# Implications of Automation and Digitalization for Maritime Education and Training

**(Autonomous operations, digital technologies and implications for Maritime Education and Training)**

**Sharma, Amit; Kim, Tae-Eun; Nazir, Salman**
Department of Maritime operations - University of South-Eastern Norway

*This is the accepted version of the paper. This version may differ from the final version published by SpringerLink. The final authenticated version is available online at DOI:*
https://doi.org/10.1007/978-3-030-69325-1_11

Sharma, A., Kim, T.-E. & Nazir, S. (2021). Implications of Automation and Digitalization for Maritime Education and Training. I A. Carpenter, T. M. Johansson & J. A. Skinner (Red.), *Sustainability in the Maritime Domain: Towards Ocean Governance and Beyond* (s. 223-233). Springer International Publishing. https://doi.org/10.1007/978-3-030-69325-1_11

# Autonomous operations, digital technologies and implications for Maritime Education and Training

*Submitted by*

Amit Sharma, Tae-Eun Kim and Salman Nazir*
Training and Assessment Research Group (TARG)
Department of Maritime Operations
University of South-Eastern Norway
Postboks 4, 3199, Borre, Norway
*Corresponding author – salman.nazir@usn.no

**Abstract.** Due to steady advancement and implementation of automation technology, autonomous operations are slowly pervading all transportation sectors. In maritime sector, the industry and regulatory bodies are in active debate regarding the implementation mechanism, the operational, regulatory and safety aspects of such changes. The introduction of autonomous shipping in various degrees will have an impact on the fundamental ways various maritime operations are conducted. A change in work processes and roles within the sector would mean that the associated education and training for the seafarers will have to be adapted to meet the novel competence demands. In this Chapter, we will discuss the maritime autonomous operations on the basis of prevailing key trends in the maritime sector and their implications for Maritime Education And Training (MET). The directions and perceived solutions that can potentially aid in preparing for challenges and opportunities autonomous operations would entail will be elaborated upon. We will discuss how digital technologies such as Virtual Reality (VR) and Augmented Reality (AR) are changing the approach towards education and training, specifically with relation to maritime domain. The need to cultivate appropriate digital skills, information processing skills as well as other non-technical skills is also highlighted. The aim is to provide a conceptual roadmap that shed lights on some of the ongoing developments occurring with respect to Maritime Education and Training.

**Keywords:** Maritime operations; Autonomous ships; Maritime education and training; Digital technology

## 1 Introduction

The maritime industry is often considered as old as human civilization itself

(Stopford, 2009). Some of the earliest remains of the seagoing boats are found in the Persian Gulf dating back to sixth/fifth millennia BC (Carter, 2006). These remains reveale a system of maritime exchange occurring in the nearby towns using ships. Over the years, ships expanded both in size and their voyage scope. They were able to transit bigger water bodies; ultimately culminating with the ability to cross large expanses of water bodies such as seas and oceans. Such changes correspondingly impacted the trade and transportation patterns all over the world. The ships steadily evolved over the years as well, as a result of change in basic technology. Shipping industry has witnessed "Age of sail" where ships utilized sails as a means of propulsion (Carter & Carter, 2010) to steam powered ships (Griffith, 1997) and finally to the contemporary ships utilizing several modes (diesel/electric/nuclear) of propulsion; as well as modern navigational technology for their operations.

The current shipping industry is often termed as the "backbone" of the global economy; being responsible of 80-85% of the global trade (UNCTAD, 2019). It has indispensable role at the moment in our society, as being responsible for the access of majority of goods which we need in day to day life. The personnel responsible for ensuring safe execution of maritime operations, traditionally have had a very challenging role to perform. The maritime industry has relied on their knowledge and competence for transferring variety of cargoes, often valuable products, on an equally if not more valuable assets – ships. However, it is worth noting that due to the advancement of shipping technology over the years, there has been a concurrent and noticeable trend in shipping, i.e. the utilization of fewer manpower onboard. The involvement of human element onboard ships is getting less labour intensive and more challenging in terms of the cognitive demands (Mallam et al. 2019). The size of crew has steadily reduced over the years and their job functions increasingly diversified. For the future operations of maritime industry, we are now looking at the possibility of deployment of ships that are remotely controlled and highly autonomous in nature with presence of bare minimum or no crew members onboard.

## 2 Maritime autonomous operations

Maritime industry stands at crossroads of technological development and at a verge on transition into next generation of shipping that would be characterized as consisting of vessels that are remotely controlled and autonomous in nature. In continuation of the ongoing trends of digitalization and automation in various transport domains, maritime industry is looking at the possibility of introducing autonomous ships in various stages of their development cycle, throughout the coming years. The International Maritime Organization (IMO), has defined four degrees of autonomous operations from Degree 1, having human presence onboard and operating with decision support systems to Degree 4 representing a completely autonomous vessel as illustrated in Figure 1.

| | *Level of autonomy* | *Human presence* | *Operational control* | *Human role* |
|---|---|---|---|---|
| Degree 1 | Ship with automated processes and decision support | Yes | Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control | Supervision and operation |
| Degree 2 | Remotely-controlled with seafarers on board | Yes | The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions | Backup to manoeuvre, supervise the systems |
| Degree 3 | Remotely-controlled without seafarers on board | No | The ship is controlled and operated from another location. There are no seafarers on board | Monitoring and remote control |
| Degree 4 | Fully autonomous | No | The operating system of the ship is able to make decisions and determines actions by itself | Monitoring and emergency management |

Fig.1 The various degrees of autonomous operations as defined by IMO (Kim et al. 2019)

As evident in this framework, the autonomous ships in this context do not necessarily mean "unmanned" ships. It is evident that the transition to "unmanned" ships in the future, is going to be in incremental stages with increasing number of functions handed over to automation agents. The IMO has also commenced a regulatory scoping exercise for Maritime Autonomous Surface Ships (MASS) (MSC101, 2019). The primary reasons for the introduction of autonomous shipping has been argued as - reduction in emissions, improving efficiency and cost effectiveness, as well as improving safety by reduction in so called human error. However, as noted by many researchers (Komianos, 2018; Kooij, Loonstijn, Hekkenberg, & Visser, 2018; Mallam, Nazir, & Sharma, 2019; Porathe, 2019), the promises regarding safety in operations, particularly deserve cautious optimism. There are many operational, regulatory, and quality challenges influencing safety that are yet to be solved. Introduction of autonomous ships are likely to initiate a myriad of interaction between a "regular" manned ship and an "autonomous" ship with varying degrees of dynamic human control over the vessel (Porathe, 2019). Furthermore, the role of humans will evolve, as the need arises for novel competences requirements for operating such vessels (Sharma, Kim, Nazir, & Chae, 2019).

According to a report jointly published by World Maritime University (WMU) and International Transportation Worker's Federation (ITF), the introduction of highly automated ships could lead to a slump in the global demand of seafarers from the current projections, by the year 2040 (WMU-ITF, 2019). Further, the workers with low/medium skills and routine task intensive work are exposed to risk of losing their jobs to the highly skilled category of workers. To adequately cater to the changes in the maritime industry and corresponding change in competence requirements, it will require efforts to re-train the workforce in a considerable scale. In addition, the regulatory framework awarding the seafarers with Certificate of Competency (CoC) will require corresponding re-visitation (Sharma et al., 2019). The Standards of Training, Certification, & Watchkeeping (STCW) '78 as amended is the International convention that lays down the minimum competence requirements that the seafarers need to demonstrate before the flag state can issue them the CoC (IMO, 2017). The flag state in this context is every nation signatory to the STCW'78 which ensures that the Maritime Education and Training (MET) institute adhere to the competence requirements stipulated in the convention. Such system, not without its own challenges in terms of subjective interpretation of the regulations, is an effort towards ensuring uniform compliance. The STCW convention has been subject to periodic revisions (for example in 1995 and 2010) taking into account the contemporary changes occurring in the shipping domain. It is already under speculation that, to cater for this new era of autonomous maritime operations and associated novel competence demands, the STCW regulations will be needed to be revised accordingly (Sharma et al. 2019). Not only the existing competence requirements for seafarers onboard will change in light of autonomous operations framework, but it might also be required to cater for entirely new roles emerging due to such developments – for example Shore/Remote Control Centre Operators (Lutzhoft et al. 2019). The technical skills required in autonomous operations will partly be a function of the technology in use (Ringbom, 2019). In addition, there is growing recognition of importance of generic "soft skills" in modern complex socio-technical systems (Flin & O'Connor, 2017). These skills, often termed as "Non-technical skills" are defined as the "the cognitive, social, and personal resource skills that complement technical skills, and contribute to safe and efficient task performance" (Flin et al. 2008).

# 3 Future competencies of seafarers

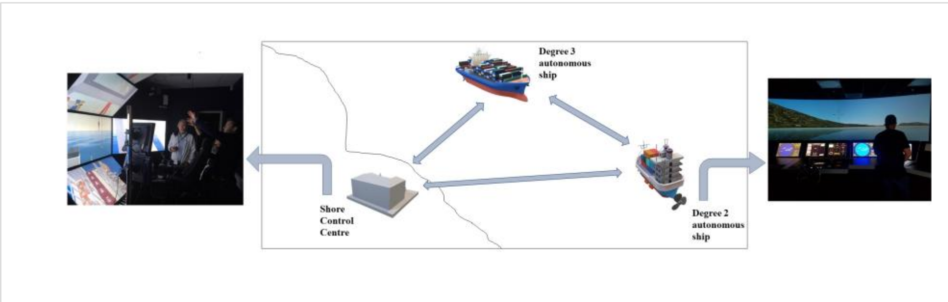


Fig.2 Interaction between autonomous ships and shore control centre

Consider a hypothetical futuristic scenario with autonomous maritime operations as illustrated in Figure 2 above. Vessels with various degrees of autonomous operations will mean that there has to be differential operational approach and even varying competence and skills required in such operations. For seafarers present in autonomous ship operating at degree 2 level of automation, they have supervisory role in operations, but it might be required to assess and evaluate the navigational scenario in a relatively short notice, should the need arise to take over the functions. For a vessel operating in degree 3 mode, as per the definition, it might even be the case that no seafarer is present onboard. However, such ship will be controlled from a remote or shore control centre. The operators of such ship may or may not be "seafarer" as we know them today. In addition, such operations even lack the benefit offered by relatively enhanced situational awareness due to the actual presence on ship as in degree 2 operations. It might also be the case that the operators responsible for degree 3 ship are monitoring/controlling multiple ships and therefore they need to be aware of relatively specific information element parameters from multiple ships. These ships will also need to interact with one another as well as with the shore control centre using standard communication protocols. The future competence requirements in such scenario will therefore take new dimensions basis on the evolving maritime operations.

The competence requirements and associated certification of seafarers are carried out as per STCW regulations describing the Knowledge, Understanding and Proficiency (KUPs) requirements for each position for merchant shipping. There has been ongoing debate regarding the relevancy and suitability of existing STCW requirements for future maritime operations. The challenge regarding uniform application exists as each member state signatory to STCW interprets differently the terms and provisions given in it. According to a recent survey carried out by Lloyds Maritime Academy (2019), about 67% of the respondents felt that there is considerable skill gap present in maritime domain. The developments with autonomous maritime operations can further exacerbate these challenges. Due to fundamentally different nature of job functions for the seafarers in autonomous ships, not all KUPs as listed at present in the competency tables will be required. The functions that will be automated or carried out by automation agents will correspondingly not be relevant anymore. In relation to this, Sharma et al. (2019) carried out an exploratory study regarding the suitability of Table A-II/1, which lists the competence requirements of navigators in an operational role, for hypothetical Degree 2 autonomous operations. The study consisted of a survey where a number of maritime professionals were asked to rate the relevance of each of the KUPs in the table for the scenario as mentioned above. The respondents indicated that the competence related to the emergency management functions will be highly relevant as routine tasks will become more and more automated. The role of human operators in such scenario will be more inclined towards handling of non-routine or emergency events. Further, the need for inclusion of novel KUPs might arise in light of more supervisory roles for the seafarers in autonomous operations. The report by Norwegian Ship owners Association (2018) predicts that competences related to – ICT, data processing and cyber technology will be in high demand in the coming decade.

The importance to train the seafarers in non-technical skills such as teamwork, leadership, communication etc. has increasingly been recognized in the past few years by the maritime stakeholders. This is evident by the recent revisions in the STCW regulations to explicitly include provisions regarding their demonstration (Sellberg & Lundin, 2017). Numerous accident analyses and case studies have illustrated the role of non-technical skills in contributing to the maritime causalities (Barnett et al. 2006). In this regard, it is important that not only the seafarers are equipped with adequate technical skills taking into account the developments with regards to technology, but they also possess relevant non-technical skills for functioning efficiently as an individual as well as a team member amidst the evolving working environment.

As of now the framework and focus towards including non-technical skills in training and assessment for seafarer seems underdeveloped and unstandardized. For example, Fjeld et al (2018) carried out a systematic review of studies which focused on non-technical skills for bridge officers in maritime industry. They identified five non-technical skills which were the focus in associated literature review, namely – (1) Situation Awareness (2) Decision making (3) Workload management (4) Communication & (5) Leadership. The first three skills belong to the category of "cognitive" skills and the latter two skills are termed as "interpersonal" or "social" skills. The authors stated that in the research literature there is insufficient exploration of these skills in enough detail to formulate meaningful guidelines for maritime industry. For example, the studies focusing on "decision making" usually focus on naturalistic decision-making forms and less or almost no focus on analytic and procedure-based decision-making forms. Further, there appears to be imbalance between research articles focusing on cognitive skills, in contrast to those focusing on interpersonal skills for bridge officers. Finally, no complete taxonomy of non-technical skills for bridge officers exists as of now for facilitating standardized training and assessment.

Challenges such as those mentioned above may contribute to the regulatory barriers maritime industry faces and thereby impact the rate of adoption of autonomous vessels and may also restrict their operations in national waters of selected states in immediate future. Therefore, the perceived benefits in relation to the more sustainable modes of transportation with such ships could initially require support in terms of international policy, guidelines and frameworks for maritime education and training.

## 4 The role of digital technologies

Maritime Education and Training has not remained insular to the wider changes occurring with respect to the usage of digital technologies for education and training of industrial workforce. From the use of simulators onshore for training the seafarers in various functional roles for their jobs, to the use of distance learning solutions utilizing ubiquitous mobile devices for supplementing the competence development onboard, maritime industry is adopting various approaches for keeping up with changing skillset demands. In relation to this, there is ongoing debate around the use of Virtual Reality (VR) and Augmented Reality (AR) for their potential application in Maritime Education and Training.

The utility of immersive technologies such as VR and AR, can provide a wide range of new possibilities and applications for MET practices. Some of the pedagogical approaches VR and AR can support are – Constructivist learning, Situated learning, Game based learning, Enquiry based learning etc. These technologies bring novel and innovative opportunities for enhancing the way we learn. They immerses users completely within a computer-generated environment providing experiences not found in other simulation mediums. A study on the training usage of immersive technologies (Nazir et al., 2014) suggests better task efficiency and increased performance in VR, while under stress compared to other conventional methods (i.e.:power point presentation and class-room based training). Another experimental study by Mallam et al. (2018) revealed that participants have better task efficiency in virual environment compared to the traditional desktop environments, which is the main focus for maritime training as well.

On the other hand, head mounted virtual reality (HMD VR) provides promising means of training in terms of better accessibility, mobility and participants' motivation (Mallam et al., 2018). With recent challenges concerning distance learning during the COVID-19 outbreak (Oranburg, 2020), the need to deploy effective remote training solutions has been amplified. Moreover, differing technological solutions (i.e. augmented reality, mixed reality etc.) within the framework of the reality-virtuality continuum are emerging amidst the necessity for diversification in the maritime training and assessment paradigm. Mallam et al. (2019) provided the context for their practical implementation (e.g.: cost and fidelity), complying with the taxonomy for these technologies being theorized by Milgram and Kishino (1994).

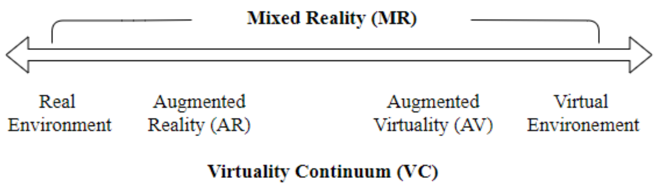


Figure 3: A representation of a "virtuality continuum" (Milgram and Kishino, 1994)

In relation to the above continuum, Augmented Reality (AR) can be defined as a "situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information (Klopfer & Squire, 2008). There has been some evidence regarding application of AR in various educational settings for increasing student engagement, motivation and helping them to achieve the intended learning outcomes (Bower et al. 2013). AR systems can also help in visualizing abstract concepts and unobservable phenomenon (Wu et al. 2013). Further, AR can provide resources to the educational context which may otherwise be costly or impractical to acquire (for example lab equipment) (Fjeld & Voegtli, 2002). AR training solutions, just like VR, can therefore make ubiquitous learning for maritime students a possibility in near future and contribute in the skills development. There have been studies related to practical application of AR for maritime operations as well. Von Lukas et al. (2014) illustrated how AR technology might be used for maritime engineering, production, operation and harbour survelliance functions. Further, projects like Maritime Augmented Reality (M-AR) by the Royal Norwegian Navy, investigate the use of AR to support the navigation and enhance the Situational Awareness (SA) of the navigator by providing augmented information (Hareide & Porathe, 2019).

Continuous research and development converging towards the refined output of VR and AR training solutions has shown potential for increased training transfer, better immersion and reduced cost (Buttussi & Chittaro, 2017; Jensen & Konradsen, 2018;

Renganayagalu et al., 2019). Various other disciplines including the process (Nazir et al., 2012) , health (Riva, 2002; Gregg & Tarrier, 2007) and aviation (Marion et al., 2007; O'Neil et al., 2000) have also been investigating the benefits of VR/AR training.

## 5 Implication for Maritime Education and Training

Implementation of maritime autonomous shipping solutions would have profound implications to skillsets required to handle the new technology, and consequently there will be a race between the techonology and domain of MET in order to keep pace with the ever-growing change in the types of competence demanded. The returns in terms of value creation for MET are potentially high, however, it should be acknowledged that the quality of schooling differs across the globe for the seafarers. Automation may further increase the gap between the developed and developing countries in MET practices as MASS is widely being researched, tested and developed in industrialized and advanced countries, such as - Norway, Japan, South Korea etc. This implies that future technological disruption will potentially have a bigger impact for the MET market in developing countries.

Based on these predictions, we believe that there are several policy priorities that MET industry should be considered in order to prepare for the future:

Firstly, automation implies new skills but also deskilling: some skills that are needed today might be eliminated by the introduction of more advanced technologies (Sharma et al., 2019). The business model should be updated and more focus can be placed on early development of new competence in order to keep pace with the technological advancements and market demands.

Secondly, it is important to provide good balance between the current competence development program and the new ones in order to ensure the seafarers are capable of operating in difference mode of MASS and remain immune to automation.

Thirdly, the use of digital technologies such as VR and AR should be further explored for training in skills required for maritime operations, as they can support the transfer of training, enhance task effectivess and provide ubiquitous learning soultions while potentially reducing associated costs.

Finally, it is important to note that the goal of introducing automation is to increase the productivity and safety by freeing personnel from working in the percieved risky, remote and repetitive jobs, which in turn has the potential to contribute for a greater welfare in society. Nevertheless, how well the automation technology will be implemented and operated is heavily dependent on the quality and relevance of education and training in preparing future ship operators. Accordingly, re-establishing the future of MET needs to be a collective effort between all stakeholders in the maritime industry. More industrial-MET alliances and collaboration will be crucial for technological progress and goal achievement.

## 6 Conclusion

Maritime industry is undergoing through a wave of automation. To keep pace with technological advancements and market demands, the global standard for maritime training and certification practices will also require revision and adaption. In the midst of this major change, it is important that the MET institutes in each jurisdictions are proactive in building competence structures for seafarers to embrace this new era of ship operations and to stay ahead of competition. The discussions and arguments in this book chapter hopefully, could encourage more contributions and research into future seafarers' competence requirements and the novel outlook towards training methods and practices.

## 7 References


Barnett, M., Gatfield, D., & Pekcan, C. (2006). Non-technical skills: the vital ingredient in world maritime technology. *In Proceedings of the International Conference on world maritime technology. London, UK* (pp 1-11) Institute of Marine engineering, Science and technology.

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education–cases, places and potentials. *Educational Media International*, *51*(1), 1-15.

Buttussi, F., & Chittaro, L. (2017). Effects of different types of virtual reality display on presence and learning in a safety training scenario. *IEEE transactions on visualization and computer graphics, 24*(2), 1063-1076.

Carter, R. (2006). Boat remains and maritime trade in the Persian Gulf during the sixth and fifth millennia BC. *Antiquity*, *80*(307), 52-63.

Carter, W. E., & Carter, M. S. (2010). The age of sail: A time when the fortunes of nations and lives of seamen literally turned with the winds their ships encountered at sea. *The Journal of Navigation*, *63*(4), 717-731.

Fjeld, G. P., Tvedt, S. D., & Oltedal, H. (2018). Bridge officers' non-technical skills: a literature review. *WMU Journal of Maritime Affairs, 17*(4), 475-495.

Fjeld, M., & Voegtli, B. M. (2002). Augmented chemistry: An interactive educational workbench. In *Proceeding of International Symposium on Mixed and Augmented Reality* (pp. 259-321). IEEE.

Flin, R. & O'Connor, P. (2017). Safety at the sharp end: a guide to non-technical skills: CRC Press.

Flin, R. H., O'Connor, P., & Crichton, M. (2008). Safety at the sharp end: a guide to non-technical skills. Ashgate Publishing, Ltd.

Griffiths, D. (1997). Steam at Sea: Two centuries of steam-powered ships. Conway Maritime Press.

Gregg, L., & Tarrier, N. (2007). Virtual reality in mental health. *Social psychiatry and psychiatric epidemiology, 42*(5), 343-354.

Hareide, O. S., & Porathe, T. (2019). Maritime augmented reality. *Coordinates Magasine, February issue*, (pp.31-35). Available at: https://mycoordinates.org/maritime-augmented-reality/ (Accessed 02 April 2020)

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies, 23*(4), 1515-1529.

Kim, T. E., Sharma, A., Gausdal, A. H., & Chae, C. J. (2019). Impact of automation technology on gender parity in maritime industry. *WMU Journal of Maritime Affairs*, *18*(4), 579-593.

Klopfer, E., & Squire, K. (2008). Environmental Detectives—the development of an augmented reality platform for environmental simulations. *Educational technology research and development*, *56*(2), 203-228.

Komianos, A. (2018). The Autonomous Shipping Era. Operational, Regulatory, and Quality Challenges. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 12*(2) 335-348.

Kooij, C., Loonstijn, M. & Hekkenberg, R.G. & Visser, K. (2018). Towards autonomous shipping: Operational challenges of unmanned short sea cargo vessels. *In Proceedings of the Marine Design XIII, Helsinki, Finland* (pp 871-880). Taylor & Francis

Lutzhoft, M., Hynnekleiv, A., Earthy, J. V., & Petersen, E. S. (2019). Human-centred maritime autonomy-An ethnography of the future. In *Journal of Physics: Conference Series* (pp. 12-32). IOP Publishing.

IMO. (2017). International Convention on Standards of Training, Certification and Watchkeeping for Seafarers,(STCW) 1978, as amended in 1995/2010. International Maritime Organisation, London, UK.

Mallam, S.C., Nazir, S & Sharma, A. (2019). The human element in future Maritime Operations – perceived impact of autonomous shipping. *Ergonomics,* 1-12. doi:10.1080/00140139.2019.1659995

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems,* 77(12), 1321-1329.

Marion, N., Septseault, C., Boudinot, A., & Querrec, R. (2007). Gaspar: Aviation management on an aircraft carrier using virtual reality. *In 2007 International Conference on Cyberworlds (CW'07)* (pp. 15-22). IEEE.

Maritime Safety Committee (MSC). 101st Session. 5–14 June 2019. Available online: http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-101st-session.aspx (accessed on 2 April 2020).

Norwegian Shipowner Association (2018). Think Ocean. *Maritime Outlook Report 2018*. Available online: http:// www.rederi.no/ (Accessed 02 April 2020)

Nazir, S., Kluge, A., & Manca, D. (2014). Can immersive virtual environments make the difference in training industrial operators. *In Proceedings of the Human Factors and Ergonomics Society, Europe Chapter*, (pp. 251-265).

Nazir, S., Totaro, R., Brambilla, S., Colombo, S., & Manca, D. (2012). Virtual reality and augmented-virtual reality as tools to train industrial operators. *In Computer Aided Chemical Engineering* Vol. 30 (pp. 1397-1401). Elsevier.

Oranburg, S. (2020). Distance Education in the Time of Coronavirus: Quick and Easy Strategies for Professors. Available at SSRN.: http://dx.doi.org/10.2139/ssrn.3553911 (Accessed 02 April 2020).

O'Neil, H. F., Mayer, R. E., Herl, H. E., Niemi, C., Olin, K., & Thurman, R. A. (2000). Instructional strategies for virtual aviation training environments. *Aircrew training and assessment*, 105-130.

Porathe, T. (2019). Interaction Between Manned and Autonomous Ships: Automation Transparency. *In Proceedings of the 1st International Conference on Maritime Autonomous Surface Ships (ICMASSS 2018)* (pp. 41-46) SINTEF proceedings

Renganayagalu, S. K., Mallam, S., Nazir, S., Ernstsen, J., & Haavardtun, P. (2019). Impact of simulation fidelity on student self-efficacy and perceived skill development in maritime training. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 13* (3). 663-669.

Ringbom, H. (2019). Regulating autonomous ships—concepts, challenges and precedents. *Ocean Development and International Law, 50*(2-3), 141-169. doi:10.1080/00908320.2019.1582593

Riva, G. (2002). Virtual reality for health care: the status of research. *Cyberpsychology & Behavior*, 5(3), 219-225.

Sharma, A., Kim, T., Nazir, S., & Chae, C. (2019). Catching up with time? Examining the STCW competence framework for autonomous shipping. In *Proceedings of the Ergoship Conference, Haugesund, Norway* (pp. 24-25). HVL open

Stopford, M. (2009). *Maritime economics 3e*: Routledge.

Sellberg, C., & Lundin, M. (2018). Tasks and instructions on the simulated bridge: Discourses of temporality in maritime training. *Discourse Studies*, 20(2), 289-305

UNCTAD. (2019). Review of Maritime Transport 2019. Retrieved from https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf (Accessed 02 April 2020)

von Lukas, U., Vahl, M., & Mesing, B. (2014). Maritime applications of augmented reality–experiences and challenges. *In International Conference on Virtual, Augmented and Mixed Reality* (pp. 465-475). Springer, Cham.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49.

WMU ITF (2019) Transport 2040: Automation , Technology, Employment - The Future of Work. World Maritime University