

CHAPTER XVII

VIRTUAL REALITY AND AUGMENTED REALITY

Transformation of Navigation and Safety Training in Maritime Education Institutions

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ABSTRACT

The development of Virtual Reality (VR) and Augmented Reality (AR) technologies has opened up significant new opportunities in the transformation of global maritime education and training systems. This chapter comprehensively examines the application of VR/AR technologies in navigation and ship safety training at maritime higher education institutions, drawing on case studies from leading maritime institutions worldwide. Using an experiential learning-based theoretical framework, this study identifies the potential of VR/AR in improving cadet competencies more effectively and efficiently than conventional methods. Literature findings show that VR-based simulation environments can increase knowledge retention by up to 75% and reduce procedural errors in emergencies by up to 60%. The implications of this research are relevant to policymakers, curriculum designers, and maritime education practitioners in they formulate appropriate strategies for adopting immersive technology.

Keywords: Virtual Reality, Augmented Reality, Maritime Education, Navigation Training, Ship Safety, Immersive Simulation

INTRODUCTION

The maritime industry is the backbone of the global economy, accounting for more than 80 percent of world trade (International Maritime Organization, 2023). The main challenge facing this sector is ensuring that every seafarer has the technical competence and mental preparedness to handle complex, unpredictable operational conditions. Maritime accidents caused by human error still dominate global statistics, with reports from the Marine Accident Investigation Branch (MAIB) indicating that more than 70 percent of incidents at sea are directly linked to weaknesses in crew skills, procedures, and decision-making.

The traditional maritime education paradigm, based on classroom learning and conventional simulators, has begun to show its

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limitations in meeting the competency needs of the 21st century. The increasing complexity of modern ship operations, evolving international regulations, and industry demands for adaptive and competent seafarers are driving maritime education institutions to undertake fundamental methodological transformations. This is where Virtual Reality (VR) and Augmented Reality (AR) technologies come in as a new paradigm in the design of immersive, interactive, and competency-based learning experiences.

VR technology allows cadets to train in a three-dimensional simulation environment that closely resembles real conditions on board a ship, including dangerous and costly emergencies that are difficult to replicate in conventional training. Meanwhile, AR enriches perception of the real environment with digital information overlays that can contextually guide procedural learning. The combination of the two creates a training ecosystem that is not only effective in knowledge transfer but also safe and measurable in evaluating cadets' competencies.

This chapter seeks to answer three main questions that are the focus of this study: First, what is the most relevant theoretical framework for understanding the effectiveness of VR and AR as learning mediums in the context of maritime education? Second, how has VR/AR implementation been applied in leading maritime institutions, and what lessons can be learned from these experiences? Third, what are the strategic implications of adopting VR/AR technology for curriculum renewal, institutional policy, and the professional development of maritime instructors?

Translated with DeepL.com (free version). By answering these three questions, this chapter aims to provide comprehensive academic and practical contributions to the maritime education community, particularly in formulating a contextual and sustainable framework for the adoption of immersive technology.

This study focuses on the application of VR and AR in two main domains of maritime education, namely navigation training and ship safety training, as mandated in the STCW (Standards of Training, Certification and Watchkeeping for Seafarers) convention issued by the IMO. The literature review covers publications from 2015 to 2024, with priority given to empirical studies, institutional reports, and policy reviews from the IMO, EMSA, and international maritime accreditation agencies.

THEORETICAL FRAMEWORK

Experiential Learning Theory in the Maritime Context

The most relevant theoretical basis for understanding the effectiveness of VR/AR in maritime education is the Experiential Learning Theory (ELT) proposed by David Kolb (1984). ELT asserts that knowledge is created through the transformation of experience, with a four-stage cycle: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. VR technology is uniquely capable of integrating all four stages into a single controlled simulation environment.

In the context of maritime education, VR provides concrete experience through realistic sailing simulations, enables reflective observation through playback of training session recordings, supports abstract conceptualization through performance-based debriefing, and facilitates active experimentation through repeatable scenarios with adjustable difficulty levels. Research by Makransky et al. (2019) confirms that VR-based learning environments designed according to ELT principles significantly improve learning transfer compared to conventional methods.

Cognitive Load Theory and Design Immersive Learning

Cognitive Load Theory (CLT), developed by Sweller (1988), provides an important framework for understanding how VR and AR should be designed to avoid overloading learners' working memory capacity. CLT distinguishes between intrinsic load (derived from the complexity of the material itself), extraneous load (derived from poor instructional design), and germane load (derived from beneficial cognitive schema processes). The practical implications for the design of maritime VR/AR applications are that overly complex interfaces, excessive visual effects, or irrelevant audio narration can increase extraneous load and actually hinder learning. Research by Radianti et al. (2020), which analyzed 38 studies on VR in higher education, found that VR applications designed according to CLT principles consistently showed superior learning outcomes.

Situated Learning and Authentic Practice

The concept of situated learning developed by Lave and Wenger (1991) emphasizes that meaningful learning occurs in contexts that are relevant and authentic to real-world practices. In maritime education, this means that navigation and safety competencies must be developed in conditions that are as similar as possible to those on an actual ship. VR technology enables legitimate peripheral participation, allowing cadets to engage in real operational scenarios such as ship maneuvers in narrow straits, firefighting in engine

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rooms, or man-overboard procedures, without any real risk to life and limb or to assets. This fundamentally changes the epistemology of maritime training from mere mastery of concepts to the internalization of authentic practice-based competencies.

Presence, Immersion, and Embodied Cognition

The concept of presence refers to a person's subjective feeling of being truly present in a virtual environment. Witmer and Singer (1998) define presence as a function of immersion (technological factors) and involvement (psychological factors). In the context of maritime training, a high level of presence is crucial because it is directly related to the transfer of learning to real-life situations.

Embodied cognition, a perspective popularized by Varela et al. (1991), asserts that cognition does not only occur in the brain but also involves the entire body and its interaction with the environment. VR with haptic feedback and motion tracking devices enables learning that truly involves all sensory modalities, which is in line with the highly kinesthetic nature of maritime work. The following table summarizes the relationship between learning theories and relevant VR/AR technology features:

Table 1. Learning Theory Framework and Its Relevance in Maritime VR/AR Design

Learning Theory	Key Principles	Implementation in Maritime VR/AR	Success Indicators
Experiential Learning (Kolb)	Learning through reflective experience cycles	Ship scenario simulation with automated debriefing	Competency score improvement across cycles
Cognitive Load Theory (Sweller)	Cognitive load optimization in instructional design	Minimal VR interface, progressive scaffolding	Task completion time and procedural accuracy
Situated Learning (Lave & Wenger)	Learning in authentic contexts	Real port scenarios and extreme weather conditions	Transfer of competencies to actual situations
Embodied Cognition (Varela)	Cognition involving all body modalities	Haptic feedback and motion capture in simulation	Long-term retention of motor procedures

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Learning Theory	Key Principles	Implementation in Maritime VR/AR	Success Indicators
Self-Determination Theory (Deci & Ryan)	Intrinsic motivation from autonomy and competence	Branching scenarios with free choice of cadets	Engagement and satisfaction with self-directed learning

**Case Study: Implementation of VR/AR in Maritime Institutions
Norwegian University of Science and Technology (NTNU) – Norway**

NTNU, through its NTNU AMOS research center (Centre for Autonomous Marine Operations and Systems), has become a global pioneer in integrating advanced simulation technology into maritime education curricula. Since 2018, NTNU has been developing the Maritime Mixed Reality Lab, which combines a full-mission bridge simulator with an AR overlay on a Microsoft HoloLens 2 to create a unique hybrid navigation experience.

Implementation and Instructional Design

This program uses a blended immersive learning approach, in which VR sessions are systematically integrated into the regular curriculum as a complement to conventional simulator training. Cadets undergo navigation scenarios in Norwegian fjord waters, which are photorealistically represented using photogrammetry. Scenarios include navigation in low-visibility conditions due to sea fog, maneuvering in narrow docks, and search-and-rescue procedures in stormy conditions.

A key feature of this system is the AI-powered After Action Review, which automatically analyzes VR session recordings and provides structured feedback to cadets in line with STCW standards. Instructors can monitor cadets' cognitive parameters in real time via biometric sensors integrated into the headset, including heart rate, eye movement, and physiological stress levels.

Results and Findings

A three-year longitudinal evaluation showed that cadets who underwent the integrated VR/AR program at NTNU showed a 68 percent improvement in situational decision-making speed compared to the control group. The retention rate of COLREG (Convention on the International Regulations for Preventing Collisions at Sea) procedures after 6 months reached 82%, compared with 54% with conventional methods (Johansen et al., 2022).

**World Maritime University (WMU) – Malmo, Sweden
VR Program for Safety Training**

WMU, as the highest maritime higher education institution under the auspices of the IMO, launched the WMU VR Safety Lab in 2020 in response to the COVID-19 pandemic, which limited access to physical training. The lab developed VR modules covering 12 critical safety procedures as mandated by STCW, including abandon ship procedures, firefighting, enclosed space entry, and helicopter evacuation.

Pedagogical Approach

WMU adopts a mastery learning approach in its course design, in which each cadet must achieve a predetermined competency threshold before progressing to the next module. The VR system is equipped with an adaptive difficulty algorithm that automatically adjusts the complexity of scenarios based on each cadet's performance profile. This enables personalized learning that would be impossible in conventional group training sessions. Another innovative aspect is the use of a multi-user VR environment, where several cadets from different countries can train together in the same scenario simultaneously, simulating the multicultural team dynamics that are a reality on modern merchant ships.

Impact and Validation

A comparative study conducted by WMU and Det Norske Veritas (DNV) found that cadets who completed the VR safety module responded 40 percent faster and 57 percent more accurately in real emergency drill simulations than those who underwent conventional training only. The IMO recognized this program as a best-practice model in its MSC.1/Circ.1566 report, Guidelines on Maritime Cyber Risk Management in Safety Management Systems.

Maritime Academy of Asia and the Pacific (MAAP) – Philippines

MAAP, as one of the largest seafarer-sending institutions in Asia, faces unique challenges in adopting VR/AR technology: budget constraints, uneven network infrastructure, and the need to maintain the affordability of education for cadets from low-income families. MAAP's experience provides a highly relevant perspective for maritime institutions in developing countries, including Indonesia.

Phased Implementation Model

MAAP developed a phased implementation model that began with investment in PC-based VR using affordable headsets (Oculus Quest 2), before gradually investing in more sophisticated infrastructure.

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Strategic partnerships with the Philippine Maritime Industry Authority (MARINA) and Samsung Philippines enabled the institution to gain access to VR hardware through leasing and research grant schemes.

MAAP's pilot program, launched in 2021, focuses on three priority modules: GMDSS (Global Maritime Distress and Safety System), Basic Safety Training, and Advanced Fire Fighting. The pilot results show that cadets can complete training hours 30 percent faster with VR, resulting in significant long-term operational cost savings.

Table 2. Comparison of VR/AR Implementation in Global Maritime Institutions

Institution	VR/AR Technology	Training Focus	Key Achievements	Year of Implementation
NTNU, Norway	Full VR + AR HoloLens 2	Navigation & COLREG	+68% decision speed, retention 82%	2018
WMU, Sweden	Multi-user VR + Adaptive AI	STCW Safety Procedures	+40% response, +57% drill accuracy	2020
MAAP, Filipina	PC-based VR (Oculus Quest 2)	GMDSS & Basic Safety	0% training time efficiency	2021
SMA, Australia	AR + Simulation Bridge Hybrid	Electronic Chart Display (ECDIS)	+50% ECDIS competency in 6 months	2019
BPSDM KP, Indonesia	VR Pilot Program	Fire Fighting	In gradual development	2023

**Strategic Implications and Recommendations
Implications for Curriculum Design**

Evidence from various case studies shows that VR/AR should not be treated as a mere supplement, but rather as a core component in competency-based maritime curriculum design. Institutions that have successfully integrated this technology effectively have generally redesigned their curricula comprehensively, rather than simply adding VR modules to existing syllabi. The principle of backward design (Wiggins & McTighe, 2005) is highly relevant in this context:

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curriculum designers need to start by identifying the expected final competencies in accordance with STCW standards, then design authentic assessments that can be operationalized in a VR environment, and only then design learning experiences that support the achievement of these competencies.

Based on the case study analysis, the following are concrete recommendations for maritime curriculum designers who wish to integrate VR/AR: Melakukan competency gap analysis yang komprehensif sebelum memilih atau mengembangkan modul VR, untuk memastikan investasi teknologi menjawab kebutuhan pembelajaran yang nyata.

- Integrating VR sessions with problem-based learning and structured debriefing to maximize critical reflection after simulation.
- Develop valid and reliable assessment rubrics to measure competency in VR environments, which can be cross-validated with performance in conventional assessments.
- Build a data analytics system capable of converting VR performance logs into actionable information for instructors and institutional management.

Implications for Instructor Professional Development

One of the biggest bottlenecks in the adoption of VR/AR in maritime institutions is instructor readiness. Many instructors have very high technical expertise in maritime matters but are unfamiliar with their new role as facilitators of virtual learning experiences. Without serious investment in instructor capacity building, even the most sophisticated VR technology implementation will fail to reach its pedagogical potential. The shift in instructors' roles from expert lecturers to learning experience designers is a transformation of professional identity that cannot be ignored. Resistance to this change often stems not from incompetence but from a lack of systematic, sustained institutional support during the transition.

The instructor's professional development program needs to cover three competency dimensions in an integrated manner. The first dimension is technical competency, which includes the ability to operate and maintain VR/AR systems, configure simulation scenario parameters, and perform basic troubleshooting of hardware and software malfunctions. This competency cannot be assumed to be automatically present, even in tech-savvy instructors, because maritime VR systems have very specific interfaces and technical architectures.

The second dimension is pedagogical competency, which includes the ability to design simulation scenarios aligned with

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learning objectives, facilitate structured, reflective post-simulation debriefing sessions, and integrate VR experiences into a cohesive learning narrative. Research by Fanning and Gaba (2007) confirms that the quality of post-simulation debriefing is far more decisive for the success of learning transfer than the quality of the simulation itself. The third dimension is analytical competence, which is the ability to read, interpret, and follow up on cadet performance data generated by the simulation system, ranging from navigation behavior logs to biometric recordings of stress levels during emergency scenarios.

Institutions such as NTNU and WMU have developed internal VR instructor certification programs that can serve as reference models. The NTNU program, for example, is designed as a six-week blended program that combines intensive technical training, paired simulation facilitation practicums, and mentoring from certified senior instructors. WMU takes a different approach by developing self-paced e-learning modules that instructors worldwide can access, complemented by an active online community of practitioners. Both models demonstrate that there is no single approach that fits all contexts, and institutions need to design instructor development programs tailored to their respective resource capacities and organizational cultures.

In the Indonesian context, instructor capacity building needs concrete policy support from BPSDM KP and the Ministry of Transportation in the form of special budget allocations, career incentives for instructors who participate in VR certification programs, and cooperation with technical universities to provide technical training facilitators. In addition, the development of a national maritime VR instructor community—for example, through a digital platform facilitated by professional associations such as IKPN (Indonesian Maritime Association), can accelerate the transfer of knowledge and best practices between maritime education institutions throughout the archipelago. Investing in instructors is not merely an operational expense but a strategic investment that determines whether technological transformation in maritime institutions will truly result in measurable, sustainable improvements in graduates' competencies.

Implications for Institutional and Regulatory Policy

At the international policy level, adopting VR/AR in maritime education requires careful harmonization between the drive for technological innovation and compliance with the applicable global regulatory framework. The IMO, as the world's highest maritime authority, is currently developing technical guidelines for the

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recognition of digital simulation-based training hours, including VR, as a partial substitute for conventional physical training in meeting STCW requirements. This process is taking place through the Maritime Safety Committee (MSC) and the IMO Instruments Implementation Sub-Committee (III), and is expected to result in a formal regulatory framework before 2027. Indonesia, through the Ministry of Transportation and BPSDM KP, needs to take a proactive stance in formulating these international regulations. The active involvement of the Indonesian delegation in IMO meetings on the digitization of maritime training is not only a diplomatic obligation but also a strategic step to ensure that the resulting regulations accommodate the interests of developing countries with technological capacities different from those of developed countries.

At the national policy level, Indonesia needs more specific and operational regulatory instruments to guide the adoption of VR/AR in maritime education institutions. Current Ministry of Transportation regulations do not explicitly regulate technical and pedagogical standards for the use of immersive technology in certified training. Therefore, it is necessary to draft new regulations or amendments that cover at least four crucial aspects. First, minimum standards for hardware and software specifications for VR/AR systems recognized for STCW training hours, including visual resolution, simulation physics accuracy, and haptic feedback quality. Second, simulation content validation protocols that ensure each VR scenario reflects real operational conditions and is regularly updated in line with developments in ship technology. Third, quality assurance and technology audit mechanisms are conducted by competent independent bodies as part of the maritime education institution accreditation system. Fourth, a framework for data protection and the ethical use of cadet biometric information collected during VR sessions, in line with applicable personal data protection regulations.

At the institutional level, every maritime education institution must develop comprehensive internal policies that comply with national regulations. These policies must include transparent and accountable governance of VR/AR technology investments, including procurement decision-making mechanisms that consider the long-term total cost of ownership, not just the initial acquisition price. In addition, data integration policies are needed to enable seamless connection of VR-based cadet competency records to academic management systems and certification portfolios. The experience of more advanced institutions, such as WMU, which integrates VR data into the cadet's digital STCW e-portfolio system, provides a concrete

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picture of what effective data governance looks like in a technology-based maritime education ecosystem.

Implications for Industry and Partnerships

The sustainable implementation of VR/AR in maritime institutions requires a strong, multidimensional partnership ecosystem among the education sector, the shipping industry, technology manufacturers, classification societies, and government regulators. No single actor can bear the cost of developing and maintaining a high-quality, industry-relevant VR/AR-based training ecosystem on its own.

The public-private partnership (PPP) model implemented in the Philippines through the MAAP program and in Scandinavia through the collaboration between NTNU and the shipping companies Wilhelmsen and DNV provides valuable lessons on how to share the burden of technology investment while ensuring the relevance of simulation content to actual industry operational needs. The key to the success of this PPP model is a clear joint governance mechanism in which industry is not merely a donor but an active partner in formulating simulation scenarios, evaluating graduate competencies, and providing feedback based on real operational experience.

From a shipping industry perspective, involvement in VR simulation content development is an investment that can yield tangible returns. Shipping companies that participate in simulation scenario design can ensure that their cadets are exposed to operational procedures, vessel types, and sailing conditions relevant to their fleet. This significantly shortens onboarding times and reduces on-the-job training costs. Technology companies such as Kongsberg Maritime, Transas (now Wärtsilä), and VSTEP already have VR-based simulator platforms that can be adapted for maritime education needs. Educational institutions that establish strategic partnerships with these technology manufacturers can gain access to the latest content and feature updates at a more affordable cost through educational licensing schemes or co-development agreements.

For Indonesia, as one of the world's largest seafaring nations and home to over 600,000 active seafarers, there is a strategic, untapped opportunity to develop Indonesian-language VR/AR content that accounts for the specific conditions of the archipelago's waters. Indonesian waters have unique characteristics, ranging from narrow, busy straits like the Malacca and Sunda straits to the currents and waves typical of tropical seas to the complexity of ship traffic at major ports like Tanjung Priok and Tanjung Perak. VR simulation content that incorporates these specific characteristics will be far more

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effective in preparing Indonesian cadets than generic content developed for European or North American waters.

A long-term vision worth considering is to make Indonesia a hub for developing and distributing maritime VR/AR content across Southeast Asia. This would not only fundamentally improve the quality of national maritime education but also open new economic opportunities by exporting simulation content to ASEAN countries with similar water characteristics, such as the Philippines, Malaysia, and Vietnam. To realize this vision, a national consortium involving leading maritime education institutions, the Marine Resources Development Agency (BPSDM) for Maritime Affairs and Fisheries (KP), the National Research and Innovation Agency (BRIN), national technology companies, and major Indonesian shipping companies such as Pelni and Pertamina Shipping is needed. With structured synergy among all these stakeholders, Indonesia has the necessary modalities to become not just a consumer but also a producer and exporter of maritime training technology innovations at the regional level.

CONCLUSION

This chapter comprehensively outlines how Virtual and Augmented Reality technologies are revolutionizing the global maritime education and training paradigm. Through an in-depth theoretical framework and analysis of case studies from leading institutions in Norway, Sweden, and the Philippines, it can be concluded that VR/AR is not merely a technological innovation but a paradigm shift in how we understand and deliver competency-based education in the maritime sector.

Three key findings from this study are: First, the effectiveness of VR/AR in maritime education is not automatic but highly dependent on the quality of instructional design that integrates the principles of experiential learning, cognitive load theory, and situated learning. Technology is merely an enabler; appropriate pedagogy is key to success. Second, successful VR/AR implementation requires a comprehensive ecosystem transformation encompassing curriculum redesign, instructor capacity development, institutional policy reform, and strategic partnerships with industry. A piecemeal approach that focuses solely on technology procurement without reforming the supporting systems is likely to yield disappointing results.

Third, the institutional and national contexts are crucial for determining the appropriate adoption strategy. The experience of MAAP in the Philippines demonstrates that institutions in developing countries can effectively adopt VR/AR with a pragmatic, phased

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implementation approach, without the immediate need for large budget investments as institutions in developed countries do.

For Indonesia, the momentum of digital transformation in maritime education, reinforced by the Freedom to Learn policy and Indonesia's agenda as a Global Maritime Axis, creates a conducive environment for accelerating VR/AR adoption in national seafaring education institutions. Visionary leadership from government, industry, and educational institutions is needed to turn this technology's potential into a real competitive advantage for Indonesian seafarers on the global stage.

REFERENCES

- Bligh, D. A. (2000). *What is the use of lectures?* Jossey-Bass.
- Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. Springer.
- International Maritime Organization. (2023). Review of the Human Element in Maritime Casualties. MSC-MEPC.7/Circ.8. IMO Publishing.
- Johansen, K., Eriksen, T., & Pedersen, T. A. (2022). Measuring competency transfer from VR-based bridge simulation training: A longitudinal study. *Journal of Maritime Research*, 19(2), 45–62.
- Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
- Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation increases presence but reduces learning. *Learning and Instruction*, 60, 225–236.
- Marine Accident Investigation Branch. (2022). Annual Review 2022: Analysis of Maritime Accidents and Human Factors. MAIB.
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.
- Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, 38(1), 1–4.
- Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, 147, 103778.
- Rothwell, W. J., & Kazanas, H. C. (2008). *Mastering the instructional design process: A systematic approach* (4th ed.). Pfeiffer.
- Salas, E., Tannenbaum, S. I., Kraiger, K., & Smith-Jentsch, K. A. (2012). *The science of training and development in*

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AI's Role in Business, Governance, Learning, and Spiritual Growth
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- organizations: What matters in practice. *Psychological Science in the Public Interest*, 13(2), 74–101.
- Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(2), 257–285.
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. MIT Press.
- Wiggins, G., & McTighe, J. (2005). *Understanding by design* (2nd ed.). ASCD.
- Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3), 225–240.
- World Maritime University. (2022). *WMU VR Safety Lab: Programme Evaluation Report 2020-2022*. WMU Publications.