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Virtual Museums as Digital Practice Learning Environments in Technical and Vocational Education and Training: A Conceptual Framework

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ABSTRACT

Despite the rapid digital transformation of Technical and Vocational Education and Training (TVET), virtual museums have received limited theoretical attention as pedagogical tools for practice-based learning. Most existing studies focus on cultural heritage or museum education, overlooking their potential in vocational contexts. This paper addresses this gap by proposing a conceptual framework that reconceptualizes virtual museums as Digital Practice Learning Environments (DPLEs). Integrating insights from Experiential, Situated, Constructivist, Museum, and Authentic Learning theories, the framework identifies four interconnected characteristics—authenticity, immersion, interaction, and reflection—through which virtual museums support vocational learning. These characteristics allow learners to experience authentic occupational scenarios, construct professional knowledge, and develop practical competence, transcending the limitations of traditional classrooms. By repositioning virtual museums from mere exhibition platforms to active learning environments, the framework provides a theoretical foundation for TVET integration and offers clear guidelines for empirical research and curriculum innovation.

Keywords: Virtual museum; Technical and vocational education and training (TVET); Digital practice learning environment; Authentic learning; Conceptual framework

1.INTRODUCTION

Technical and Vocational Education and Training (TVET) is undergoing significant transformation as digital technologies reshape industrial production, workforce requirements, and vocational learning. Emerging technologies such as artificial intelligence (AI), virtual reality (VR), digital twins, and immersive media are changing not only how people work but also how vocational competencies are developed. Consequently, many TVET institutions are moving beyond traditional workshop-based instruction and exploring digital learning environments that can better prepare students for increasingly technology-intensive workplaces (UNESCO-UNEVOC, 2022).

Despite these developments, practical learning remains a fundamental characteristic of TVET. Unlike general academic education, vocational education requires learners to integrate theoretical knowledge with workplace practice through authentic experiences. Such learning is

traditionally achieved through laboratories, workshops, apprenticeships, and industrial placements, where students interact directly with equipment, processes, and professional communities (Billett, 2011). However, these forms of practical instruction are often constrained by high operational costs, limited access to industrial facilities, safety requirements, and unequal educational resources. These challenges have prompted educators to explore digital approaches that can complement, rather than replace, physical practical training.

Among emerging digital technologies, virtual museums have attracted increasing attention in education. Advances in three-dimensional modelling, immersive visualisation, and interactive technologies have enabled museums to extend beyond their physical spaces and provide learners with rich digital experiences. Through virtual exhibitions, interactive artefacts, and immersive environments, learners can explore historical developments, industrial heritage, scientific innovations, and professional practices regardless of geographical constraints (Carrozzino & Bergamasco, 2010). As a result, virtual museums are increasingly recognised as educational environments rather than merely digital archives.

Existing research has reported several educational benefits of virtual museums, including increased learner engagement, enhanced motivation, improved accessibility to learning resources, and richer learning experiences (Kabassi et al., 2019; Radianti et al., 2020). Most of these studies, however, have been conducted within the fields of museum education, cultural heritage, history education, and educational technology. Consequently, virtual museums are commonly discussed as tools for cultural interpretation or visitor engagement, while their potential role in supporting vocational learning has received comparatively little theoretical attention.

This represents an important gap in the literature. Learning in TVET differs from learning in many other educational contexts because vocational competence develops through authentic participation in professional practices, contextual problem-solving, and reflective engagement with workplace situations (Billett, 2011). Although virtual museums provide authentic artefacts, professional narratives, and immersive environments, existing studies rarely explain how these characteristics contribute to practice-oriented learning. More importantly, there is currently no conceptual framework that positions virtual museums within the pedagogical discourse of TVET.

This paper addresses this gap by reconceptualising virtual museums as Digital Practice Learning Environments (DPLEs). Rather than viewing virtual museums primarily as digital exhibition platforms, this study argues that they represent educational environments capable of supporting authentic vocational learning through immersive interaction, contextual exploration, and reflective engagement. To develop this argument, the paper synthesises five complementary learning theories—Experiential Learning Theory, Situated Learning Theory, Constructivist Learning Theory, Museum Learning Theory, and Authentic Learning Theory—to explain the pedagogical mechanisms through which virtual museums can facilitate vocational competence development.

The paper makes two contributions. First, it extends the conceptual understanding of virtual museums beyond museum education by positioning them within the context of vocational pedagogy. Second, it proposes a conceptual framework that explains how virtual museums can

support practice-oriented learning in TVET. The framework provides a theoretical foundation for future empirical research and offers practical implications for curriculum design and the integration of digital learning environments in vocational education.

2. Virtual Museums in TVET: Current Understanding and Research Gap

2.1 The Evolution of Virtual Museums in Education

The concept of the virtual museum has evolved alongside advances in digital technologies and changing perspectives on learning. Early virtual museums were primarily developed to digitise museum collections and improve public access to cultural heritage. Their main functions included preserving artefacts, overcoming geographical barriers, and providing online exhibitions for wider audiences (Sylaiou et al., 2009). At this stage, digital technologies were mainly regarded as tools for information storage and dissemination, and educational functions received relatively little attention.

As digital technologies matured, particularly through the development of three-dimensional visualisation, virtual reality (VR), augmented reality (AR), and interactive media, virtual museums gradually shifted from information repositories to learning environments. Rather than simply presenting digital collections, they began to support user interaction, immersive exploration, and personalised learning experiences (Carrozzino & Bergamasco, 2010). This shift reflects a broader change in educational philosophy, where learners are viewed as active participants who construct knowledge through exploration and experience rather than passively receiving information.

Recent research has further expanded the educational applications of virtual museums. Studies have shown that immersive digital environments can increase learners' motivation, engagement, and conceptual understanding by providing interactive learning experiences that are difficult to achieve in conventional classrooms (Radianti et al., 2020). Consequently, virtual museums are increasingly recognised as educational environments capable of supporting both formal and informal learning.

Despite these developments, the educational role of virtual museums remains largely associated with museum education, cultural heritage, history, and art education. Comparatively little research has examined how these environments may contribute to vocational learning, where practical knowledge, occupational competence, and workplace understanding are central learning outcomes.

2.2 Virtual Museums in TVET: Current Applications and Research Gap

The integration of digital technologies into TVET has accelerated in recent years, driven by the increasing demand for digitally competent graduates and the emergence of Industry 4.0. Virtual simulations, digital twins, and immersive learning technologies have been widely adopted to complement traditional workshop-based instruction (UNESCO-UNEVOC, 2022). Within this context, virtual museums have also begun to attract attention because they provide access to authentic artefacts, industrial heritage, technological development, and professional knowledge

that may otherwise be inaccessible to students.

Existing studies suggest that virtual museums can enrich vocational education in several ways. First, they provide authentic learning resources that enable students to explore professional practices beyond the classroom. Second, they support flexible learning by allowing students to access learning materials regardless of time and location. Third, immersive digital environments encourage learner engagement through interactive exploration rather than passive observation (Kabassi et al., 2019).

However, current research remains fragmented. Most studies evaluate virtual museums from technological perspectives, such as usability, interface design, or user satisfaction, while relatively few examine their pedagogical functions in vocational education. Similarly, educational studies often focus on learners' motivation or learning experience without explaining how virtual museums contribute to the development of vocational competence. Consequently, the relationship between virtual museums and practice-oriented learning remains theoretically underdeveloped.

Another limitation concerns the theoretical foundations of existing research. Studies frequently adopt technology acceptance models or general educational theories to explain learning outcomes, but these approaches do not fully reflect the distinctive characteristics of TVET, where learning is closely connected to authentic practice, professional identity, and workplace participation (Billett, 2011). As a result, there is currently no integrated framework that explains how virtual museums can support practical learning within vocational education.

2.3 Research Gap and Conceptual Positioning

The literature reviewed above indicates that virtual museums have gradually evolved from digital exhibition platforms into interactive learning environments. Nevertheless, existing studies rarely conceptualise virtual museums from the perspective of vocational pedagogy. Their educational value is generally discussed in terms of cultural learning, visitor engagement, or technology-enhanced learning, leaving their contribution to practice-oriented learning largely unexplored.

This gap is significant because practical learning is the defining characteristic of TVET. Developing vocational competence requires more than access to information; it requires learners to engage with authentic professional contexts, interpret occupational knowledge, and reflect on workplace practices. These characteristics suggest that virtual museums should be understood not simply as digital resources but as environments that support practice-oriented learning.

To address this gap, this paper proposes the concept of the Digital Practice Learning Environment (DPLE). The concept extends current understandings of virtual museums by emphasising their pedagogical role in facilitating authentic, immersive, interactive, and reflective learning experiences. Rather than replacing physical workshops or workplace training, virtual museums are viewed as complementary learning environments that prepare students for professional practice and enrich vocational learning through digitally mediated experiences.

Building on this conceptual position, the next section synthesises five established learning theories to explain the educational mechanisms through which virtual museums function as

Digital Practice Learning Environments in TVET.

3.Theoretical Foundations

3.1 Understanding Practice-Oriented Learning in TVET

Practical learning has long been recognised as the defining characteristic of Technical and Vocational Education and Training (TVET). Unlike general education, where learning outcomes are often measured through conceptual understanding, TVET aims to develop occupational competence by enabling learners to apply knowledge in authentic workplace contexts (Billett, 2011). Consequently, effective vocational learning requires more than the acquisition of technical knowledge; it also involves developing professional judgement, problem-solving skills, and the ability to perform tasks within real or simulated work environments.

This perspective has important implications for digital learning. While many online learning platforms successfully support knowledge acquisition, they often provide limited opportunities for learners to experience authentic professional situations. Virtual museums differ from conventional digital learning systems because they present knowledge through artefacts, industrial processes, historical developments, and occupational narratives situated within meaningful contexts. These characteristics suggest that the educational value of virtual museums lies not simply in delivering information but in creating learning environments where students can interpret professional knowledge through authentic experiences.

To explain how such learning occurs, this study draws upon five complementary educational theories: Experiential Learning Theory, Situated Learning Theory, Constructivist Learning Theory, Museum Learning Theory, and Authentic Learning Theory. Rather than viewing these theories independently, they are synthesised to explain four pedagogical characteristics of Digital Practice Learning Environments: authenticity, immersion, interaction, and reflection.

3.2 Experiential Learning: Learning Through Experience and Reflection

Experiential Learning Theory (ELT), developed by Kolb (1984), proposes that learning is a continuous process in which knowledge is created through the transformation of experience. According to Kolb, effective learning involves four interconnected stages: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Learners do not simply receive information; instead, they construct understanding by reflecting on experiences and applying new knowledge in subsequent situations.

This perspective is particularly relevant to vocational education because occupational competence develops through repeated interaction with practical activities. Workshop practice, industrial placements, and laboratory exercises all provide opportunities for learners to gain experience and refine professional skills through reflection (Kolb, 1984). However, opportunities for authentic practice are often constrained by limited resources, safety requirements, and restricted access to industrial facilities.

Virtual museums provide an alternative environment in which learners can engage with authentic artefacts, production processes, and professional case studies before entering real

workplaces. Although these experiences differ from physical practice, they encourage learners to observe, interpret, and reflect on occupational activities. In this sense, virtual museums extend experiential learning beyond the traditional workshop by creating opportunities for experience-based learning within digitally mediated environments.

Importantly, experiential learning also explains the role of reflection within Digital Practice Learning Environments. Learners construct vocational understanding not simply by exploring virtual exhibitions but by connecting these experiences with existing knowledge and future professional practice. Reflection therefore becomes a key mechanism linking digital experience with competence development.

3.3 Situated Learning: Learning in Authentic Contexts

While experiential learning explains how knowledge develops through experience, Situated Learning Theory explains why learning is closely connected to the contexts in which it occurs. Lave and Wenger (1991) argued that knowledge is inseparable from the social and cultural environments in which it is used. Learning therefore occurs most effectively when learners participate in authentic activities that resemble real professional practice.

For vocational education, this perspective is particularly significant because workplace competence cannot be separated from occupational contexts. Students must learn not only technical procedures but also professional norms, communication practices, and decision-making processes embedded within specific industries (Lave & Wenger, 1991). Consequently, learning environments should provide opportunities for contextual participation rather than isolated knowledge transmission.

Virtual museums possess several characteristics consistent with situated learning. Industrial museums, science museums, and heritage museums often present technological development within realistic production contexts, enabling learners to understand how vocational knowledge has evolved in response to industrial needs. Rather than presenting isolated facts, virtual museums organise learning through professional narratives, authentic artefacts, and contextualised problem situations. These characteristics help learners connect theoretical knowledge with workplace practice, thereby strengthening contextual understanding.

Situated Learning Theory therefore provides an important explanation for why authenticity represents a core dimension of Digital Practice Learning Environments.

3.4 Constructing Knowledge Through Interaction: A Constructivist Perspective

Constructivist Learning Theory argues that learning is an active process in which learners construct knowledge through interaction with their environment rather than passively receiving information from instructors (Piaget, 1972; Vygotsky, 1978). From this perspective, meaningful learning occurs when learners explore problems, interpret information, and connect new experiences with prior knowledge. Consequently, the effectiveness of a learning environment depends not only on the quality of instructional content but also on the opportunities it provides for active engagement and knowledge construction.

This perspective is highly relevant to virtual museums. Unlike conventional digital resources that primarily present information in linear formats, virtual museums encourage learners to

navigate exhibitions independently, examine artefacts from multiple perspectives, and make connections between historical developments, technological innovations, and professional practices. Learning therefore becomes an exploratory process rather than a one-way transfer of information. Through interaction with digital objects and contextual information, learners actively construct professional understanding instead of simply memorising factual knowledge.

For TVET, this interactive process is particularly important because vocational competence requires learners to interpret complex workplace situations and make informed decisions. Virtual museums cannot replicate every aspect of workplace practice, but they provide opportunities for learners to investigate authentic cases, analyse industrial development, and relate technical knowledge to occupational contexts. Such activities support higher-order thinking, including analysis, interpretation, and problem-solving, which are increasingly recognised as essential competencies in modern vocational education (OECD, 2021).

Constructivism therefore explains why interaction represents a key characteristic of a Digital Practice Learning Environment. It is the learner's active engagement with authentic digital resources—not the technology itself—that facilitates meaningful vocational learning.

3.5 Museum Learning and Authentic Learning: Extending Practice Beyond the Classroom

While constructivism explains how learners construct knowledge, Museum Learning Theory explains why museums provide distinctive educational experiences. Falk and Dierking (2016) argue that learning in museums is influenced by the interaction of three contexts: the personal context, the sociocultural context, and the physical context. Knowledge is therefore shaped not only by the exhibits themselves but also by learners' previous experiences, motivations, and interactions with their environment. This perspective shifts attention from museum objects to the learning experiences that museums facilitate.

The educational implications of this theory extend beyond traditional museums. In virtual environments, digital technologies can recreate many of the contextual characteristics that support museum learning, including authentic artefacts, interpretive narratives, and opportunities for self-directed exploration. Although virtual museums differ from physical museums in their mode of delivery, they retain the capacity to situate learning within meaningful cultural and professional contexts. As a result, learners are encouraged to interpret knowledge actively rather than consume information passively.

Museum Learning Theory is complemented by Authentic Learning Theory, which emphasises that meaningful learning occurs when educational activities resemble the complexity of real-world practice (Herrington et al., 2014). Authentic learning environments present learners with realistic problems, encourage multiple perspectives, and require them to apply knowledge in context. These characteristics closely align with the objectives of TVET, where the ultimate goal is to prepare learners for professional practice rather than solely for academic achievement.

Virtual museums possess several features that support authentic learning. Industrial heritage collections, engineering exhibits, medical artefacts, and technological archives expose learners to real professional practices and their historical development. Through these resources, students gain insight into how theoretical knowledge is applied across different occupational

settings. Such experiences enrich classroom learning by connecting abstract concepts with authentic professional contexts.

The integration of Museum Learning Theory and Authentic Learning Theory provides a strong educational rationale for understanding virtual museums as Digital Practice Learning Environments. Rather than functioning simply as repositories of digital information, virtual museums create opportunities for learners to engage with authentic professional knowledge through contextual exploration, independent inquiry, and reflective interpretation. These characteristics complement traditional practical training and extend learning beyond the physical classroom.

3.6 A Theoretical Synthesis for Digital Practice Learning Environments

The five theories discussed in this chapter do not operate independently. Instead, they explain different dimensions of the same educational process. Experiential Learning Theory highlights the importance of learning through experience and reflection (Kolb, 1984). Situated Learning Theory emphasises the role of authentic contexts in shaping professional understanding (Lave & Wenger, 1991). Constructivist Learning Theory explains how learners actively construct knowledge through interaction (Piaget, 1972; Vygotsky, 1978). Museum Learning Theory demonstrates that learning is influenced by the interaction between learners and meaningful environments (Falk & Dierking, 2016), while Authentic Learning Theory stresses the importance of connecting educational activities with real-world practice (Herrington et al., 2014).

Viewed collectively, these theories provide a coherent explanation for why virtual museums can support practice-oriented learning in TVET. They suggest that effective vocational learning depends on four interconnected pedagogical characteristics: authenticity, which situates learning within meaningful occupational contexts; immersion, which promotes engagement with professional environments; interaction, which enables learners to construct knowledge actively; and reflection, which transforms learning experiences into vocational understanding.

This theoretical synthesis forms the foundation of the conceptual framework proposed in the next chapter. Rather than treating virtual museums as technology-enhanced learning tools, the framework positions them as Digital Practice Learning Environments that facilitate vocational competence through the integration of these four pedagogical characteristics.

4. A Conceptual Framework for Virtual Museums as Digital Practice Learning Environments

4.1 Reconceptualising Virtual Museums as Digital Practice Learning Environments

The preceding chapters have demonstrated that virtual museums have evolved considerably from their original role as digital repositories of cultural heritage. Advances in digital technologies, including virtual reality, three-dimensional visualisation, and interactive multimedia, have transformed virtual museums into increasingly sophisticated learning environments. At the same time, research has shown growing interest in their educational

applications across museum education, cultural heritage studies, and technology-enhanced learning. Despite these developments, the pedagogical role of virtual museums within Technical and Vocational Education and Training (TVET) remains insufficiently conceptualised. Existing studies have largely focused on technological capabilities, user experience, or museum visitor engagement, providing only limited explanations of how virtual museums contribute to practice-oriented vocational learning.

This conceptual gap is particularly significant because vocational education differs fundamentally from many other educational contexts. The primary objective of TVET is not only to facilitate knowledge acquisition but also to develop practical competence, professional judgement, and workplace readiness. Consequently, the educational value of any digital learning environment should be evaluated according to its ability to support authentic vocational learning rather than its technological sophistication. While previous studies have acknowledged that virtual museums provide access to rich educational resources, they rarely explain the pedagogical processes through which learners transform these resources into meaningful professional knowledge and skills.

To address this limitation, this paper proposes the concept of the Digital Practice Learning Environment (DPLE). Rather than viewing virtual museums simply as digital exhibition platforms or technology-supported learning systems, the DPLE perspective reconceptualises them as pedagogically designed environments that facilitate practice-oriented learning. The emphasis therefore shifts from technology to learning. Digital technologies remain important, but their educational significance depends on how they create meaningful learning experiences that encourage learners to engage with authentic professional contexts, construct knowledge actively, and reflect upon vocational practice.

The proposed framework also differs from existing descriptions of virtual learning environments. Conventional digital learning environments frequently prioritise content delivery, communication, and information access. In contrast, the DPLE framework emphasises learning through digitally mediated professional experiences. It assumes that vocational competence develops when learners participate in educational activities that resemble authentic workplace situations and encourage continuous interpretation, exploration, and reflection. From this perspective, virtual museums become more than digital collections; they become environments that connect theoretical knowledge with professional practice through carefully designed learning experiences.

Building upon the theoretical synthesis presented in the previous chapter, this study identifies four interconnected pedagogical characteristics that define a Digital Practice Learning Environment: authenticity, immersion, interaction, and reflection. These characteristics are not proposed as isolated variables or sequential stages of learning. Instead, they operate as complementary pedagogical processes that collectively explain how virtual museums support practice-oriented learning and vocational competence development. Together, they provide a theoretical foundation for understanding the educational value of virtual museums beyond their technological functions.

Figure 1. Proposed Conceptual Framework of Virtual Museums as Digital Practice Learning Environments

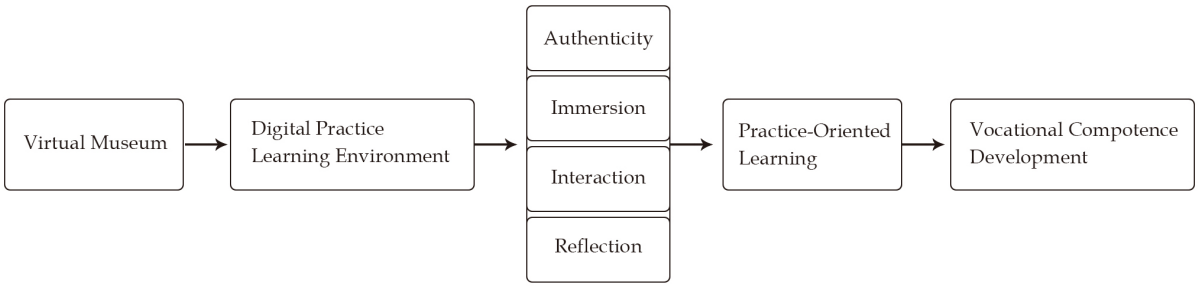

Figure 1 illustrates the conceptual framework proposed in this study. The framework positions virtual museums as Digital Practice Learning Environments that facilitate vocational learning through four interconnected pedagogical characteristics: authenticity, immersion, interaction, and reflection. Rather than representing a linear learning sequence, these characteristics interact dynamically throughout the learning process to support practice-oriented learning and the development of vocational competence.

4.2 Authenticity as the Pedagogical Foundation

Authenticity constitutes the pedagogical foundation of the proposed Digital Practice Learning Environment (DPLE). Among the four pedagogical characteristics, authenticity occupies a foundational position because vocational learning is inherently connected to professional practice. Unlike many forms of general education, Technical and Vocational Education and Training (TVET) aims to prepare learners for specific occupational roles that require not only theoretical understanding but also the ability to apply knowledge in realistic workplace contexts. Consequently, learning activities that lack authentic professional relevance are unlikely to support meaningful vocational competence development (Billett, 2011; Herrington et al., 2014).

Within the proposed framework, authenticity extends beyond the presentation of realistic digital objects or accurate historical information. Instead, it refers to the extent to which learning experiences reflect the complexity, context, and practices of real occupations. Authentic learning environments enable students to understand how professional knowledge is created, applied, and continually refined within specific industries. Therefore, authenticity should be understood as a pedagogical quality rather than merely a technological feature of virtual environments.

Virtual museums possess distinctive characteristics that allow authenticity to be incorporated into vocational learning. Through collections of industrial artefacts, historical machinery, engineering innovations, medical instruments, architectural models, and documentary archives, virtual museums preserve professional knowledge that has evolved across different historical periods. Unlike conventional instructional materials, these resources are embedded within narratives that explain technological development, industrial change, and professional practice. Learners are therefore encouraged not only to observe artefacts but also to understand the historical, cultural, and occupational contexts in which these artefacts were created and used. Such contextualisation strengthens learners' appreciation of professional practice and supports the transfer of theoretical knowledge into vocational understanding.

Authenticity also provides the educational conditions necessary for the remaining pedagogical

characteristics to function effectively. Immersive technologies may attract learners' attention, yet immersion alone cannot guarantee meaningful learning if the learning environment lacks professional relevance. Similarly, interaction with digital resources becomes educationally valuable only when learners engage with authentic vocational problems and realistic workplace situations. Reflection is likewise dependent upon authentic experiences because meaningful reflection requires learners to evaluate situations that resemble those encountered in professional practice. In this sense, authenticity acts as the contextual anchor that gives educational purpose to immersion, interaction, and reflection.

From the perspective of the DPLE framework, authenticity should therefore be regarded as the starting point of practice-oriented learning. By situating learners within realistic professional contexts, virtual museums create opportunities for learners to connect disciplinary knowledge with occupational practice, develop professional awareness, and build the contextual understanding required for vocational competence. Rather than functioning simply as repositories of digital heritage, virtual museums become environments in which authentic learning experiences prepare learners for increasingly complex workplace settings.

4.3 Immersion as Meaningful Engagement

Following the establishment of authentic professional contexts, the next challenge is to ensure that learners actively engage with these contexts in ways that promote meaningful learning. Within the proposed Digital Practice Learning Environment (DPLE), immersion represents the pedagogical process through which learners become cognitively, emotionally, and behaviourally engaged in authentic vocational experiences. Rather than referring solely to advanced technologies such as virtual reality (VR), augmented reality (AR), or three-dimensional simulations, immersion is understood as a learning condition that encourages sustained attention, curiosity, and active participation (Makransky & Petersen, 2021).

In discussions of digital education, immersion is frequently associated with technological sophistication. However, from a pedagogical perspective, technology itself does not guarantee meaningful learning. Highly immersive visual environments may attract learners' attention, yet they contribute little to vocational competence if learners remain passive observers. Consequently, the DPLE framework distinguishes technological immersion from educational immersion. Educational immersion occurs when learners actively engage with authentic professional contexts, interpret vocational information, and develop a sense of connection with the practices represented within the virtual environment.

Virtual museums are particularly well positioned to facilitate this type of engagement because they provide experiences that extend beyond traditional classroom instruction. Through interactive exhibitions, virtual tours, multimedia narratives, and three-dimensional reconstructions of workplaces or industrial heritage sites, learners are able to explore environments that might otherwise be inaccessible due to geographical distance, financial limitations, safety regulations, or the rarity of historical artefacts. Instead of reading about professional practice, learners are placed in environments where they can observe workplace processes, examine technical equipment, and appreciate the historical development of vocational knowledge.

Immersion also contributes to learner motivation by encouraging exploration and self-directed inquiry. Unlike teacher-centred instruction, virtual museums allow learners to determine their own learning pathways, revisit exhibitions, investigate artefacts from multiple perspectives, and explore topics according to their individual interests. This flexibility promotes learner autonomy while supporting deeper cognitive engagement with vocational content. As learners become more actively involved in exploring authentic professional environments, they are more likely to connect theoretical concepts with practical applications, thereby strengthening their understanding of occupational knowledge.

Within the DPLE framework, immersion functions as the pedagogical bridge between authentic contexts and active learning. Authenticity provides the professional setting in which learning occurs, whereas immersion encourages learners to become meaningfully involved in that setting. Without immersion, authentic contexts may remain static sources of information rather than dynamic learning experiences. By fostering sustained engagement with authentic vocational environments, immersion transforms observation into participation and creates the conditions necessary for learners to construct meaningful professional understanding.

4.4 Interaction as Active Knowledge Construction

While authenticity provides meaningful vocational contexts and immersion encourages learners to engage with these contexts, meaningful learning cannot occur unless learners actively process and construct knowledge from their experiences. Within the proposed Digital Practice Learning Environment (DPLE), interaction represents the pedagogical mechanism through which learners interpret information, solve problems, and gradually develop vocational understanding. Rather than viewing interaction simply as physical engagement with digital technologies, the framework conceptualises interaction as an active process of knowledge construction that enables learners to connect experience with professional understanding.

From a constructivist perspective, learning is not the passive reception of information but the active construction of meaning through exploration and interpretation (Vygotsky, 1978). Learners continuously compare new experiences with existing knowledge, evaluate alternative explanations, and refine their understanding through ongoing engagement with their learning environment. Consequently, the educational value of interaction depends less on the quantity of technological features available and more on the quality of cognitive activities that learners perform while engaging with digital resources.

Within virtual museums, interaction extends beyond simple technological operations such as clicking hyperlinks, rotating three-dimensional objects, or navigating digital exhibitions. Although these functions improve accessibility and usability, they do not necessarily promote meaningful learning on their own. Educational interaction occurs when learners examine artefacts critically, interpret historical evidence, compare technological developments across different periods, and relate professional narratives to contemporary workplace practices. Through these activities, learners are encouraged to move beyond observation and participate actively in the construction of vocational knowledge.

Interaction also supports inquiry-based learning, which is increasingly recognised as an important pedagogical approach within contemporary TVET. Rather than following

predetermined instructional sequences, learners investigate authentic vocational questions, analyse workplace cases, and explore multiple perspectives before reaching informed conclusions. For example, an engineering student exploring a virtual industrial museum may compare the evolution of manufacturing technologies to understand why production processes have changed over time. Similarly, students in hospitality, healthcare, or construction programmes may examine professional artefacts and workplace practices to understand how technological innovation has influenced occupational standards and professional responsibilities. Such inquiry-oriented interaction encourages learners to develop analytical thinking, professional judgement, and problem-solving abilities that extend beyond factual knowledge.

Interaction within virtual museums also creates opportunities for collaborative learning. Although many virtual museum experiences are designed for individual exploration, digital platforms increasingly support discussion, collaborative interpretation, and knowledge sharing among learners. Through group discussions, collaborative projects, and instructor-guided reflection, learners are exposed to multiple viewpoints that broaden their understanding of vocational practice. These social interactions reinforce constructivist principles by recognising that professional knowledge is developed not only through individual exploration but also through dialogue and shared interpretation.

Within the DPLE framework, interaction therefore functions as the mechanism that transforms immersive experiences into meaningful learning. Authentic professional contexts provide relevance, immersion encourages sustained engagement, and interaction enables learners to analyse, question, interpret, and apply vocational knowledge. Without meaningful interaction, immersive experiences remain largely observational, limiting their contribution to professional competence. By actively engaging learners in inquiry, interpretation, and collaborative knowledge construction, interaction serves as the bridge between experience and understanding, preparing learners for reflective professional practice.

4.5 Reflection as Professional Growth

Reflection represents the final pedagogical characteristic of the proposed Digital Practice Learning Environment (DPLE). While authenticity provides meaningful professional contexts, immersion encourages learners to engage with these contexts, and interaction facilitates the active construction of knowledge, reflection enables learners to interpret these experiences and transform them into professional understanding. In vocational education, learning is not completed when students acquire knowledge or perform a task successfully. Instead, meaningful learning occurs when learners critically evaluate their experiences, recognise the reasoning behind their actions, and consider how newly acquired knowledge may be applied in future professional situations. Reflection therefore functions as the mechanism through which learning experiences are consolidated into vocational competence.

The importance of reflection has long been recognised in professional education. Schön (1983) argued that competent professionals continuously reflect on their actions in order to improve future practice, while experiential learning theory emphasises that experience alone does not guarantee learning unless it is accompanied by thoughtful reflection (Kolb, 1984). Building upon

these perspectives, the DPLE framework positions reflection not as an isolated activity conducted after learning, but as an ongoing cognitive process that accompanies learners throughout their engagement with virtual museums. As learners observe professional artefacts, interpret historical developments, and investigate workplace practices, they are encouraged to question assumptions, compare alternative perspectives, and evaluate the significance of what they have learned.

Virtual museums provide distinctive opportunities for reflective learning because they present professional knowledge within rich historical and cultural contexts. Rather than exposing learners only to current workplace practices, virtual museums allow them to examine how professions, technologies, and industries have evolved over time. Such longitudinal perspectives encourage learners to consider why professional practices change, how technological innovation influences occupational standards, and what lessons may be drawn from previous experiences. Reflection therefore extends beyond recalling factual information and instead promotes a deeper appreciation of professional development and lifelong learning.

Reflection also strengthens learners' professional identity. Vocational competence involves not only mastering technical skills but also developing professional values, ethical awareness, and sound judgement. By reflecting upon authentic workplace cases, technological innovations, and historical developments presented within virtual museums, learners begin to understand the responsibilities, decision-making processes, and professional expectations associated with their chosen occupations. This reflective process helps learners move from simply acquiring vocational knowledge towards thinking and acting like future professionals.

Furthermore, reflection supports the transfer of learning from digital environments to real workplace settings. Experiences gained within virtual museums become educationally valuable only when learners are able to connect them with future professional practice. Activities such as reflective journals, guided discussions, digital portfolios, case analyses, and collaborative debriefing encourage learners to evaluate their learning experiences and identify how these experiences may inform future workplace decisions. In this way, reflection bridges the gap between digitally mediated learning and authentic professional performance.

Within the DPLE framework, reflection therefore represents the culmination of the learning process. Authenticity provides meaningful contexts, immersion encourages active engagement, interaction facilitates knowledge construction, and reflection transforms these learning experiences into professional judgement and vocational competence. Rather than functioning as the final step of a linear sequence, reflection continuously reinforces learning by enabling learners to reinterpret previous experiences as their professional understanding develops. Consequently, reflection serves as the pedagogical mechanism that connects digital learning experiences with long-term professional growth and lifelong learning.

4.6 The Dynamic Relationships Among the Four Pedagogical Characteristics

The four pedagogical characteristics proposed in the DPLE framework are presented separately for conceptual clarity; however, they should not be interpreted as independent dimensions or sequential instructional stages. Instead, they operate as an integrated pedagogical system in which each characteristic strengthens and supports the others. The educational effectiveness of

virtual museums emerges from the dynamic interaction among authenticity, immersion, interaction, and reflection rather than from any individual characteristic in isolation.

Authenticity establishes the professional context within which learning becomes meaningful. Without authentic occupational settings, learners may perceive digital activities as disconnected from real vocational practice. Immersion then encourages learners to engage cognitively and emotionally with these authentic contexts, creating the conditions necessary for sustained participation. However, engagement alone does not guarantee learning. Interaction enables learners to analyse information, investigate professional problems, compare alternative perspectives, and construct vocational knowledge through active inquiry. Finally, reflection allows learners to evaluate these experiences, integrate new knowledge with previous understanding, and consider how learning can be transferred to future workplace situations.

Importantly, these relationships are reciprocal rather than linear. Reflection may encourage learners to revisit authentic contexts with new perspectives, while interaction can deepen immersion by increasing curiosity and engagement. Similarly, authentic professional contexts become more meaningful as learners develop richer vocational understanding through repeated cycles of interaction and reflection. Learning within virtual museums should therefore be understood as an iterative process in which learners continuously move between observation, engagement, interpretation, and critical reflection.

This dynamic perspective distinguishes the DPLE framework from technology-centred models of digital learning. Rather than explaining learning outcomes through technological functions alone, the framework emphasises the pedagogical processes that transform digital experiences into vocational competence. It therefore offers a holistic explanation of how virtual museums can support practice-oriented learning by integrating meaningful contexts, learner engagement, active knowledge construction, and reflective professional development.

5.Discussion and Implications

5.1 Theoretical Implications

The primary contribution of this paper lies in extending the educational understanding of virtual museums within the context of Technical and Vocational Education and Training (TVET). Previous studies have largely conceptualised virtual museums as platforms for cultural heritage preservation, museum education, or technology-enhanced learning (Carrozzino & Bergamasco, 2010; Kabassi et al., 2019). While these perspectives have enriched research on digital museums, they offer only limited explanations for how virtual museums support vocational learning. By introducing the concept of the Digital Practice Learning Environment (DPLE), this paper provides an alternative perspective that positions virtual museums within the broader discourse of vocational pedagogy.

A second theoretical contribution is the integration of multiple learning theories into a coherent conceptual framework. Rather than relying on a single theoretical perspective, this study synthesises Experiential Learning Theory, Situated Learning Theory, Constructivist Learning Theory, Museum Learning Theory, and Authentic Learning Theory to explain why virtual museums can facilitate practice-oriented learning. This theoretical synthesis highlights that

vocational learning in digital environments is shaped by the interaction of authenticity, immersion, interaction, and reflection, rather than by technological features alone.

Finally, this paper contributes to the growing literature on digital learning environments by proposing that technology should be viewed as a pedagogical mediator instead of an educational objective. The effectiveness of virtual museums depends less on the sophistication of digital technologies than on how these technologies are designed to support meaningful learning experiences. This perspective may also provide insights for the development of other immersive learning environments in vocational education.

5.2 Practical Implications for TVET

The proposed framework has several implications for vocational education institutions and curriculum designers. First, virtual museums should be considered complementary learning environments rather than substitutes for workshops or workplace training. Their value lies in extending opportunities for students to explore authentic professional contexts before or after practical instruction. Integrating virtual museums into vocational curricula may therefore strengthen the connection between theoretical learning and workplace practice.

Second, the framework suggests that instructional design should receive greater attention than technology selection. Simply introducing virtual reality or three-dimensional visualisation is unlikely to improve learning unless educational activities encourage exploration, collaboration, and reflection. Teachers should therefore design learning tasks that require students to analyse artefacts, interpret professional practices, compare technological developments, and relate museum resources to vocational problems.

Third, collaboration between vocational institutions and museums deserves greater consideration. Many museums possess valuable industrial, technological, and cultural collections that can enrich vocational education. Partnerships between museums and TVET providers could support the development of digital resources tailored to vocational disciplines such as engineering, manufacturing, tourism, healthcare, and cultural industries. Such collaboration would broaden access to authentic learning materials while strengthening links between education and industry.

5.3 Directions for Future Research

As a conceptual paper, this study establishes a theoretical foundation rather than providing empirical evidence. Future research is therefore needed to examine the applicability of the proposed framework across different vocational disciplines and educational contexts.

One important direction is the empirical validation of the framework. Quantitative studies could examine the relationships between authenticity, immersion, interaction, reflection, and learning outcomes, while qualitative research could explore how students experience virtual museums during vocational learning activities.

Future studies may also investigate disciplinary differences. The educational functions of virtual museums are likely to vary across vocational fields. For example, engineering students may benefit from industrial heritage museums, whereas healthcare students may engage more effectively with medical museums. Comparative studies across disciplines would provide a

deeper understanding of how different types of virtual museums contribute to vocational competence.

Finally, emerging technologies such as artificial intelligence, digital twins, and adaptive learning systems are likely to reshape virtual museum experiences. Future research should therefore explore how these technologies can enhance personalised learning, collaborative problem-solving, and professional decision-making within Digital Practice Learning Environments.

6. Conclusion

The rapid digital transformation of education has created new opportunities to rethink how learning environments can better support the development of vocational knowledge and skills. Within Technical and Vocational Education and Training (TVET), where practical learning and workplace relevance are central objectives, digital technologies are increasingly expected to complement traditional forms of instruction. Against this background, virtual museums have emerged as a promising educational resource. However, despite growing interest in virtual museums across the fields of museum education, cultural heritage, and educational technology, their potential contribution to vocational education has remained largely underexplored. Existing studies have primarily focused on technological innovation, visitor experience, or cultural preservation, while relatively little attention has been given to how virtual museums can support practice-oriented learning and vocational competence development.

This paper addressed this gap by proposing the concept of the Digital Practice Learning Environment (DPLE) as a new theoretical perspective for understanding the educational role of virtual museums in TVET. Rather than viewing virtual museums simply as digital repositories or immersive technological platforms, the proposed framework reconceptualises them as pedagogically meaningful environments that facilitate learning through four interconnected characteristics: authenticity, immersion, interaction, and reflection. These characteristics provide a coherent explanation of how virtual museums can create learning experiences that connect theoretical knowledge with professional practice and foster learners' vocational competence.

A key contribution of this study is the integration of five complementary learning theories—Experiential Learning Theory, Situated Learning Theory, Constructivist Learning Theory, Museum Learning Theory, and Authentic Learning Theory—into a single conceptual framework. Instead of relying on one theoretical lens, this synthesis demonstrates that effective vocational learning in digital environments results from the interaction between authentic contexts, active learner engagement, meaningful social and cognitive interaction, and reflective learning processes. In doing so, the study extends current understandings of virtual museums beyond their traditional educational functions and positions them as valuable components of digitally mediated vocational learning.

The proposed framework also offers practical implications for educators, curriculum designers, museum professionals, and policymakers. It suggests that virtual museums should not be

regarded as replacements for workshops, laboratories, or workplace learning, but rather as complementary learning environments that enrich vocational education by expanding access to authentic professional experiences. Curriculum developers may use the framework to design learning activities that encourage inquiry, critical thinking, collaboration, and reflective practice, while museums may explore closer partnerships with TVET institutions to develop educational resources that align with vocational curricula and industry needs. Such collaboration has the potential to strengthen the relationship between cultural institutions and vocational education in an increasingly digital society.

As a conceptual paper, this study inevitably has limitations. The proposed framework has not yet been empirically validated, and its applicability across different vocational disciplines, cultural contexts, and technological platforms remains to be examined. Future research could investigate how the four pedagogical characteristics influence learning outcomes through qualitative, quantitative, or mixed-method approaches. Comparative studies across different vocational fields and educational settings would further enhance understanding of how virtual museums can best support diverse forms of vocational learning. In addition, emerging technologies such as artificial intelligence, digital twins, extended reality (XR), and adaptive learning systems provide promising directions for further expanding the educational potential of virtual museums.

In conclusion, this paper argues that virtual museums should be understood not merely as digital innovations but as pedagogically significant learning environments capable of supporting authentic and practice-oriented learning in TVET. By introducing the concept of the Digital Practice Learning Environment (DPLE), this study provides a theoretical foundation for future research and educational practice. As digital transformation continues to reshape vocational education worldwide, virtual museums have the potential to become an integral component of innovative learning ecosystems that prepare learners with the knowledge, practical skills, and professional competencies required for the future world of work.

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