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Assessing the Challenges to the International Convention of Standards of Training, Certification and Watchkeeping in the Era of Digitalization and Automation

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Abstract: Society is undergoing socio-technical disruptions. The shipping domain is not immune to these revolutions. To address these challenges, the maritime industry, including stakeholders such as shipping companies, regulatory authorities, classification societies, and education providers cannot afford to be reactive to digitalisation and automation advances. These end users must confront these wicked problems to ensure that safety, environmental protection issues and relevant business case(s) allow the shipping domain to thrive into the next century.

Keywords: digitalization; automation; STCW

1. Introduction

Industry is now understanding better the operational and technical disruptions implicit to the emergence of digitalisation and automation in future shipping operations. The International Maritime Organisation (IMO) has had a lens on these developments, promoting its e-Navigation [1] and MASS [2] concepts regarding future challenges and needs of the shipping industry. To date, most of the attention has been directed at technology readiness levels and system integrations. More practically, consideration of how to integrate with the human factor, emerging vocational roles and operator competencies has largely been ignored.

A holistic, comprehensive visioning needs to consider both technical and non-technical aspects within this new complex socio-technical landscape. While there are IMO working groups focused on regulatory considerations, less foresight and attention has been placed on the recruitment and retention of persons employed in the future Shipping 4.0 reality. This includes those entering the profession (i.e., Nautical Studies students), existing seafarers (i.e., continuing professional education) and the pedagogical professionals (i.e., instructors) where the impacts upon these stakeholder gaps have been identified [3, 4].

These education-based objectives can only be achieved if there is alignment between standards such as the International Convention of Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and the context of the environment (i.e, system technologies) typically delivered through third party vendors. A relevant example of poor human integration within a system is the design of the Electronic Chart Display and Information System (ECDIS) for navigation support [5]. Mismatches between the operator and the technology create conflict in the *¨work as imagined¨* (by the technology developers) and the *¨work as performed¨* (by maritime operators). While it might be thought that this is a fault of the technology developers, complicit are regulators, educators, and service providers in the perpetuation of these problems. These outcomes have created a situation that can ultimately increase the cognitive workload, create deviations in workflow/best practices and cause performance error escalation towards incidents and accidents.

There are many assumptions that the introduction of AI-driven technologies will ease the decision-making burdens of command, control, and communications in complex systems [6]. Specific to navigation and traffic safety, it has been proposed that the introduction of automation and artificial intelligence technologies could:

1. increase performance through automation intervention;

2. decrease operator workload;
3. require less operator knowledge;
4. create more flexibility in task procedures;
5. reduce operator error.

These *supposed* putative benefits must be considered through technological, regulatory, and educational lens so that potential punitive costs to navigation safety do not become the reality.

This paper aims to elucidate the socio-technical paradigm shift that should inform a rescoping of the educational and training outcomes related to the introduction of digitalisation and (low level) automation. The paper will advocate an appropriate human-centred/end-user approach to assess stakeholder needs and education development. This work will build upon activities related to the review of the STCW Convention and Code (IMO 2023, Sub-Committee on Human Element, Training and Watchkeeping, 9th Session (Item 7) and will consider the following recommendations to::

I. address the impact and possibilities of digitalization and emerging technologies on ships and ship operations;
II. address the impact and possibilities from the implementation and use of digitalization and emerging technologies in seafarers' education, training and certification;
III. ensure that the Convention and Code are fully aligned with the IMO standards on ship's operation, construction and equipment;
IV. take into account different approaches to organizing and structuring education, training and certification, including formats of delivery of training.

2. Ironies of Automation

Digitalization, (levels of) automation, artificial intelligence and machine learning continues to create significant disruptions in the maritime domain, particularly for the safe and efficient operations of vessels. One would think that moving cognitive challenging functions from humans to ¨machines¨ would result in positive impacts. This has repeatedly been proven an incorrect assumption [6].

In 2006, MSC 82/15/2 [7] identified issues regarding the proliferation of digitalization and automation within the maritime domain and are still pertinent today. MSC 82/15/2 (xii) recognized the inconsistencies in the display formats between manufacturers and called for a higher degree of standardization. While not the only example of the disruptions from digitalization and automation, the evolution of the Electronic Chart Display and Information System (ECDIS) serves as an example. Largely recognized in the seafaring vocation, the design of ECDIS for navigation support suffers from a typical operational paradox: it can create conflict in the ¨*work as imagined*¨ (by the technology developers) and the ¨*work as performed*¨ (by the end user group). While it might be thought that this is a fault of the technology developers, complicit are regulators, educators and service providers in the perpetuation of these problems. These outcomes have created a situation that can become precursors to increases in the workload required by the ECDIS users, deviations in workflow/best practices and performance errors that could escalate into incidents and accidents. These observations build upon a 2021 report [5] regarding the application and usability of ECDIS. Upon reviewing accident reports citing ECDIS as part of the accident chain and interviewing over 100 Subject Matter Experts (SMEs), the report concludes that *"ECDIS requires significant cognitive resources to use its functions, which has contributed to a minimalist approach by its users. ¨*, pointing towards challenges associated with ECDIS system design, practices and training. While ECDIS serves as an example of how technology may be friend or foe, it is not the only example(s). With increasing digitalization and automation, big data/AI/Machine Learning technologies related to alarm management and cyber security (for example) are suffering from similar poor design outcomes, lack of data transparency and inadequate training and education.

MSC 82/15/2 (ix) refers to systems that may not adequately support how operator(s) situation awareness (SA) is obtained and maintained. Simply described, SA is rooted in operator(s)' cognitive capacity to make accurate and timely decisions. In the navigation vernacular, this process can be generically described as an operator being *in*, *on* and *out* of the loop. But as the levels of automation becomes more embedded in real-time operations, operator SA may become more difficult to achieve.

3. Pedagogy, Regulations and Continuous Professional Education

Nautical academies have a responsibility not only to adhere to requirements prescribed by international shipping regulations and conventions, but to maintain a level of academic scrutiny whilst delivering credible academic programs. This trust includes educating beyond minimum prescribed standards but recognizing higher standards of best practices.

Technology and its applications to support the end-user(s) is not always straightforward and intuitive. In fact, using the ECDIS example above [5], often cite mode error as a contributing factor to the loss of situation awareness. In spite of model courses for ECDIS training, type-specific training and International Standard for equipment and systems (e.g. [8]) accidents and incidents occur and, anecdotally, many functions are difficult for the user to locate and deploy properly. Technology integration is often not user driven; human centered design is often ignored in the development process. Consequently, education providers are automatically one step behind. Technology developers view design through a *work as imagined* lens rather from the end user needs, who solves problems through a *work as done* heuristic. The training required to keep people, environments and assets safe in complex socio-technical systems cannot by prescriptive in design but must consider a more goal-based approach.

The environment for training and education is critical to allow sound learning to occur. Given the ubiquitous usage of complex technologies, integrated workstation, and teams, then learning platforms such as real-time, full mission simulators, virtual and augmented reality technologies need to be considered. While this might pose some economic and technical challenges for some education training providers, it seems likely that these platforms are the foundation for delivery solutions.

Current and near-future technologies in safe navigation will not be transparent and intuitive. It will create disruptions in the delivery of sound education. Theoretical ¨lectures¨ will only provide the basics and a general understanding of a technology. To really understand the technology, students will need time to use it in practice. To address these problems, one may argue that the curriculum requirements may be stripped of “old school items” no longer necessary to know. However, which items are we to remove? What will be the impact of removing a subject on general understanding on navigation and ability to navigate when technology fails?

Moving forward, educators, regulators and research must ensure that the Convention and Code are fully aligned with the IMO standards on ship’s operations, construction and equipment (if not promote performance standards well above these minimum prescriptive proposals. HTW9/7/4, item 7.8 (the base document used at IMO for the work with the revision of STCW) states that a *¨significant number of inconsistencies were identified in the text of the annex to the STCW Convention and Code. Many of those are a consequence of amendments that were adopted in different periods of time. In addition, provisions having similar aims should be harmonized, especially but not limited to those in chapters II and III. The above may lead to ineffective implementation of the Convention. Thus, the Parties to the Convention and those involved in implementing, applying or enforcing its measures may not always give to the Convention full and complete effect in a uniform manner.”*

Recognizing the importance of both technical and non-technical competencies/skills in the reliable, efficient and safe navigation of vessels in an increasingly evolving complex socio-technical system must inform regulatory and training standards. In document HTW9/7/4 (the following text is cited:

HTW9/7/4, item 7.3 E-learning : With the experience already gained in using new technologies in education and training, it is envisaged that further use of those technologies will continue. Therefore, a review of the STCW Convention and Code would allow for the development of teaching and teaching aids to supplement and support shore-based training, methods for assessment of competence, and approval and monitoring of courses including those outside the jurisdiction of the Party.

HTW9/7/4, item 7.4 Onboard training and use of simulators: It is important to focus on improving the quality of onboard and workshop skills training and seagoing service required in different chapters of the Convention, taking also into account up-to-date learning technologies, including simulators. The work already done at the IMO level and the new output on the "Development of measures to ensure quality of onboard training as part of the mandatory seagoing service required by the STCW Convention" can serve as the basis for the initial review.

Continued development and exploitation of training technologies and e-learning platforms may seem to be a ¨quick fix¨. However, our experiences of e-learning are not always been positive. It is easy to ¨click from one section to the next without learning in depth¨, but these technologies could be useful in the lifelong learning education paradigm. There has been a migration towards virtual training and perhaps it suits the people (i.e. millennials) we need to recruit and retain into the industry. However, technology ¨fixes¨ are not the near-term solution. Leaders in the domain must abandon band aid approaches.

4. Conclusions

The discourse of this paper are the collective thoughts of the authors. These thoughts have their foundations in both the academic and research literature, but most importantly the ¨coalface¨ experiences of technical lecturers with many years at sea, in the classroom and as valued subject matter experts informing the research strategy and program at our university. That being said, the future facing maritime education and training are challenging and difficult to operationalize from a pedagogical perspective.

Given the challenges and opportunities through digitalization and an increase of automated functions striving towards fully automated and autonomous operation of ships, the training requirements and vocational competencies must be revisioned [3, 4]. Recent research has made attempts to identify future training needs for seafarers by comparing the shipping industry to other domains such as aviation, rail, nuclear and mining [9]. Three key areas within these domains' training needs were identified; (a) Cognitive: the skill to think faster and learn easier through exercise, (b) Communicative: in addition to reading and writing, nonverbal communication through observing to infer the meaning and (c) Operational: the skill that includes analytical thinking, effective communication and taking efficient action. The top seven important skills listed were (i) emergency response (ii) communication (iii) well trained and multi skilled (iv) safety awareness, (v) seamanship (vi) tool handling and (vii) IT and cybersecurity [10]. These skills were related to the need for the ability of future operators´ to learn and relearn and to adapt and manage new situations, such as those resulting from emergent AI based technologies and resultant operational procedures. Scanlan et.al. [11] identified cyber security as a skill gap and suggest a revision of the existing Bridge and Engine Resource Management courses to provide necessary skills and awareness to address these challenges. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) (IMO, 2011) focuses mainly on technical and operational skills although the Manila amendments to the STCW Convention and Code added changes in the training requirements concerning among other things leadership and teamwork together with modern training methodology including distance learning and web-based training. However, given the above-mentioned research results mainly focusing on "soft skill" development, one might argue the necessity to revisit the SCTW Convention to be able to meet the anticipated future training need for seafarers operating in a digital and highly automated environment.

In the near future Seafarers will remain on the bridge and in control; the education, training, and "core navigational knowledge" will remain both essential and required. It was further identified that the potential dangers associated with the use of any automated system including complacency and over-reliance should be taken seriously. These risks are also present with existing navigational aids, including ECDIS and radar which were clearly noted in IMO MSC 82/15/2. The participants in a research project investigating the influence of algorithm-based software to solve traffic solutions were clear that the technology manufacturers should not market these systems towards inexperienced, fatigued or poorly educated officers. Instead, at early adoption stages of automation and operational integration, decision support should be advisory in nature and provide well trained officers' rule-based information (COLREG) to make and execute a final decision for safe navigation [12]. Paradoxically, even with the risks described eloquently as the ¨ironies of automation¨ [13] in mind, most participants argue that knowledge of the COLREGs might be even more critically considered when using similar support tools. As such, the core knowledge of navigation in education may be improved because of these types of supportive technologies.

In many respects, navigation is social in nature. Is this because a navigator projects him/herself into the "shoes of a navigator on another vessel's bridge¨? Is the human operator trying to use past data or experience from the other vessel to try and understand the future intentions for both bridges? What about the next vessel to be encountered? Does a navigator necessarily allow the ship to be put in a vulnerable position, which relies on the ¨common sense¨ of other agents within the traffic situation to remain safe? Tacit knowledge, critical thinking and other non-technical skills are clearly required to answer these questions. Current regulations and

training tend to me more explicit and prescriptive in nature. It seems that a more constructivist approach to the education of future seafarers and other maritime stakeholders (*e.g.* shore control systems, intermodal logistics) will be in demand.

Will ships and the shipping system become fully autonomous in the near future? Given today's state of technology development and training paradigms, the answer is a considered ¨NO¨! It would likely be too dangerous to create an environment in which humans may be barriered against making safety critical decisions. Decision support systems will have some utility in the near future, but not without considerable reflection of the current regulatory, environment and the training standards. Continuing professional education will also be critical to solving these issues, to identify how the continuous disruptions brought about by new technologies will be managed.

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