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The (ir)Relevance of Current Maritime Education and Training in the Transitioning Workplace: An Activity Theory perspective

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Abstract: The maritime industry is experiencing a phase of rapid digitalization and automation. Modern ships are increasingly fitted with novel technologies and complex tools that are changing the ways in which seafarers perform their jobs. However, researchers are questioning the efficacy and ability of the present-day maritime education and training in developing the skills and competencies needed in a dynamically evolving work environment. The investigation reports of many maritime accidents and incidents, point to seafarers' lack of expertise in timely responding to developing hazards. A review of literature indicates a paucity of studies focusing on cognitive human factors and competence development of seafarers, relevant for a high-technology workplace. This paper partially addresses that gap by proposing a novel, practice-based approach to analyze the challenges arising onboard ships during the transition period to a digitalized future. We utilize the cultural-historical activity theory (CHAT) or simply, Activity Theory as a lens that provides a holistic socio-technical perspective. Within this, learners, mentors, technologies, pedagogical values, roles/identities, and rules/cultures act as interdependent elements of a collective activity system. Resolving any contradictions, incoherencies, and dilemmas existing between these elements, is essential for achieving the desired outcome, i.e., competent mariners who can safely operate highly digitalized future ships.

Keywords: Maritime Education and Training; Cultural-historical activity theory; Digitalization; Automation; Human-machine interactions; Cognitive Human Element.

1. Introduction

The rapid advance of digital technologies over the past few decades is transforming the shipping industry. Increasingly, novel automated systems using Information Technology (IT) is deployed on board ships, and that is altering the ways in which human operators work (Man, Lundh, and MacKinnon 2018; Narayanan and Emad 2020). While the ongoing digitalization and automation drive has always been an attempt to enhance safety and increase competitiveness, it has also made the work of seafarers onboard more demanding and complex (Man et al. 2018). Further, these technologies demand new skill sets for future mariners when working with or within such automated systems (Lutzhoft, Hynnekleiv, Earthy, and Petersen 2019; Sellberg and Viktorelius 2020), and new ways of learning and competence development (Narayanan and Emad 2020; Sellberg and Viktorelius 2020).

The relevance of human element in the maritime domain becomes evident through studying the maritime accidents and incident reports of the recent past, blaming the failure on the many mistakes, poor decision-making, or lack of communication, of the mariners involved. Some of the recent analysis point to the fact that to get a full understanding of such causal factors, it is necessary to view the human element as part of the larger system, that includes the technology, organization, work practices, and the work environment (Grech, Horberry, and Koester 2019). Thus, it becomes evident that accidents and incidents occur whenever there is a breakdown in the socio-technical system. Such a breakdown could be related to, or caused by, for example, poor design of the equipment or any inconsistencies between the work practice and written procedures (Grech et al. 2019; Rajapakse, Emad, Lützhöft, and Grech 2019). Hence, there is always a need to look beyond the individual and see the system as a whole. However, in all the recent research on the effects of digitalization and automation in shipping industry, primarily focus appears to be solely on the effect of the technology rather than addressing the human factors involved (Lutzhoft et al. 2019). Hence, there is an urgent need to address the skill

requirements, training needs and, moreover the requirement for providing adequate human support to technology before introducing any autonomous systems.

A review of the literature reveals that many issues pertaining to the preparation of maritime workforce for the upcoming digital transformation have been studied in detail by various authors. For example, Relling, Lützhöft, Ostnes, and Hildre (2018) highlighted the requirement for many new competences for personnel involved in the future ship operations, in view of dramatical restructuring of onboard work processes. Sharma, Kim, Nazir, and Chae (2019) also carried out a detailed study to verify the seafarer competence standards required in future digitalized ships. They concluded that the internationally mandated maritime education training and certification standards as described under the STCW Convention will require a thorough revision. Their study highlighted some of the competences that may remain relevant even in a digitalized future. But they have also identified many other competences that will become insignificant as and when the related onboard functions are taken over by automation technologies.

Although, digitalization and automation on board ships is being introduced with the claim of reducing human error, Lutzhoft et al. (2019) warns that may not always be the case, in reality. Authors feel that even if in future vessels start being operated remotely from shore, any drawbacks connected to humans will arguably move with the people from ship to shore. Fan et al. (2020) did a study on the operational risks related to future shipping. They too concur with the view that human factors will not be fully removed from the system during remote operation of ships. Firstly, any such shore-based operator will need to possess specific skills and professional knowledge at least similar to that of the existing crews of traditional ships. Moreover, any data that they receive from the vessel can be related not only to ship navigation but also to machinery and other critical systems. This means that their knowledge of ship operations should cover both deck as well as engine functions. If the remote operator is expected to simultaneously monitor several ships operating across various geographical locations and numerous environmental conditions, that may also impact his/her quality of judgement and decision making. Authors also caution about the fact that the remote operator is detached from the real sea conditions and the onboard environment. This will not only impact their ability to fully grasp the context, but also diminish their situational awareness.

Some authors feel that with fewer people onboard ships to operate the vessel or during the remote operation of ships from ashore in future, there will be occasions such as emergencies that will require operator to promptly take over from the machines. This means, future marine operators will need to be trained to react quickly to avoid errors due to delays in decision-making, also known as human-out-of-the-loop syndrome (Janßen, Baldauf, Müller-Plath, and Kitada 2021; Lutzhoft et al. 2019; Porathe, Prison, and Man 2014). Janßen et al. (2021) further argues that it is not just the training, but also the experience of future vessel operators that matters. Authors highlight the dangers of missing seafaring experience in future vessel operators who will just rely on displays of technical data for decision-making. They recall the collision incident between two ships in the fjord of Kiel in 2014, wherein the navigating officers on both ships fully trusted the ECDIS data without ever realizing that there was a GPS failure in that area.

All the studies mentioned so far have touched upon various aspects of training requirements of future seafarers. However, what is lacking is a comprehensive study that encompasses the whole process, that follows a sequential order, ascending from the abstract and reaching to the concrete. Such a study needs to investigate human practices in a socio-cultural perspective, across multiple contexts and networks, as a developmental process wherein the individual, organizational, societal, and cultural levels are dynamically interrelated. The Cultural-Historical Activity Theory (CHAT) or simply, Activity Theory, fulfills such a requirement.

In this paper, we propose the use of CHAT as a theoretical lens to analyze the challenges arising onboard ships during the transition period to a digitalized future. The CHAT provides a holistic socio-technical perspective, wherein the learners, mentors, technologies, pedagogical values, roles/identities, and rules/cultures act as interdependent elements of a single collective activity system. In the next section, we will describe the cultural-historical activity theory (CHAT), and the various interdependent elements. It is argued that it is only through resolving any contradictions, incoherencies and dilemmas between those elements, we can facilitate the achievement of the desired outcome, in this case, competent mariners who can safely operate highly digitalized future ships.

2. Cultural-Historical Activity Theory (CHAT) as a theoretical framework

The Finnish educationalist Yrjo Engeström (2016) built upon the earlier works of Vygotsky, Leontiev and other cultural-historical psychologists from the Soviet school and expanded their activity theory framework for exploring transformative work activities. He broadened Vygotsky's original 'mediated-action' triangular model by adding the components of community, rules and division of labour as illustrated in the figure 1 below. In this multi-triangle model of an activity system, the apex triangle represents Vygotsky's original mediated-action model comprising of the *subject*, the *object*, and the *tools* (and signs). A vertical flip of this triangle introduced the *community* as a mediator, thus extending the model to social and collective activities; A side-wise flip of the triangle introduced *rules*, thereby incorporating historical traditions, rituals, guiding values etc., as a mediator between the subject and the community; A side-wise flip of the triangle to the other end introduced *division of labour*, thereby defining the social, or organizational roles as a mediator between the community and object. The object itself is depicted within an oval shape, suggesting that 'object-oriented actions are always, explicitly or implicitly, characterized by ambiguity, surprise, interpretation, sense making and potential for change' (Engeström 2001, p. 134). Finally, an activity *outcome* is added, that could form the basis for starting a fresh new activity.

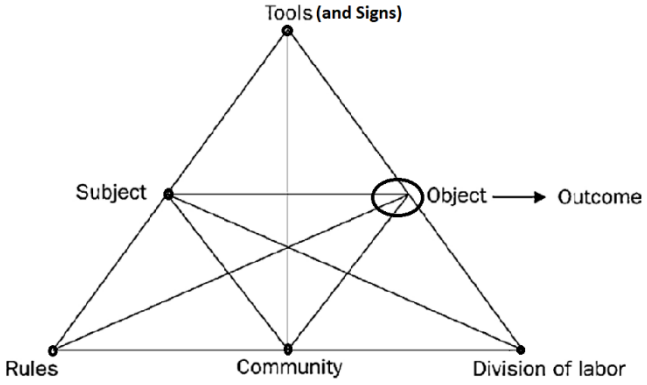

Figure 1: Activity System (Engeström 2001, p. 135)

Contradictions or tensions or any disturbances can arise within and between the constituents of an activity, or between two or more different activities, or within and between activity systems as they evolve over a time. Analysis of such contradictions is the key to understand the sources of trouble as well as the basis for innovative and developmental potentials and transformations of the activity system (Engestrom 2000).

3. Contradictions within the onboard activity system due to introduction of digital tools

The STCW Convention has mandated the maritime education and training (MET) to include a phase of apprenticeship training onboard ships for all seafarers. The reason for making the onboard training mandatory was to help the trainees develop their disciplinary knowledge and competencies by means of workplace learning through legitimate participation in real work onboard ships (Emad 2017). Moreover, the onboard phase of training will afford a learning environment characterized by situations, activities, and real-life challenges that the students will continue to face on board ships in the future (Emad 2011). The influx of high technology is rapidly changing the work environment onboard ships, and this, to a great extent, is precluding many of the traditional and authentic learning opportunities that earlier existed during the onboard apprenticeship (Emad 2017). For instance, digitalization may result in intransparent or opaque systems as the work or decision-making processes directed by (hidden) algorithms may not be readily observable to a bye-stander, thus affecting his or her learning process (Emad 2017; Harteis 2018).

The introduction of novel digitalized tools and systems onboard ships is gradually and irreversibly obliterating the need for the 'expertise' on manual systems that the senior experienced personnel possessed. In some ways, this is annihilating parts of work activities that were dependent on the competences based on the

experience of more senior crew (Harteis 2018). This in turn has led to the creation of 'distributed expertise', democratization of the onboard workplace, and furthermore, to a break-down of the strict hierarchical controls that traditionally existed onboard ships.

Digitalization of onboard systems has resulted in an increase in the speed and power of the work processes. It has resulted not only in more efficient (quicker or denser) processes but also merger of few processes, and thus, the introduction of a variety of new processes. Onboard modern ships, with limited number of crew overseeing multiple and complex tasks, the job intensifies, thus, causing operator's cognitive overload, error in judgement, and in many cases, costly accidents. The investigation reports of some of the recent maritime accidents and incidents point to the improper use of technology as among the major causal factors. All this underscores the urgent need for re-addressing cognitive human factor and competency development of seafarers, relevant to the use of the modern technology and human-machine interactions.

Digitalization and automation onboard may also bring some drastic changes to the onboard mentoring process. As stated earlier, the almost unidirectional flow of competence and expertise, from the senior (master) to the junior (novice), is now disrupted with introduction of new tools and equipment. With onboard workspace more democratized with the new emphasis on team building and shared expertise, the trainees may often find better mentorship by junior officers who in most cases are more at ease and familiar with the digitalized tools when compared to their seniors on board. This, in future, will lead to more onboard learning through shared mentorship and leadership. As such, a team member could simultaneously be an expert in, and contribute to one task, but a novice in, and ready to learn in the very next. Furthermore, a multi-directional information flow can support open, transparent communication that can clarify and address some of the opacity of work processes introduced by digitalization and automation onboard.

Thus, it can be seen that digitalization and automation process is introducing many new contradictions and tensions among the components of the onboard learning activity system consisting of the learners, mentors, technologies, pedagogical values, roles/identities, and rules/cultures. The idea of contradictions as a source of change and development plays a constitutive role in Engeström's theory of expansive learning (Engeström, 2014; Engeström, 2016; Engestrom and Sannino 2010). Expansive learning within an activity system can be implemented through setting up a 'change laboratory' involving a series of interventions ranging from Questioning, Analyzing, Modelling, Examining, Implementing, Reflecting and Consolidating as described in Engeström, Rantavuori, and Kerosuo (2013). Engeström (2014) through his change laboratory experiments in various workplaces has shown that successful resolution of any contradictions within or between activity systems, can lead to development of new practices, or in other words, expansive learning. In view of ongoing digitalization onboard ships, the identification, and the resolution of any such contradictions, incoherencies and dilemmas between the elements becomes paramount for achieving the desired outcome, i.e., competent mariners who can safely operate highly digitalized future ships.

4. Conclusions

This paper presents activity theory as a novel, conceptual framework for modeling, analyzing, and redesigning onboard learning of mariners in view of steadily increasing digitalization and automation onboard ships. Using the elements of Engestrom's activity system, we suggest specific transformation towards digitalized future in a democratized learning environment onboard that appears well-aligned to the needs of future mariners. It is our hope that this proposal will provide industry stakeholders a practical modus operandi for bringing reforms to future onboard learning programs and thereby meet the 21st Century knowledge and future skill requirements of the shipping industry.

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