The Role of 3D Asset Design in Simulation-Based Cognitive Training

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ABSTRACT

As simulation-based learning continues to advance, the integration of high-fidelity 3D art is no longer just an aesthetic choice, it is a cognitive and learning engineering tool that shapes learner perception, decision-making, and situational awareness. This paper explores how 3D asset design, grounded in game art principles, impacts the development of situational awareness in novice trainees navigating a 360-degree maritime training environment. The use case involves a digital pre-hire simulation tool in which learners explore general maritime topics, including careers, the industrial environment, ship compartments, tools, and measurement concepts. Drawing on cognitive task analysis and design-based research methods, the case study examines how visual cues, asset fidelity, spatial layout, and environment storytelling influence learners' ability to orient themselves, recognize key features, and make sense of their digital surroundings. Preliminary findings suggest that well-designed 3D assets, such as proportionally scaled tools, signage, and dynamic environmental features, enhance perception and knowledge transfer by reducing cognitive load and supporting mental model development. Additional this paper proposes a design framework aligning game art strategies with cognitive learning outcomes to optimize novice training effectiveness. This paper highlights the importance of interdisciplinary collaboration between artists, cognitive scientists, and simulation developers in crafting immersive training environments that are both visually compelling and cognitively supportive. The implications extend to K-12, postsecondary, and industry training contexts, offering guidance for future simulation-based learning experiences that leverage 3D assets not just for realism, but for measurable cognitive performance gains.

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INTRODUCTION

The demand for skilled trades workers across technical domains is accelerating and projected to grow significantly over the next decade. The U.S. Bureau of Labor Statistics (2023) anticipates that the construction and extraction sector alone will require over 663,000 new workers annually through 2033. In manufacturing, up to 2.1 million jobs may remain unfilled by 2030 due to skill gaps and an aging workforce (Deloitte & The Manufacturing Institute, 2021). Labor shortages also persist in defense manufacturing, shipbuilding, and aerospace, where delays in trades such as welding and electrical work are beginning to affect naval readiness (Schank et al., 2020). Meanwhile, health services and green energy roles are expanding rapidly, with BMET positions projected to grow 18% and wind turbine service technicians 44% by 2032 (BLS, 2023; U.S. DOE, 2022). These trends underscore an urgent, cross-sector challenge: how to rapidly train and upskill new workers, particularly from underserved backgrounds, without sacrificing quality or operational readiness.

Addressing this challenge demands modernization of pre-hire and early-stage training. For decades, simulation-based learning has offered a powerful alternative to traditional instruction, helping novices develop mental models, procedural fluency, and situational awareness for high-risk, cognitively demanding roles (de Freitas & Routledge, 2013; Salas et al., 2009). Static methods such as lectures and slide decks often fall short of preparing learners for the spatial and sensory complexity of field operations (Gaba, 2004). In contrast, simulations offer interactive, context-rich experiences where trainees can rehearse decisions, interpret cues, and learn from failure, especially when grounded in principles of cognitive psychology and learning engineering (Lindgren & Johnson-Glenberg, 2013).
Recent advances in extended reality (XR), virtual reality (VR), and 360-degree interactive environments have further elevated simulation's impact by enabling immersive rehearsal of spatially and procedurally complex tasks with greater consistency and lower cost (Radianti et al., 2020). This paper examines how such technologies can be purposefully applied to maritime pre-hire training through the development of a 360-degree simulation. Using cognitive task analysis (CTA), design-based research (DBR), and game art principles, this use case explores how 3D asset design can be aligned with cognitive learning goals to enhance situational awareness and support readiness in novice trainees thus offering a scalable model for future simulation-based workforce education.

BACKGROUND

Pre-hire training programs in the maritime trades, typically hosted by workforce development boards, community colleges, or shipyard partners, have historically relied on static materials and isolated mockup experiences that lack the spatial realism and cognitive scaffolding necessary for complex industrial environments. These legacy approaches often leave trainees, many of whom are new to technical workspaces, unprepared for the perceptual and procedural demands of shipyards, contributing to early disorientation and attrition.

To address these limitations, this study introduced a 360-degree simulation environment designed to bridge the cognitive gap between classroom theory and operational readiness. The environment immerses learners in a geospatially accurate dry dock, allowing repeated exploration of compartments, tools, safety indicators, and blueprint concepts without the logistical constraints of on-site visits. Importantly, the simulation serves not as a substitute for hands-on training, but as a cognitively aligned primer that supports mental model development, reduces extraneous cognitive load, and enhances transfer of learning. Accessible across desktop and VR platforms, the simulation offers a scalable, low-cost solution for workforce training partners. Its design integrates game art principles and learning engineering strategies, ensuring each 3D asset (whether a tool, compartment, or signage) contributes to learner orientation, recognition, and decision-making. Features such as proportionally scaled tools, environmental storytelling, and color-coded spatial cues are grounded in principles of cognitive science and situated learning.

This paper argues that the artistic decisions behind 3D models, such as scale, texture, spatial layout, environmental storytelling, and interactive affordances, are not merely aesthetic features, but core components of cognitive training. When properly aligned with learning science principles, 3D assets become scaffolding mechanisms that support perception, comprehension, and decision-making. Drawing from game art methodologies, cognitive task analysis (CTA), and design-based research (DBR), this work explores how intentional asset design impacts novice situational awareness in simulation-based environments. The study is anchored in a 360-degree maritime training simulation used to prepare pre-hire learners for shipyard environments, introducing them to foundational topics such as compartment navigation, safety zone identification, and measurement tools. By analyzing learner performance and perception, this research highlights how cognitive engineering can be operationalized through visual design choices and how such integration can enhance workforce training pipelines in other disciplines and domains.

THEORETICAL FRAMEWORK

This use case was grounded in a multi-theoretical framework that combined principles from learning engineering, cognitive science, and UX to investigate how 3D asset design shaped learning outcomes in simulation-based training. Learning engineering emphasizes the use of human-centered, data-driven approaches to build scalable, adaptive learning environments (Chandler, 2020; Goodell & Kolodner, 2023; Kessler et al., 2022; Roschelle et al., 2020). It extends beyond traditional instructional design by framing the simulation as a complex system where data flows, perceptual interfaces, and embedded feedback loops co-evolved with learner cognition. In the context of this research and use case, learning engineering provided a roadmap for translating instructional goals into interactive, perceptually rich environments that supported skill acquisition and transfer. The simulated environment was not merely evaluated for usability or content accuracy rather it was engineered to optimize the alignment between environmental stimuli and cognitive processing mechanisms. Central to the theoretical orientation of this study were four cognitive frameworks: Situated Cognition, Embodied Cognition, Cognitive Load Theory, and Multimedia Learning Theory.

Situated Cognition

Situated cognition, as described by Brown, Collins, and Duguid (1989), posit that learning was most effective when embedded within authentic contexts. This view challenged the notion that knowledge could be separated from its application, arguing instead that meaning emerged from doing. The simulation's design reflected this theory by embedding learners in a visually and procedurally realistic maritime environment, allowing them to engage with spatial layouts, tool interactions, and safety signage in ways that mirrored the operational setting of a shipyard. This situated context aimed to activate the kinds of decision-making and perceptual awareness required in real-world tasks.

Embodied Cognition

Embodied cognition further supported this theoretical stance. Wilson (2002) and Barsalou (2008) suggested that cognition was not only influenced by internal processes but was also shaped through the body's interactions with the physical and sensory environment. Within the simulation, learners navigated 360-degree environments, engaged with scaled tools, and responded to spatial cues, thereby activating motor and spatial schemas that contributed to deeper encoding. The notion of "offloading cognition" onto the environment, by leveraging affordances like color-coded hazard zones or spatially organized workspaces, was central to how the visual design scaffolded learners' decision-making. The simulation's spatial logic, for instance, was designed to reduce disorientation and support predictive navigation, key components in maritime situational awareness.

Cognitive Load Theory

Cognitive Load Theory (CLT), as introduced by Sweller (1988) and expanded by Sweller, van Merriënboer, and Paas (2019), offered a crucial framework for evaluating whether the simulation reduced extraneous load and enabled learners to focus on germane processing. In this study, asset fidelity, visual contrast, and information density were evaluated based on their impact on learners' working memory. Features such as simplified background textures, clear iconography, and spatial consistency were introduced to minimize distractions and ensure that the learner's cognitive resources were directed toward relevant task goals. These strategies were aligned with CLT's emphasis on optimizing the balance between cognitive demand and instructional efficacy.

Multimedia Learning Theory

Finally, Mayer's Multimedia Learning Theory (2001, 2005) reinforced how learners processed visual and verbal information in the simulation. The study employed design principles such as spatial and temporal contiguity, signaling, and the coherence principle to enhance the effectiveness of visual instruction. Interactive elements, such as tool labels, animated guides, and scaffolded prompts, were co-located with their referents in the environment to reduce split attention. These features supported the dual-channel processing model Mayer described, enabling learners to build integrated mental representations from sensory inputs. This theoretical framework not only guided the initial design but also informed the iterative revisions carried out during the design-based research cycles, ensuring that both content and presentation were aligned with empirically validated learning principles.

Taken together, these theoretical foundations allowed the simulation to be conceptualized as a learning system, not just a digital artifact. Learning engineering served as the operational layer coordinating how data, design, and domain expertise came together while cognitive theories informed the underlying scaffolds through which learners perceived, interpreted, and acted within the environment. This integration positioned the 3D asset design process as a form of cognitive engineering where each texture, interaction, and layout served a functional role in the learner's construction of knowledge and task competence.

METHODOLOGY

This use case employed the Learning Engineering Framework, see Figure 1 below (Goddell & Kolodner, 2023; Kessler et al., 2022). The research team integrated cognitive task analysis (CTA), design-based research (DBR), and iterative feedback loops to inform the development of a cognitively supportive simulation-based training environment. The methodology was driven by the principle that learning environments must be engineered as adaptive systems that are responsive to both cognitive demands and instructional design goals (Chandler et al., 2020; Roschelle et al., 2020). Rather than simply evaluate a pre-built simulation, the research team actively designed, implemented, and refined the environment through cycles of empirical investigation and instructional alignment. The simulation served as a testbed for examining how 3D asset design impacts situational awareness and cognitive performance in novice maritime trainees.

Figure 1. The Learning Engineering Framework

Cognitive Task Analysis

The first phase involved conducting a Cognitive Task Analysis (CTA) to extract the perceptual, procedural, and decision-making components of common maritime tasks within an industrial environment. SMEs (subject matter experts) with experience in shipyard operations were interviewed using the Critical Decision Method (Klein et al., 1989) to identify key decision points, contextual cues, and sources of complexity in novice-expert performance. Particular attention was paid to spatial orientation within ship compartments, hazard recognition, tool identification, and blueprint interpretation. The CTA findings directly informed the initial design constraints of the simulation, such as where to place signage, how to scale tools, and which environmental cues should be made visually prominent. This data was also aligned with theoretical constructs from situated and embodied cognition (Brown et al., 1989; Wilson, 2002), ensuring that asset interactions were grounded in real-world task flows and physical ergonomics. For instance, tools were not only visually modeled to scale but placed in contextually appropriate locations, encouraging learners to derive meaning from placement, wear, and proximity. All key strategies in activating situated learning.

Design-Based Research

Following the CTA, the team employed a design-based research (DBR) methodology to iteratively develop, test, and refine the simulation environment. DBR is well-suited to educational technology design because it allows for the simultaneous development of practice and theory through iterative cycles (Collins et al., 2004; Wang & Hannafin, 2005). Each DBR cycle began with a design prototype grounded in the CTA findings and theoretical framework. Initial prototypes were reviewed by SMEs and instructional designers, followed by user testing with novice maritime trainees (n=28) in a controlled lab setting.

During each cycle, user walkthroughs were recorded, and participants engaged in concurrent think-aloud protocols (Ericsson & Simon, 1993) to capture moment-to-moment cognitive strategies. The research team annotated these sessions using video-coding tools to tag instances of disorientation, confusion, successful navigation, and tool-task matches. These tags were then triangulated with structured post-simulation interviews and task performance metrics (e.g., navigation time, hazard identification accuracy).

This multi-source data was analyzed to identify patterns of effective cognitive support and visual ambiguity, leading to targeted adjustments in asset design, such as reducing extraneous texture detail, improving lighting contrast on signage, or modifying spatial layout for wayfinding. This approach was informed by cognitive load theory (Sweller et al., 2019) and multimedia learning principles (Mayer, 2001), ensuring each iteration worked to optimize attention allocation, reduce perceptual overload, and support schema formation.

Data Integration and Learning Engineering Alignment

The final aspect of the methodology focused on aligning empirical findings with the learning engineering goals of the project. All data from CTA, DBR, and usability testing were aggregated using a design matrix that mapped each 3D asset and spatial zone to its cognitive purpose, expected learner behavior, and theoretical justification. This matrix functioned as both a development artifact and a validation tool, allowing the design team to trace how each visual or interactive feature supported learner goals through a clearly defined cognitive mechanism. It also enabled modularity for future adaptation, which is an essential feature of scalable, reusable learning engineering systems (Roschelle et al., 2020). In summary, the methodology integrated CTA to extract the cognitive underpinnings of expert practice, DBR to iteratively refine learner-facing designs, and structured usability and performance data to validate simulation efficacy. By grounding each design decision in empirical and theoretical justification, this approach exemplified how learning engineering can be used not only to build simulations but to optimize them as cognitive systems.

Integration of Cognitive Data into Game Art and Visualization Design

A key methodological component involved the translation of cognitive and perceptual findings from the CTA and DBR phases into concrete visual and spatial design decisions during the asset development pipeline. To achieve this, a parallel design stream was launched focusing on 3D modeling, environment authoring, and real-time rendering optimization using industry-standard tools: Maya (for asset modeling and texturing), Unreal Engine 5 (for simulation deployment), and Cesium for Unreal (for geospatial fidelity and 360-degree environmental control). All assets were uploaded onto the software platform Thinglink, which permitted the web-based deployment of the 360-degree environment on an LMS.

The development team applied the learning engineering design matrix, created during iterative DBR cycles, to guide every stage of 3D asset creation. For example, the CTA revealed that novices frequently overlooked task-critical tools in cluttered scenes. This insight led to targeted adjustments in Maya, where tool meshes were redesigned with clean edge loops, scaled to human factor standards, and textured with high-contrast wear marks to cue usage patterns. The textures and normal maps were also optimized for perceptual salience under real-time lighting conditions in Unreal Engine, aligning with the signaling principle of multimedia learning theory (Mayer, 2001) and principles of perceptual anchoring in cognitive load theory (Sweller et al., 2019). Spatial data from Cesium's georeferenced terrain tiles, digital mapping of the environment, and 3D Tileset capabilities allowed for a geographically accurate rendering of the shipyard dry dock environment (see Figure 2, below). This accuracy was not just aesthetic, rather it supported the principles of situated cognition by placing learners in a layout that mimicked real-world spatial orientation and navigational complexity (Brown et al., 1989). Positional audio, lighting volumes, and interactive navigation sequences were embedded within Unreal Engine to scaffold novice wayfinding strategies identified during the DBR walkthroughs.

Figure 2. Example real-world environmental zone.

Each asset and environmental zone were tagged in Unreal's Blueprint system with metadata linked to the cognitive outcome it supported (e.g., attention capture, recognition, spatial sequencing). These tags were not only used for analytics but also to inform future adaptive feedback scripts (designed to ensure that when future learners hesitate in a zone or fail to recognize a tool, an embedded system could prompt re-engagement without overwhelming the scene).

The resulting pipeline allowed the game art process to function as a visualization system for cognitive training, tightly coupled with user data and grounded in theoretical frameworks. Maya ensured accurate and readable 3D assets; Unreal Engine offered real-time interactivity, lighting control, and spatial storytelling; and Cesium provided a foundation for environment fidelity that respected both the geographical logic and perceptual demands of the maritime domain. By embedding this pipeline within a learning engineering framework, the research team ensured that the visual design was not merely immersive but cognitively functional and andragogically aligned.

FINDINGS

Preliminary analysis of pilot data collected across three training cohorts (N = 50) revealed compelling evidence that simulation-enhanced training significantly improves cognitive performance and situational awareness among novice maritime learners. Participants who engaged with the 360-degree simulation environment demonstrated notable improvements in both quantitative performance metrics and qualitative indicators of readiness when compared to those who completed the traditional, lecture-based curriculum alone.

On the tool identification task, simulation-trained participants correctly matched tools to their functions with an average accuracy rate of 87%, a substantial increase compared to the 63% accuracy rate observed in cohorts exposed only to legacy instruction. This 24-percentage-point improvement suggests that interaction with scaled, spatially contextualized 3D models enabled learners to more accurately encode and recall functionally relevant tool features. This performance was particularly pronounced in scenarios involving clustered tool areas, where visual contrast, placement, and wear cues embedded in the simulation appeared to support pattern recognition and contextual inference. Navigation-based task performance revealed similarly strong effects. Participants trained using the simulation completed assigned spatial orientation and compartment navigation tasks 35% faster than those in the traditional group, with mean task times reduced from 100 seconds to approximately 65 seconds. Observational data and think-aloud transcripts revealed that these learners adopted more efficient scanning strategies, made fewer wrong turns, and demonstrated earlier recognition of spatial landmarks such as safety signage and compartment identifiers. These behavioral markers are consistent with improved formation of mental models and suggest enhanced predictive reasoning about the structure and flow of the environment.

These performance differences are visualized in Figure 3, below, which compares average tool identification accuracy and navigation efficiency across the two groups. The graph illustrates a clear benefit in both speed and accuracy when cognitively aligned visual scaffolds are embedded into simulation-based training environments.

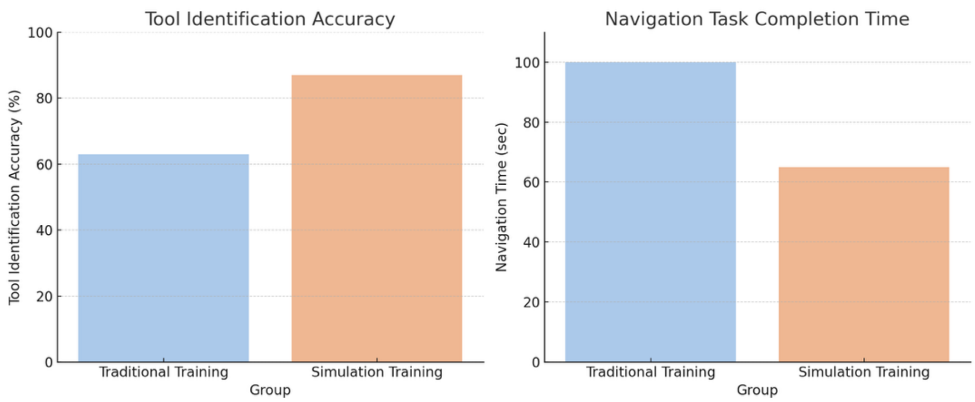

Figure 3. Comparative performance metrics between traditional training and simulation-based training using the 360-degree environment.

Learner self-report data gathered through structured interviews and post-session surveys further corroborated these findings. Many of participants reported that the simulation gave them a "mental map" of the dry dock layout, increasing their confidence and reducing anxiety about entering similar real-world environments. Learners frequently referenced visual cues in the environment, such as hazard zones, spatial labels, or tool placement, as helping them make sense of unfamiliar maritime terminology. Notably, over 70% of participants indicated that they felt more prepared for hands-on tasks after the simulation, despite having never been physically present in a shipyard. Instructors independently confirmed a noticeable shift in learner engagement, noting higher-quality questions during debriefs and increased reference to simulation features in discussion. Learners began using technical language more fluently and referenced tool-task relationships that had been embedded within the visual environment. These observations suggest that 3D asset design, when guided by principles of embodied and situated cognition, can promote deeper semantic encoding and facilitate faster access to procedural knowledge.

While the current sample size limits broad generalization, the consistent improvements across all three cohorts, coupled with convergent qualitative data, underscore the cognitive benefits of simulation-based training environments when they are intentionally aligned with learning theory. The integration of perceptual scaffolds such as lighting gradients, interactive signage, and spatially contextualized models appeared to play a pivotal role in reducing extraneous cognitive load and enhancing germane processing. These early results establish a strong foundation for future longitudinal studies and provide empirical justification for expanding simulation use within technical pre-hire pipelines, especially in domains where early attrition and readiness gaps continue to challenge workforce development programs.

IMPLICATIONS

The findings from this use case offer several significant implications for the future of simulation-based training embedded within prior legacy methodology modalities, particularly within pre-hire and novice-level technical education pipelines. First and foremost, this work demonstrates how visually rich, cognitively aligned environments can function as accessible entry points into complex technical fields and domains. In the maritime context, where spatial reasoning, situational awareness, and familiarity with industrial language are critical to performance, many pre-hire trainees historically arrive with little to no exposure to the environments in which they are expected to succeed from their onset of their employment. By integrating immersive 360-degree simulations early in the training process, learners can begin building mental models of spatial layouts, procedural flow, and environmental cues before ever entering a physical workspace. This early scaffolding of cognitive and perceptual knowledge may be especially critical for learners from underserved backgrounds or those transitioning into technical careers.

The simulation also highlights the need for multidisciplinary collaboration in simulation design and workforce training innovation. The success of the environment depended not only on content knowledge and instructional design but also on the integration of domain-specific modeling (via Maya), real-time rendering and interaction scripting (via Unreal Engine), and geospatial fidelity (via Cesium). When game designers, 3D artists, cognitive scientists, learning engineers, maritime SMEs, and workforce program administrators work in tandem, the result is a training experience that is immersive, theory-driven, and grounded in domain realism. This model of collaboration should serve as a template for how future simulation-based learning environments are conceptualized, prototyped, and scaled harnessing learning engineering frameworks. In advancing the field of learning engineering, this use case provides a practical demonstration of how digital assets and simulation elements, when informed by cognitive theory, can be treated as functional scaffolds rather than decorative enhancements. Game art and visual storytelling, traditionally seen as tools for engagement, are reframed here as tools for perception management, cognitive orientation, and skill transfer. This research also supports the need for formalized design frameworks that connect asset-level decisions to cognitive outcomes. As such, this paper contributes to an emerging body of work that seeks to codify the methods by which digital learning environments are optimized for human performance using iterative, data-driven approaches.

Finally, the implications extend to cost-effective training innovations for industry and education partners. High-fidelity 360 simulations can be deployed in low-cost configurations using existing hardware in training centers, hybrid classrooms, and even remote learning labs. This expands the reach of pre-hire preparation and reduces reliance on site visits, facility walk-throughs, and time-intensive onboarding processes. The scalable nature of simulation assets, particularly when built modularly and tagged with cognitive design metadata, offers a blueprint for adaptive reuse across career pathways, from shipbuilding to construction, advanced manufacturing, energy systems, and more.

LIMITATIONS

As an initial pilot and use case investigation, this paper presents several limitations that should be addressed in subsequent phases of research and development. First, the findings are based on a single 360-degree simulation scenario deployed within a pre-hire maritime training context. While the design was carefully informed by cognitive task analysis and grounded in relevant theory, the breadth of tasks and variation in environmental conditions was intentionally constrained to support early evaluation and usability testing. This narrow scope limits the generalizability of results to other training domains or advanced operational contexts. Additionally, the study sample consisted of novice learners only, meaning that the effects of 3D asset design on expert-novice differentiation, adaptive expertise development, or high-stakes decision-making remain unexplored.

Second, while early data suggest promising impacts on navigation, tool recognition, and hazard identification, the research did not include longitudinal tracking of knowledge retention or skill transfer into real-world settings. Future studies should incorporate delayed post-tests, real-world task observation, or workplace performance assessments to measure how well learners transfer their perceptual and procedural understanding from the simulation to actual work contexts. Similarly, the simulation did not yet include dynamic scenario variation or adaptive challenge adjustment, such as features that could support deeper engagement and mastery through personalized learning trajectories. Another limitation involves the data granularity and feedback mechanisms currently available in the simulation. Although the learning engineering framework included observational tagging and performance metrics, more robust analytics such as eye tracking, gesture analysis, and biometric indicators of workload could yield deeper insights into how learners interact with visual cues and simulation scaffolds. Future research should explore integrating multimodal data streams into the simulation environment, enabling adaptive feedback loops that respond to learner hesitation, missteps, or confusion in real time.

Additionally, this use case was focused on one simulation built using Cesium, Unreal Engine, and Maya as a demonstration of multidisciplinary collaboration. However, scalability and asset reusability across domains (e.g., construction, aviation, energy) were not tested. Future work should examine how the proposed design framework, linking game art strategies with cognitive learning outcomes, translates into other technical training environments with different task flows, terminology, or operational hazards. This could include developing modular simulation "components" (such as interactive tool kits, safety walkthroughs, or blueprint readers) that can be reused across disciplines with minimal rework.

FUTURE WORK

While this use case study was rooted in a pre-hire training context for maritime trades, there is substantial opportunity to extend this work into broader industry and workforce development domains where legacy training methodologies are increasingly misaligned with evolving operational complexity. Fields such as manufacturing, logistics, energy, healthcare, and defense, all of which rely on task-critical precision and environmental awareness, continue to face challenges in modernizing their training pipelines. Many of these sectors either lack the budget or the technical workforce required to design, deploy, or maintain high-end simulation-based systems, which often involve proprietary platforms, expensive head-mounted displays (HMDs), or extensive IT infrastructure. In these contexts, 360-degree simulation environments offer a cost-effective, accessible alternative that enables organizations to deploy immersive, visually rich training modules using standard desktop systems, tablets, or lightweight VR headsets.

What makes this approach especially promising is its scalability and cognitive alignment. Built on sound learning engineering and cognitive design principles, 360-degree environments can improve human performance outcomes, such as situational awareness, spatial orientation, and task readiness, without "breaking the bank" or requiring dedicated simulation labs and centers. These environments can also be deployed across geographies and devices, enabling distributed learning and performance tracking without the overhead of real-time 3D rendering engines or large-scale multiplayer networks. In sectors where workforce upskilling must occur at speed and scale, this presents an actionable solution. Furthermore, the architecture of these environments lends itself to modular expansion, making them ideal candidates for integration into formative assessment systems, adaptive tutoring platforms, and competency-based credentialing ecosystems. With embedded data-capture capabilities and interoperable design layers, these simulations can feed into instructor-facing dashboards and learner analytics platforms, enabling real-time insight into skill development, error patterns, and behavioral readiness. As interoperability becomes a defining feature of modern training systems, 360 simulations can serve as a transitional layer that bridges legacy systems with more advanced cognitive and XR platforms, while maintaining compatibility with LMSs and SCORM/xAPI protocols.

In this way, the use case transcends maritime and offers a strategic blueprint for interdisciplinary simulation adoption, particularly for organizations seeking to modernize training under budgetary, staffing, or technical constraints. Whether for onboarding, task rehearsal, compliance, or scenario-based decision-making, 360-degree environments represent a low-barrier, high-impact tool for transforming legacy instructional delivery into scalable, data-informed training ecosystems.

CONCLUSION

This paper demonstrated how 3D asset design, when informed by cognitive theory and grounded in a learning engineering framework, can significantly enhance the effectiveness of simulation-based training for novice maritime learners. Through the integration of cognitive task analysis, design-based research, and cross-disciplinary collaboration, the project delivered a scalable 360-degree training environment that supports perceptual scaffolding, spatial reasoning, and situational awareness. Early pilot data from pre-hire trainees suggest that intentionally designed visual environments can reduce cognitive load, accelerate navigation skills, and improve tool recognition offering both learners and training organizations a more immersive and instructionally aligned alternative to legacy training methods. By operationalizing game art principles as cognitive supports, this work contributes to a growing field of practice where simulation is not just a medium for engagement, but a strategic platform for skill transfer, assessment, and workforce readiness. As this research continues to expand, it offers a replicable model for modernizing training using learning engineering frameworks and strengthening entry points into high-consequence trades through evidence-based simulation design.

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