliberate strategy where the tension between transparency and disruption becomes a generative mechanism. By oscillating between absorbed action and metacognitive reflection, learners develop robust professional expertise resilient to the complexities of real-world technological environments.

2.2.2 Integration and Multimodality of Body Perception

This dimension draws on Merleau Ponty's phenomenology of perception, emphasizing that bodily subjectivity is constituted through multisensory engagement. In virtual environments, effective learning requires integrating vision, audition, haptics, and proprioception into a coherent field. Walkington **Error! Reference source not found.** demonstrates that embodied technologies rely on coordinating gestures, speech, and gaze for conceptual understanding. This multimodal synthesis enables the reconfiguration of the body schema, the prereflective structure organizing motor intentionality. As Mills**Error! Reference source not found.**argues, 3D multimodal designing allows learners to expand their body schema into virtual workspaces by integrating spatial reasoning with digital creation.

When sensory inputs align, the learner inhabits the task rather than observing a screen. Chang**Error! Reference source not found.** notes that scientific inquiry requires specific multimodal perspectives to ground abstract concepts in physical experience. This inhabitation is enhanced by haptic interaction, providing the tactile resistance necessary for mastery. A meta-analysis by Gu **Error! Reference source not found.** confirms that haptics play a pivotal role in extended reality learning, correlating tactile feedback with improved outcomes. Similarly, Qi **Error! Reference source not found.**highlights that haptics bridge the gap between digital observation and physical manipulation, increasing satisfaction and performance.

Furthermore, integrating feedback is essential for refining motor skills. Atatekin **Error! Reference source not found.**suggests that real time alignment of visual and kinesthetic information is crucial for corrective learning. This approach is supported by Webb **Error! Reference source not found.**, who demonstrates that haptic-enabled collaborative learning fosters a shared perceptual field, allowing learners to synchronize actions toward common goals. Combined with Heideggerian tool transparency, this dimension ensures that simulated actions are internalized as practical dispositions, facilitating the transfer of digital practice to real-world performance.

2.3The disembodiment risk of current technology applications

Current virtual simulation technologies in vocational education often exhibit a shared limitation: a fundamental neglect of embodiment in their design logic.

In terms of tool interaction, many systems prioritize seamless reliability and deterministic outcomes, eliminating the very moments of friction or ambiguity that could provoke critical reflection. While such optimization aims for efficiency, it inadvertently suppresses what phenomenological approaches identify as the productive breakdown of readiness-to-hand, a condition through which users become aware of technological mediation and engage in adaptive sense-making **Error! Reference source not found.**. The result is a rigid instrument that enforces procedural compliance rather than functioning as a "living" medium for exploratory learning.

In bodily perception, the dominance of visual channels further exacerbates this disembodiment. Empirical surveys on VR adoption in educational settings reveal a paradox that underscores this sensory imbalance. Among the most favorable factors for the application of VR in education, the 37.5% of students believed that the most beneficial application of VR technology in education is to enhance students' interest in learning. For the difficulties faced by the application of VR in education, the 22.5% believed that the main reasons are the complexity of equipment with not easy to operate; the main reason for the 20.5% expected that the equipment was not exquisite enough, resulting in a poor experience; the 26% counted that the high cost is the reason why VR technology cannot be widely implemented in education; the 10.5% supposed that the preparation time for VR classes was long and insufficient; and the 20.5% felt that there are no suitable teaching resources available**Error! Reference source not found.**. These reported challenges, particularly those concerning hardware complexity, quality, and resource scarcity, directly point to the underdevelopment of non-visual sensory modalities.Crucially, haptic and proprioceptive feedback remain underdeveloped or absent, preventing the formation of a coherent perceptual field necessary for embodied cognition**Error! Reference source not found.Error! Reference source not found.**.

This article discusses the existing ITS and AR systems and their flaws, followed by some potential benefits that can be achieved by combining ITS and AR effectively. We propose a novel architecture for improving the combined AR and ITS system scalable for supporting interaction for the diverse users and domain. The proposed system makes an effective use of three tier architecture, load sharing algorithms, data management techniques, multiple servers, marker-less AR, and modeling 3D object models on the fly, in order to make the system more effective, secure, reliable, and seamless for the users. For realizing 3D object modeling on the fly, the article presents an improved method by combining Level of Detail and Rasterization techniques in order to render in steps in accordance with the demand , which will help us use the architecture for small-scale to large-scale systems**Error! Reference source not found.**. True embodiment, therefore, requires not just sensory richness, but also ecological fidelity. This design principle preserves the openness and contingency essential to skilled practice.

III. THREE PREVAILING PATHWAYS IN VIRTUAL SIMULATION TEACHING

3.1 Theory Simulation Practice Pathway

The theory simulation practice pathway is primarily driven by pragmatic concerns, particularly the urgent need for reducing operational costs and mitigating safety risks through risk free rehearsal in virtual environments**Error! Reference source not found.**. While this design prioritizes training efficiency, it frequently neglects a core principle of embodied cognition which states that robust skill acquisition depends on multisensory integration emerging from continuous and dynamic interaction between the body of the learner and a responsive environment. As Merleau Ponty argues, authentic vocational expertise manifests as bodily intelligence, a unified capacity in which perception and action coalesce across vision, touch, proprioception, and movement. Yet current simulation technologies frequently fall short of supporting this essential unity, creating a sensory gap that limits the depth of professional mastery.

Evidence from recent empirical studies on spray painting simulators suggests that while such tools are effective for knowledge acquisition and procedural familiarity, the development of professional attitudes is not uniquely dependent on immersive simulation and could be cultivated through alternative pedagogical means **Error! Reference source not found.**. This finding implies that mere visual immersion may not be the decisive factor in forming a deep professional identity. More critically, observations regarding the sensory limitations of these systems indicate that most virtual environments rely overwhelmingly on visual input but fail to replicate essential haptic cues such as the recoil of a spray gun or the viscous resistance of paint **Error! Reference source not found.**. Such sensory impoverishment directly impedes the formation of a coherent body schema, as the learner is denied the tactile feedback necessary to calibrate their physical movements with the resistance of the material world.

This lack of sensory fidelity creates significant barriers during the transition to physical tasks, as learners often must unlearn maladaptive motor patterns acquired during the digital rehearsal**Error! Reference source not found.**. Because the virtual interface does not provide the correct physical resistance, the body develops habits that are specific to the software constraints but detrimental to real-world performance, effectively extending the cycle of skill internalization rather than accelerating it. Consequently, the fundamental limitation of the theory simulation practice pathway lies in its fragmentation of perceptual experience. This fragmentation creates a representational gap that demands excessive compensatory effort during real-world practice. By forcing learners to bridge this gap through trial and error in the physical workplace, the current simulation model undermines the very efficiency it seeks to achieve, highlighting a profound disconnect between digital training and the embodied reality of professional expertise.

3.2 Theory Practice Simulation Pathway

The theory practice simulation pathway seeks to ground virtual training in authentic experience by first engaging learners in real-world practice. Almost nine per cent (14 studies) of the research focused on VR and AR implementation at the vocational education level. VR and AR were discovered as potentially effective tools for training vocational learners on various equipment and tools they may work with after graduation**Error! Reference source not found.**.

From a situated learning perspective, however, the transfer of professional competence depends not only on procedural fluency but also on tacit understandings cultivated within actual workplaces. Such understandings encompass organizational routines, social dynamics, professional norms, and strategies for managing ambiguity or crisis**Error! Reference source not found.**. Genuine expertise emerges through sustained participation in communities of practice, where learners continuously negotiate meaning and refine practical judgment through embodied interaction with their environment.

To clear the bar, a virtual reality and simulation platform is co-developed by University A (a pseudonym used in this study) in Beijing and one of its partner enterprises, aimed at enabling students to see in person the transmission processes of the invisible radio waves and to hear the Doppler Frequency Shift, which involves the change in sound caused by a professional phenomenon Doppler effect in physics. Moreover, the platform also allows students to set parameters in their own right so that students are able to summarize regularities about wave transmission under different circumstances**Error! Reference source not found.**.For instance, while the AI-enhanced mixed reality nursing platform developed by Sepanloo**Error! Reference source not found.** enabled learners to recognize and respond to critical patient needs, such as initiating fluid resuscitation or administering oxygen, participants frequently omitted fundamental safety protocols, including hand hygiene and correct oxygen flow calibration. These omissions suggest that even sophisticated simulations may fail to embed the habitual discipline and normative awareness that characterize expert practice in real clinical environments. Consequently, the pathway risks reinforcing technical actions while neglecting the socio-ethical scaffolding essential to professional competence.

3.3 Simulation Theory Practice Pathway

The simulation theory practice pathway seeks to engage learners by immersing them in virtual environments before formal instruction, capitalizing on experiential curiosity to motivate subsequent theoretical learning In the context of this study, the educational benefits that can be yielded through the use of gamified virtual reality refer to the aspects that render teaching and learning more effective, the new educational opportunities that arise, the positive learning outcomes, the elements that lead to the cognitive, social-emotional, and physical development of students, as well as the aspects that result in students' personal development and well-being **Error! Reference source not found.**. While this approach can enhance initial interest, its reliance on pre-scripted scenarios risks fostering a reified understanding that equates simulated procedures with the open-ended, context-sensitive nature of real-world work.

Empirical studies illustrate this limitation. In culinary education, Hu **Error! Reference source not found.** found that VR-based courses effectively convey standardized recipes and sequential workflows; however, by fixing ingredient properties and eliminating variability in heat response or material behavior, such simulations promote a rigid conception of correct cooking that neglects the improvisational judgment essential to expert practice. Similarly, in furniture-making training, AR/VR systems excel at visualizing predefined assembly steps but fail to represent the dynamic affordances of wood, such as grain variation, moisture-induced warping, or opportunities for adaptive craftsmanship **Error! Reference source not found.**.

Consequently, learners accustomed to deterministic virtual environments often struggle when confronted with the material indeterminacy and creative demands of authentic settings. Cooking students falter when stove temperatures fluctuate, or ingredients behave unexpectedly; woodworking students hesitate to deviate from prescribed methods when materials resist idealized models. Rather than cultivating adaptive expertise, this pathway may inadvertently reinforce procedural compliance over practical wisdom.

IV. RETURNING TO THE EMBODIED THREE-DIMENSIONAL FRAMEWORK AND THE CORRESPONDING LOGICAL CONSTRUCTION SCHEME

The preceding analysis systematically examined three typical disembodied teaching approaches, revealing structural deficiencies in virtual simulation design within vocational education across the dimensions of perception, context, and cognition. To fundamentally address these challenges, this paper proposes a three-dimensional framework centered on embodiment-based reintegration, as illustrated in Table 1. The core concept of this framework is to transform virtual simulation from an isolating screen for learners into an interface extending the body by reestablishing a cyclical mechanism of perception and interaction between technology and the physical body. This transformation necessitates a shift from passive observation to active sensorimotor engagement, ensuring that digital tools are no longer perceived as external objects but as transparent extensions of the learner's sensory apparatus.

This proposed framework responds to the sensory impoverishment identified in previous models by prioritizing the alignment of multimodal feedback with motor intentions. As established by the synthesis of phenomenological and cognitive perspectives, the reintegration of the body requires that virtual environments sustain the ready-to-hand state of technological mediation. This is achieved by designing interfaces that do not merely represent professional tasks but facilitate the dynamic update of the body schema through real-time haptic and proprioceptive feedback. By anchoring digital practice in the physical reality of the learner's body, the framework aims to bridge the representational gap that currently hinders skill transfer. Consequently, the embodiment-based reintegration model serves as a pedagogical blueprint for developing virtual simulations that foster adaptive expertise and practical wisdom rather than mere procedural compliance.

Table 1 Paths of Critical Disembodiment and Corresponding Dimensions of Embodiment Regression

Question	**Solutions**	**Design Principles for Re-embodiment**
Disrupting Perceptual Continuity	Perceptual Integration	Integrate force/tactile/thermal feedback across sensory channels
Weakening Contextual Transferability	Generative Interaction	Program stochastic tool failures to disrupt automation
Solidifying Cognitive Preset	The Imperfect Nature of Tools	Simulate socio-technical complexity

Frameworks	Themselves	via dynamic event generators

4.1The Imperfect Nature of Tools

We define ontological imperfection as the deliberate introduction of controlled uncertainties, resistances, or failures into virtual tools. By mirroring the unpredictable materiality of real-world instruments, this approach disrupts cognitive transparency and provokes reflective practice.

To fight the rigid thinking caused by the simulation theory practice pathway, this framework suggests the idea of tools being not perfect. Based on Heidegger's philosophy of technology, this part says we should put uncertainty into virtual tool design. This will stop learners from depending too much on the system being perfect. It will make them think about the tool's role in learning activities.

In a usual simulation design, tools are seen as things we can control perfectly. But in real work, tools often act unpredictably and resist us. This uncontrollable nature is part of the skill in professional work. So, virtual simulation should make these imperfections on purpose. This will change the learning process from just following rules to creating understanding. It will help learners make good judgments while they work. Imperfection is not a problem, but a way to teach. It helps learners see the limits of technology and their own ability to act.

4.2 Perceptual Integration

To fix the problem of the theory simulation practice pathway breaking how we sense things, the second part focuses on perceptual integration. This idea comes from Merleau-Ponty's body schema theory. It says that learning a skill is not just taking in information but also keeping the body, senses, and environment working together. Right now, most virtual simulations focus on what you see and forget important senses like touch, movement, and feeling force. To get back a full experience that feels real, we should change from making things look real to making the whole experience feel real. We can use things like haptic gloves, force feedback devices, or controls that change how hard it is to push. This way, learners can "feel" weight, friction, temperature, and different materials in virtual spaces.

These signals from many senses not only make actions more precise but also help learners feel connected in virtual environments. This changes technical interfaces from something outside to a natural part of how we act. The goal of perceptual integration is not to make technology look real but to let learners feel "bodily presence." This helps them truly connect doing something with understanding it.

4.3 Generative Interaction

Unlike algorithm-driven adaptation,which often follows predetermined and linear paths, generative interaction emphasizes emergent scenario complexity, socio material unpredictability, and collaborative meaning making. This approach effectively simulates the liveness and fluidity of authentic professional workplaces. The third dimension, interactive generativity, focuses on the dynamic and evolving nature of contexts within virtual simulations. This perspective is deeply rooted in the concept of being in the world proposed by Heidegger as well as the principle of body world interaction articulated by Merleau Ponty. Both philosophical stances suggest that learning occurs within social contexts that undergo constant change rather than through isolated cognitive activities or abstract thinking.

This shift toward generativity aligns with the situated cognition framework, which argues that knowledge is fundamentally inseparable from the activity and social interactions in which it is developed. For example, recent empirical findings indicate that even for diverse populations, such as older adults, the construction of digital literacy is heavily dependent on specific environmental contexts and social engagement**Error! Reference source not found.**. Therefore, virtual simulations must move beyond mere representation or the passive showing of objects. Instead, they should employ a design that changes dynamically based on the immediate situation, accounting for the complex social and material factors that influence how professional expertise is both learned and exercised in practice.

To implement this dimension, virtual systems can introduce unpredictable elements such as surprise tasks, limited resource availability, or interpersonal teamwork conflicts. These designed interventions move the learning process closer to the realities of actual work situations, where professionals must navigate ambiguity and stress. When the simulated environment functions as a living system rather than a pre-scripted software package, learners are no longer restricted to following a procedural script. Instead, they are challenged to solve problems creatively under realistic and pressured conditions. This fundamental transformation changes simulation learning into situated learning, where the focus shifts from procedural compliance to the cultivation of adaptive expertise. By fostering a state of continuous engagement with a responsive and unpredictable world, generative interaction ensures that the learner develops the practical wisdom necessary to navigate the complexities of authentic professional environments.

V. DISCUSSIONS FROM THEORETICAL FRAMEWORKS TO PRACTICAL IMPLICATIONS

5.1Summary of Key Findings

Through systematic analysis, this study identifies three primary issues with virtual simulation technology in vocational education and proposes a corresponding embodied solution framework. The findings indicate that these systemic problems stem from a fundamental disconnect between virtual simulation interfaces and the bodily experiences of the learner. To address the rigid technical cognition that often characterizes the simulation theory practice pathway, this paper introduces the dimension of tool imperfection. By intentionally designing moments of friction and calibrated uncertainty, this approach restores the essential capacity for reflection and adaptation during the learning process, preventing the learner from becoming a mere operator of pre-programmed software.

To address the lack of perceptual continuity frequently observed in the theory simulation practice pathway, the perceptual integration dimension is introduced. This dimension focuses on reconstructing continuous multisensory feedback loops that align visual, auditory, and haptic inputs. By ensuring that the digital environment responds to the physical movements of the learner in a way that is sensorially consistent, this solution aims to rebuild the body schema and eliminate the fragmentation of experience that often hinders the development of professional intuition. Furthermore, to overcome the difficulty in experience transfer caused by the theory practice simulation pathway, the generative interaction dimension is proposed. This strategy re-embeds learning within dynamic and unpredictable contexts, moving beyond static scenarios to simulate the liveness and social material complexity of authentic workplaces.

Through this precise correspondence between identified problems and embodied solutions, the study establishes a clear logical connection between philosophical theory and pedagogical practice. This framework does not merely seek to improve the visual fidelity of technology but aims to transform virtual simulation into a mediating interface that extends the body of the learner. By fostering a state of continuous and active engagement with a responsive world, the proposed dimensions provide actionable insights for enhancing virtual simulation in vocational education. Ultimately, this research suggests that the future of vocational training lies in creating digital environments that respect and leverage the inherent bodily intelligence of the learner, thereby ensuring that the mastery gained in the virtual realm can be seamlessly translated into the skilled performance required in the physical world.

5.2 Implications for Course Design and Teaching Methods

Based on the three-dimensional framework, course design should break away from traditional linear thinking to construct a dynamic and cyclical teaching process. We propose a practice simulation re practice sandwich teaching model, as illustrated in Figure 1. This model positions virtual simulation strategically between layers of real-world operations, creating a pedagogical rhythm that prioritizes bodily experience. The process begins by establishing physical awareness through brief hands on practice in a concrete environment. This initial phase ensures that the learner develops a baseline sensory attunement to the materials and tools of their trade, anchoring their subsequent digital interactions in a tangible reality.

Following this physical grounding, the learner enters a virtual environment for reflective training on critical steps. This is not a mere repetition of the task but a targeted intervention where the unique affordances of simulation, such as the ability to pause, rewind, or visualize hidden internal mechanisms, are used to deepen procedural understanding. However, the simulation remains effective only because it is preceded by actual physical engagement. Finally, the learner returns to real scenarios to consolidate their skills, applying the digital insights back into the messy and unpredictable conditions of the physical workplace. This cyclical design transforms virtual simulation into an effective bridge connecting raw physical experience with sophisticated skill enhancement.

By structuring the curriculum in this way, the model prevents the digital tool from becoming a substitute for reality. Instead, it functions as a mediating space for reflection and refinement. The transition from the physical to the virtual and back again creates a feedback loop that sustains the ready-to-hand state of the technology while preventing the fragmentation of the body schema. This approach acknowledges that professional expertise is not a collection of abstract rules but a form of situated know-how that must be nurtured through a continuous dialogue between the body and the environment. Ultimately, the sandwich model ensures that the learner remains sensorially grounded, transforming simulation from an isolated digital exercise into a powerful catalyst for authentic vocational mastery.

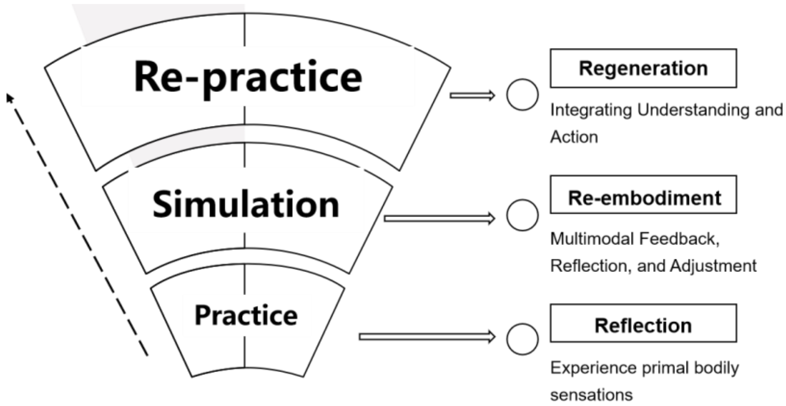

Figure 1 Three-Stage Generative Model for Embodiment-Based Courses

In this redesigned pedagogical process, the role of the teacher requires a fundamental shift from being a mere instructor of technical operations to becoming a guide for the embodied experiences of the students. This transition acknowledges that professional expertise is not simply a matter of following a sequence of commands but involves a deep and prereflective connection between the person and their craft, reflecting the essential presence of the body in digital education as a primary medium for experience**Error! Reference source not found.**. Phenomenologically, such a connection is always intersubjective: it is forged when teacher and learner co-inhabit a shared lifeworld in which both bodies are geared toward the same vocational horizon **Error! Reference source not found.**.

Teachers must therefore move away from explaining isolated operational steps and instead facilitate somatic awareness. By using short, open prompts like "Where did you feel the weight just now?" or "Which joint led that movement?", they transform procedural checklists into opportunities for proprioceptive noticing **Error! Reference source not found.**. These questions are not technical trivia but deliberate intercorporeal invitations that help learners tune their lived bodies to the resistances and rhythms of the virtual environment. Such instructional strategies align with recent findings that engaging student teachers with embodied cognition theories can transform their pedagogical experiences by deepening their understanding of how the body functions as a primary site of learning **Error! Reference source not found.**. Over time, these repeated acts of shared noticing sediment into a robust body schema, fostering a tacit and situation-specific know-how that withstands the temporal pressures of real-world practice.

Crucially, the teacher's own bodily demeanour functions as the first model of this attunement. When an educator pauses, mirrors a student's gesture, or subtly adjusts her own centre of gravity while demonstrating a simulated procedure, she is not merely showing the right move; she is publicly negotiating the meaning of being "in" the task**Error! Reference source not found.**. Empirical studies of mathematics classrooms show that the very act of teachers producing iconic or metaphoric gestures around abstract concepts increases the probability that learners will reproduce,and thereby re-embody,those concepts in their subsequent problem-solving **Error! Reference source not found.**. Transferring this principle to vocational simulations, the teacher's gestures become micro-demonstrations that students can imitate, vary, and ultimately internalise.

To ensure that such imitation evolves into authentic understanding, educators can embed students in cycles of embodied enquiry. Danish **Error! Reference source not found.** proposes a Learning in Embodied Activity (LEA) framework in which teachers first coordinate learners' physical actions with shared representational tools, then explicitly prompt reflection on how shifting body position changes the meaning of the representation. In a virtual welding simulator, for example, the teacher might ask: "How does your elbow angle relate to the bead profile you see on screen?"—thereby converting a visual outcome into a somatic datum. Through these cycles, the technological tool remains an extension of the human body rather than a barrier to authentic learning, and the teacher becomes the mediator who ensures that every digital interaction is transmuted into a lasting physical memory.

5.3 A Guide to Embodied Development in Simulation Technology

The focus of technological development in vocational simulation should shift from pursuing visual fidelity, which is characterized by high-resolution graphics and photorealistic rendering, toward cultivating experiential fidelity. This refers to the capacity to engage learners' sensorimotor, affective, and social dimensions in ways that mirror authentic professional practice.The educational value of simulation systems lies not in sharper images or increased polygon counts, but in fostering a sense of embodied presence through multisensory feedback and responsive interaction. Accordingly, design priorities must be realigned: haptic devices that deliver force feedback are more consequential than upgrades to 4K displays; simulating the dynamic material properties of real tools is more critical than visual realism alone.

This experiential fidelity approach is gaining empirical support. Boel **Error! Reference source not found.** found that the iVR SAVR SG, a low-cost mobile VR serious game, was positively evaluated by both students and teachers as a valuable tool for teaching hazard perception in secondary vocational education. This assessment was based precisely on its prioritization of functional interaction over visual polish. However, achieving such effectiveness requires systematic design frameworks. Drawing on evidence-based guidelines for immersive collaborative virtual environments**Error! Reference source not found.**, this study proposes the Re-embodiment 3D Framework, comprising three core principles for technology developers:

Adaptive Friction: Enable instructors to modulate levels of productive breakdown such as tool wear, environmental interference, or delayed feedback based on learner proficiency. This cultivates adaptive expertise and sound judgment under uncertainty.

Contextual Contingency: Integrate a scenario engine that generates pedagogically meaningful disruptions to reflect the open-ended, non-linear nature of real-world practice.

Collaborative Co-presence: Support multi-user interaction with shared spatial awareness and real-time communication, thereby replicating workplace team dynamics and fostering collective sensemaking through joint action.

5.4 Research Limitations and Future Prospects

As a conceptual and philosophically grounded study, this work does not provide empirical validation of the proposed three-dimensional framework for technological embodiment. Its primary limitation lies in its reliance on theoretical critique rather than experimental or quasi-experimental evidence from real-world vocational classrooms. Additionally, while the framework identifies pathways of disembodiment across cognitive, affective, and social dimensions, it does not yet specify concrete design heuristics for different occupational domains .

These limitations point to clear avenues for future research. First, comparative studies could test the skill transfer fidelity of imperfect virtual reality simulators designed to prioritize embodied engagement over visual realism against high fidelity but cognitively detached alternatives. Second, longitudinal investigations might examine how learners situational adaptability differs when trained in generative versus scripted virtual scenarios. Third, participatory design projects involving vocational instructors and apprentices could co develop domain specific embodiment reconstruction interfaces, thereby grounding the framework in pedagogical practice. Such efforts would transform this conceptual orientation into actionable innovation.

VI. CONCLUSIONS

While grounded in phenomenological critique, this study yields concrete guidance for the development of virtual reality-based vocational training systems. The three dimensions proposed in this framework, namely ontological imperfection, perceptual integration, and generative interaction, provide a robust foundation for the next generation of instructional design. These dimensions inform the creation of haptic interfaces that preserve material resistance, scenario engines that simulate socio-technical unpredictability, and feedback mechanisms designed to disrupt cognitive automation. Such features move beyond mere visual realism toward a deeper form of experiential fidelity. This shift ensures that virtual environments support rather than substitute bodily learning, allowing the digital space to function as a genuine arena for skill acquisition.

The digital transformation of vocational education must not be allowed to sever its ontological tie to the lived body. This paper argues that current virtual simulation technologies often privilege visual realism over embodied presence, thereby risking the deepening of multiple forms of disembodiment. Whether cognitive, affective, or social, these forms of detachment undermine the very essence of skilled practice. In response, we propose reconceptualizing simulation not as a mirror of the physical world but as an embodiment reconstruction interface. This new conceptualization suggests that technology should be evaluated not by its ability to replicate appearances but by its capacity to restore the active role of the body in the learning process.

Grounded in the rich traditions of phenomenology and embodied cognition, this three-dimensional framework affirms that the true value of technology lies in its capacity to scaffold authentic sensorimotor engagement, situated judgment, and collaborative meaning making. By shifting design priorities from how things look to how experiences feel, educators and developers can preserve the practical integrity and ethical core of vocational education. This approach recognizes that the professional identity of a craftsperson is forged through the resistance of materials and the unpredictability of social contexts. In doing so, we ensure that digital tools serve, rather than supplant, the human body as the irreplaceable site of skill, identity, and professional becoming. The future of vocational training depends on our ability to design technologies that respect the wisdom of the hand as much as the logic of the code, ultimately fostering a more human-centric and embodied approach to digital expertise.

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