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Developments in Engine Room Simulator Training Technology for Future Ships: Facilitating Training in Context

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Abstract: Recent developments in ship engine room simulator technology support the more contextualised high-fidelity training and facilitate the transition to training for future ship operations. With the gradual adoption of automation and digitalization onboard, modern ships are increasingly equipped with remotely monitored unmanned spaces such as the modern engine room. Marine engineers are no longer required to be co-located within the boundaries of the engine room to carry out their duties. Maritime Education and Training (MET) needs to evolve and reflect the developments in the changing work context wherein the marine engineer is removed from the physical work locale. Advancements in engine room simulator training are suited to modern and future ship operations. Situated in-context training has been the mainstay of competence development in shipping. Previously seafaring training took the form of on-board apprenticeships and gave way to shore-based MET provision over time. This led to an increase in the distance between the training environment and the context of work. This paper presents the recent developments in engine room simulator technology, the walk-through engine room simulator, and argues that the immersive training experience afforded by this novel technology facilitates near-context training especially for the technologically advanced and future ships. We envisage that in the future, the digital twin of the engine will be part of the digital space that constitutes the future workplace of autonomous ships. We discuss that utilizing the walk-through engine simulators affords a bridge between the current and the future autonomous engine room training.

Keywords: Maritime Education and Training; Marine engine room simulator; Future ships; MASS; Walk-through engine room; Digital Twin

1. Introduction

Maritime Education and Training (MET) has evolved tremendously from when formal structured maritime instruction commenced onshore as a move away from the onboard apprenticeship training. This move, physically separated teaching and learning from the workplace environment, adding distance between shore-based MET provision and the shipboard work context and between the employers and their seafaring workforce. Near-context, on-the-job workplace training has been considered the gold standard of training (Billett, 2020) and attempts have always been made in MET to make the training relevant and effective (Emad & Roth, 2008). Over the last half a century there has been an increasing introduction of technology onboard ships reflected in today's modern integrated technologies, automated systems, and unmanned spaces. The developments in technology in the shipboard workplace have been reflected in MET with the increasing incorporation of simulator technology in the design and delivery of seafarer training. Simulator training is known to bring the training close to the context of work, thereby contributing towards the relevance and the efficacy of the training. The Global Maritime Professional (GMP) (IAMU, 2019) will benefit from immersive high fidelity engine room simulator training technologies that support near-context training and enable the trainee to vicariously experience the workplace in the virtual world (Baldauf, Schrder-Hinrichs, Kataria, Benedict, & Tuschling, 2016).

Due to diverse factors, including the efficacy of technological advancements in simulator training technology, there is an increasing demand from some countries to consider simulator training in lieu of sea time in maritime training requirements for certification (Nautilus-International, 2020). Work on identifying sea time equivalence is already being undertaken whereby the required sea service time can be reduced by up to thirty days in certain niche maritime sectors such as dynamic positioning vessels in the offshore operations (Sea-Maritime, 2022; STC, 2023). This reduction in sea time is extremely attractive for the maritime industry although it raises questions regarding the efficacy of the training. Previously, the proposal of simulator training in lieu of sea service was largely motivated due to the lack of training berths available on-board ships. Currently, however, the developments in simulator training technology make it a powerful pedagogical tool that can facilitate enriching near-context training. This paper presents the developments in engine room simulator training technology and argues that the immersive training experience afforded by this novel walk-through engine room simulation technology facilitates near-context training. The technology also facilitates the transition to future ship operations wherein the workplace itself would be digitally re-imagined as the digital twin technology of a vessel would be the future workplace for marine engineers.

2. Technology-intensive MET environment for modern and future shipping

With respect to modern and future ship operations, the International Maritime Organization (IMO) has delineated 4 degrees of Maritime Autonomous Surface Ships (MASS) underpinned by technological advancements in operations, control, and the presence/absence of humans onboard. Modern ships of today are in degree 1 of MASS with some automated processes and decision support systems (DSS) onboard where seafarers can take control when required. Degree 2 of MASS is imminent and denotes a vessel that is remotely controlled, but with seafarers present onboard to take control if required. Degrees 3 and 4 of MASS do not have seafarers onboard. While the ship is remotely controlled and operated in stage 3; stage 4 is characterised by a fully autonomous ship capable of independent decision-making and action.

The MET environment for modern and future shipping will be technology and resource intensive. Three current and complementary trends in the maritime industry will inform and shape the training environment of future shipping operations. Trend 1 is the increasing adoption of technology onboard ships that has led to increased digitalisation and automation that will culminate in autonomous ships of the future (Emad, Narayanan, & Kataria, 2022; Narayanan & Emad, 2020); Trend 2 is the increasing uptake of technology in MET such as continually advancing simulator training technology (Emad & Kataria, 2022); Trend 3 is the blurring of the physical and the virtual workspace in MASS stages 3 and 4 wherein human operators will not be present on board and the workplace itself will be digital in nature. In future, where the shipping industry embraces the autonomous shipping, the training of the future workforce utilising the digital twin of a vessel appears to be a logical pedagogical development in the MET continuum (Kataria & Emad, 2022). There is a significant distance between the current degree of MASS and the advanced integrated automated systems and autonomous ships. Advancements in simulator training technology such as the walk-through marine engine room can be mapped to the training requirements of MASS degree 1 and 2 ships and provide a pathway for future training of MASS degrees 3 and 4.

3. The walk-through marine engine room

The walk-through marine engine room simulator is a new development for the training of marine engineers that provides an immersive environment and affords access to different spaces, systems, and equipment of the ship's engine room. The technology permits trainees to undertake realistic actions and see consequences in real time (Lokuketagoda, Miwa, Ranmuthugala, Jayasinghe, & Emad, 2017) (see figures 1 and 2).

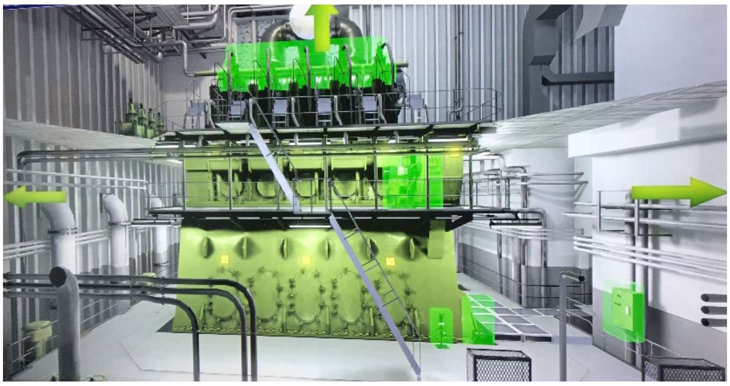

Figure 1. A view of the main engine in the marine engine room simulator.

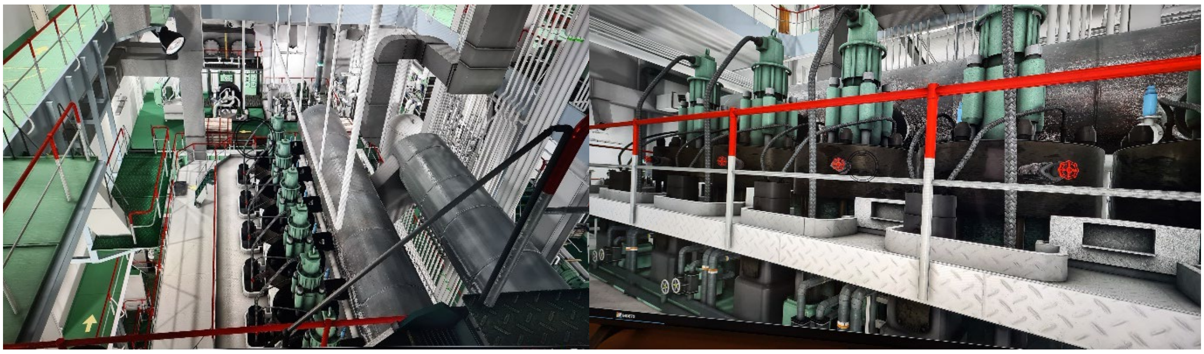

Figure 2. Different views of the main engine.

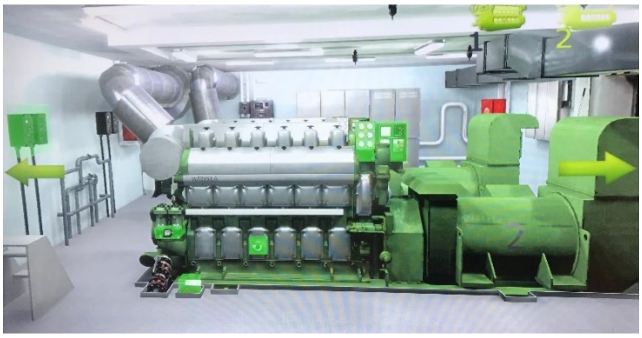

Figure 3. A view of the auxiliary engine in the marine engine room simulator.

3.1 Key features and affordances

The walk-through engine room simulator comprises engine room simulator software which enables the students to walk through the virtual reality view displayed on a wide-screen monitor (usually a 65-inch Television) with the aid of a handheld controller. The gamified environment facilitates student engagement with learning. The placing of a series of large monitors along the walls of a teaching-learning space encompasses the entire engine room and transports the students to an immersive learning environment. The inclusion of the sights and sounds of the engine room including the sounds of equipment and alarms adds to the realism/high fidelity of the teaching-learning environment. Students develop an attraction to these video-game-style moves navigating through a real engine room, as it gives an immersive learning experience in a real-life environment and work situations. The interactions between the students and the equipment and spaces inside the walk-through marine engine room simulator closely mimic real life. For instance, the virtual environment provides options for nuances such as wiping a dipstick after checking the level of oil in an equipment. The students can toggle between the 2-dimensional (2D) schematic diagrams and the 3-dimensional (3D) models of the engine room equipment and spaces. This movement enables them to holistically take in the teaching-learning engine room environment at a glance and then navigate to the equipment or space they would like to take a closer look at. The touch screen TV monitors facilitate ease of navigating. The entire virtual engine room is available at the touch/click of a button or alternatively through the handheld controller device. The students can navigate to, and closely examine a particular equipment/space utilizing the stylus. The students are in control of the engine room machinery and plant which synchronizes with the future remote operation of the ship's machinery with the 'digital twin'.

Figure 4. Steering gear and the purifiers in the marine engine room simulator (left to right).

The walk-through marine engine room simulator is suitable for all degrees of MASS ships to varying degrees. A limited number of degree 1 MASS ships have unmanned engine rooms and the simulator presents the opportunity to familiarise the engine room crew with the space, equipment, and training requirements. Additionally, the principle of this simulator is to vicariously experience the engine room and take remote action and see consequences in real-time. It is also suitable for degrees 2, and 3 of MASS operations where the vessels are remotely monitored and operated. Estimates suggest that the widespread implementation of MASS for oceangoing vessels is about two decades away. In this scenario, the walk-through marine engine room simulator is a powerful and relevant pedagogical tool to support the training of marine engineers for the next few decades, or as long as degrees 1, 2, and 3 of MASS vessels ply the oceans. In degrees 3 and 4, the workplace would be digitally reimagined as the physical workplace would no longer require human presence. In this case, the development of the digital twin of a vessel will be a gamechanger for MET as training can be then provided in the digital workplace itself.

4. Research study

In recent years the affordability and accessibility of state-of-the-art technologies at maritime training institutions afford engineer trainees with access to a learning environment close to real life. In this study, the walk-through marine engine room simulator was used at the Australian Maritime College (AMC), in combination with desktop-based systems for the delivery of the simulation related component of the unit – Ship and Engine Resource Management. The simulator-based component includes developing competence in a series of simulation exercises that prepare the ship for sailing, starting from a cold ship to ensuring readiness for full away. This study is part of a larger ethnographic study on competence development of maritime workforce. The data for this preliminary study comprises research fieldnotes, interviews, audio-video recordings, and pictures. The data was analysed using Thematic Analysis that identifying, analysing, and interpreting pattern of meaning is at the centre of making sense of qualitative data. The experience at the Australian Maritime College with the real-life application of simulation in teaching clearly showed the trainees' preference in learning was always centred around the Full Mission engine room simulator with virtual reality views rather than the desktop systems. The desktop system exercises with the 2-D mimic diagrams provide trainees with the basic equipment and tools to develop an understanding of how the engine room systems work. However, the visual effect with the virtual reality views of the full mission provided a whole new level of student experience. This includes practicing different tasks with 'full mission' exercises with a mix of mimic diagrams, virtual reality views, and hardware such as main engine controls and electrical switchboard touch screens. The introduction of 'walk-through' with 3-D views of machinery in high fidelity engine room settings revolutionised the students' expectations and experiences. Students' feedback highlights that the 3-D views and settings are significantly more realistic and immersive. The identified advantages of utilising the walk-through marine engine simulator room were realism, immersive nature, increased student engagement, improved student interest, kinetic nature of learning utilising the learner's physical body as a resource, and motor cognition (Sellberg, 2017).

What the walk-through engine room simulator provides to students' learning goes beyond the addition of useful new features. It fundamentally changes the concept of learning for engineers. The pragmatic addition to learning allows the 'motor cognition' of students to develop by allowing them to experience the actionability of their body in the process of learning. The concept of motor cognition refers to the notion that cognition and thinking is embodied in action. It refers to the ability of humans to learn by doing. This not only refers to the processes of performing a task but includes the mental processes of social interaction as it happens in teamwork in workplaces. The affordability of walk-through engine room simulator allows students to relate their cognitive processes of their planning and decision making with the affordability and consequences of their actions. The simple tasks such as opening/closing a valve would involve different cognitive processes compared to thinking, planning, and deciding about the action. Accident investigation into maritime accidents such as Amoco Cadiz (Bonnieux and Rainelli 1993) shows how a simple planning for switching to alternative steering gear provides unpredicted consequences leading to disaster.

As the industry moves toward implementation of MASS degree 2 and 3, it is expected that the remote-control centre (RCC) ashore would provide a workplace similar to the walk-through simulators. This also provides an opportunity for the maritime training institutions, by utilising walk-through engine room simulator, to not only elevate the training of current marine engineers by providing immersive seamless learning environment but to prepare the future workforce with an authentic near-real-life experience training (Emad, Enshaei, and Ghosh 2022; Emad and Ghosh 2023).

In the transition to autonomous shipping of MASS degree 2, where remote controllers would be utilised for the operation of ships from ashore, the walk-through engine room simulator will be a powerful teaching and learning aid in the near future. The authors suggest that the 'walk-through' simulation platform in combination with 'full mission' would be the foundation for the future 'Digital Twin' of a vessel.

5. Digital twin in MET for future shipping

The digital twin of a vessel is a virtual, (largely cloud-based) digital representation of a physical asset. In the maritime industry, the digital twin is being deployed to optimise the vessel's lifecycle from ship design, ship building, to ship operations, and maintenance, to the end of the ship's life. Its uses are being seen in maritime security and safety, the optimisation of supply chains, parameters of ship operation, port and terminal optimisation, and fleet optimisation. In addition to the aforementioned benefits of the digital twin in the industry, a key benefit of the technology is in MET. The digital twin can be utilised as a powerful pedagogical tool that affords the provision of training within the context of work itself. In stages 3 and 4 when the digital space *is* the workspace, it would be beneficial to utilise the digital twin for training. Utilising the digital twin for both working and training implies the merging of the gap between the context of training and work.

6. The context of work and the teaching-learning context

Shore based MET provision separated the context of teaching-learning from the context of work. Simulator training with advanced technologies help to bring the work context back into training. The adoption and integration of advanced technologies into MET bring the context of work closer to the context of training due to their high fidelity and affordances. The affordances of technologies such as the walk-through marine engine room simulator support near-context training – the access to virtual spaces, realistic engine room acoustic environment, opportunities for navigation, interaction, and realistic action and reaction help the students to see the consequences/outcomes of their actions embedded in the work context in real-time, thereby re-enforcing the learning. Technologies such as the walk-through marine engine simulator room facilitate the transition to tech-saturated training for future ship operations by supporting the training for remotely monitored and controlled unmanned engine room spaces. Advanced training technologies bring the hitherto separated work context and the context of teaching-learning closer until there are no boundaries between the digital and the physical workspace as in the case of the digital twin. With the advent of the digital twin, MET provision can take the leap into the technologically saturated future of training. The MET move to utilise the digital twin of a vessel is momentous as in the future the digital space will *be* the workspace/context of work. The MET pedagogical shift to the digital twin blurs the boundaries between the context of work and the context of teaching-learning until they merge and are indistinguishable. Training for future shipping operations will take place in the digital workplace. This development brings MET full circle; from moving away from the context of work to incorporating the work context back into training.

7. Conclusion

This paper suggests that simulator technology developments in MET such as the walk-through marine engineering simulator bring the trainee as close to the context of work as possible. This is extremely valuable in current modern ship operations with increasingly unmanned engine room spaces to give the marine engineer the opportunity to vicariously immerse in the context of work. Not only does it help the marine engineers to familiarise themselves with the space, but also enables them to interact with diverse components and see the effects in real time as they would in a physical engine room. The remote monitoring and controlling work required of the marine engineer is well supported by this technology contributing to its relevance. Furthermore, technological advancements such as the digital twin when incorporated into training would enable the trainee to train in the (digital) workplace itself, thereby bringing the context back into training and positively impacting its relevance and efficacy. This paper highlights the advancements in marine engine room simulator training technology that would serve MET well into the few coming decades. Additionally, it highlights the value of incorporating the digital twin into MET. Embracing these novel developments will enable MET to remain relevant for the coming decades by being abreast of the developments in the industry. The authors note the limited scope of the study. Further research would need to be carried out to unpack the teaching-learning affordances and efficacy of novel technologies in preparing the workforce for rapidly evolving modern and future shipping.

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