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ARTICLE

Theorizing seafarers' participation and learning in an evolving maritime workplace: an activity theory perspective

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Abstract

This paper presents the cultural-historical activity theory (CHAT) or simply activity theory (AT) as a suitable framework to theorize seafarers' learning in a technologically evolving shipboard environment. The recent increase in the digitalization and automation onboard ships is introduced with the aim of enhancing maritime safety and efficiency. However, maritime incidents and accidents continue to occur when seafarers overwhelmed by the complexity of novel technologies and automated tools, often fail to recognize and timely respond to developing hazards. The fundamental changes in the shipboard workplaces and the seafarers' need for interaction with smart tools calls for a fresh look at cognitive and learning processes and situated action onboard ships. The activity theory provides a theoretical lens that affords a holistic, socio-technical perspective on the inter-dependent elements of a collective shipboard learning activity system. Any misalignment among the elements of this activity system or between itself and other relevant activity systems may result in contradictions. Resolving such contradictions becomes essential for achieving the desired outcome, i.e., competent seafarers who can safely operate highly digitalized future ships.

Keywords Maritime education and training · Cultural-historical activity theory · Digitalization · Automation · Competency development · Cognitive human element

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1 Introduction

The progressive introduction of digitalization and automation onboard ships is bringing rapid and vast transformation in the global shipping industry. The deployment of novel technologies is altering not just the workplaces, but also the ways in which operators perform their tasks (Man et al., 2018; Narayanan & Emad, 2020). Although the ultimate objective of implementing newer technology is to improve safety and efficiency, it has also made the seafarers' work more complex and demanding (Man et al., 2018). Moreover, the unabated occurrence of maritime accidents and incidents that are attributed to human-related causes underscores the continued relevance of the human element in an increasingly socio-technical shipboard environment. The investigation reports mostly attribute such failures to human factors such as mistakes, poor decision-making or lack of communication among the seafarers involved, or some inadequacies or breakdown within the system (Grech et al., 2019; Rajapakse et al., 2019). This underlines the need for adopting a more holistic and encompassing view that looks beyond the individual elements to see the system as a whole. In other words, the human element needs to be seen as an integral part of a larger activity system that includes technology, organization, work practices, and the environment (Grech et al., 2019).

Modern technology and automated systems deployed onboard ships have created demands for new skillsets (Emad et al., 2021; Lutzhoft et al., 2019; Sellberg & Viktorelius, 2020) and new ways of learning and competence development for seafarers (Narayanan & Emad, 2020; Sellberg & Viktorelius, 2020). However, a review of the literature shows that recent research on digitalization and automation in the shipping industry has primarily focused on the effect of technology rather than the human factors involved (Lutzhoft et al., 2019). Addressing this gap will provide insight into the skill requirements and training needs of future seafarers to work in a technology-rich shipboard work environment.

Recent studies on the preparation of the maritime workforce for the upcoming digital transformation highlight the need for some new competencies for future ship operators (Relling et al., 2018). The internationally mandated maritime education, training, and certification standards as described under the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers 1978, (STCW Convention) may also need a thorough revision (Sharma et al., 2019). Although some current competencies mentioned therein may remain relevant in a digitalized future, the majority other may become insignificant or obsolete as and when the shipboard functions are taken over by automation technologies.

Digitalization and automation are introduced on board ships with the claim of reducing erroneous action by humans. However, studies on the operational risks of future shipping have shown that human factors cannot be fully eliminated from the system even during the future remote operation of ships (Fan et al., 2020). In fact, when vessels start to get operated remotely, any drawbacks connected to humans will arguably move with the people from ships to the shore (Lutzhoft et al., 2019). The fact that remote operators will always remain detached from the real sea conditions and shipboard environment may not only impact their ability to fully grasp the real-world context but also diminish their situational awareness. In the future, with fewer or no people onboard to operate the vessels, there can still be occasions, such as shipboard emergencies, when the human operators will have to promptly take over from the machines (Fan et al., 2020; Ifenthaler, 2018). This implies that future maritime operators will need to be trained to react quickly to avoid any errors due to a delay in decision-making, also known as the human-out-of-the-loop syndrome (Janßen, Baldauf, Müller-Plath, and Kitada 2021; Lutzhoft et al. 2019; Porathe, Prison, and Man 2014). Yet another apprehension is whether all the required competencies of future vessel operators can be developed through training alone, without them ever getting the opportunities to gain valuable seagoing experience (Janßen et al., 2021). On top of them lacking seafaring experience, there is also the danger of them solely relying on displays of technical data on screens for any decision-making. The criticality of this can be showcased through many examples such as the collision incident between two ships in the fjord of Kiel in 2014 (see, Federal Bureau of Maritime Casualty Investigation—Report 276/14), wherein the navigating officers on both ships fully trusted the ECDIS data without ever realizing that there was a GPS failure in that area.

To be able to fully understand and analyze the various training-related requirements of future seafarers, there is a need for a comprehensive theoretical framework that encompasses the entire process. Such a framework needs to view the human practices as a socio-cultural activity and as a developmental process, across multiple contexts and network, wherein the individual, organizational, societal, and cultural levels are dynamically interrelated. Albeit there are many socio-cultural theories (for example, cultural-historical activity theory, actor-network theory, distributed cognition, situated action theory, et al.) that are suitable for the analysis of human activities within work environments, each with its own strengths and advantages. However, past studies such as Wiser et al. (2018) have highlighted the advantages and the suitability of cultural-historical activity theory (CHAT) over other sociocultural theories when analyzing complex human-computer interaction (HCI) systems. The main advantage of CHAT is that it provides a holistic perspective on the socio-technical environment, where the learners, mentors, technologies, pedagogical values, roles/identities, and rules/cultures act as interdependent elements of a single collective activity system.

Although very popular, the activity theory is not without its share of criticisms. Some researchers argue that the AT framework is inadequate for investigating human culture and psychology (Toomela, 2000, 2008). Pratt et al. (2015) concur with the above and further state that AT fails to adequately highlight the sources of subjects' motives in wider sociological frames. Hopwood and Stocks (2008) perceive a lack of accounting for personal agency and power in the AT. Trowler and Turner (2002) argue that activity theory is "especially poor at adequately locating the operation of power, inequality, and differences in organizational dynamics" (p. 251). However, over the years, with increasing research and improvements, the AT has evolved to address such issues. Despite all such criticisms and alleged shortcomings, AT soon gained acceptance as an effective, comprehensive tool for analyzing situated, mediated, and goal-directed action. In the past few decades, the use of AT has spread internationally across various disciplinary boundaries: to human-computer interaction, organizational studies, engineering human factors, ergonomics, and educational research (Kaptelinin & Nardi, 2006).

In this paper, we propose using CHAT as the theoretical lens to analyze the various challenges arising in the complex shipboard environment. This is timely since the introduction of novel digital technologies is already causing disruptions in the shipboard workplaces and changing the conventional ways in which work is carried out. The next section will describe in detail, CHAT, and its various inter-dependent elements. It is argued that only through resolving incoherencies and dilemmas between the elements of onboard ship training activity system can we facilitate the achievement of the desired outcome, i.e., develop competent seafarers who can safely operate highly digitalized ships of the future.

2 Cultural-historical activity theory (CHAT) as a theoretical framework

The cultural-historical activity theory (CHAT), popularly known by its shorter form activity theory (AT), has its roots in the Russian psychologist *Lev Semyonovich Vygotsky's (1896–1934)* works on socio-cultural cognition and learning (Vygotsky, 1978). The original theory emanated from Vygotsky's understanding of the mediated activity connecting human beings to both the external world as well as with one another (Vygotsky, 1997). While material tools help mediate human activity with external objects, internally oriented psychological tools such as signs, symbols, and language help transform psychological processes into higher mental functions (Leontiev, 1997). Vygotsky's concepts were further extended by Vygotsky's students, Alexei Nikolaevich Leontiev and Aleksandr Luria. They incorporated other dimensions of cultural, social, and historical, by introducing the collective notion of activity (Bertelsen & Bødker, 2003; Cole, 2002). Leontiev considered mediated activity as the central unit of analysis. According to him, the object of an activity is what differentiates it from other activities. In other words, the object of an activity defines its true motive.

The activity theory gained much prominence by the latter half of the twentieth century, mainly through the works of Engestrom (1987), Cole (1988), Wertsch (1991), Bodker (1991), and Nardi (1996). In particular, the work of Finnish educationalist Yrjo Engeström gained much attention. Engestrom incorporated all earlier theoretical positions and graphically depicted the entire activity systems in a triangular form (Engestrom, 2000). This model soon became popular and was successfully replicated by other researchers in a variety of work environments and learning contexts. Engestrom viewed Vygotsky's original idea of mediation as the first wave of activity theory and the later contribution by Leontiev as the second wave. He further upgraded the theory through the introduction of a more systemic construct, the activity system, which considers the context in which activity/practice take place (Engeström, 2001, p. 134). To achieve this, he added three new components, i.e., *community*, *rules,* and *division of labour* in his multi-triangular model as

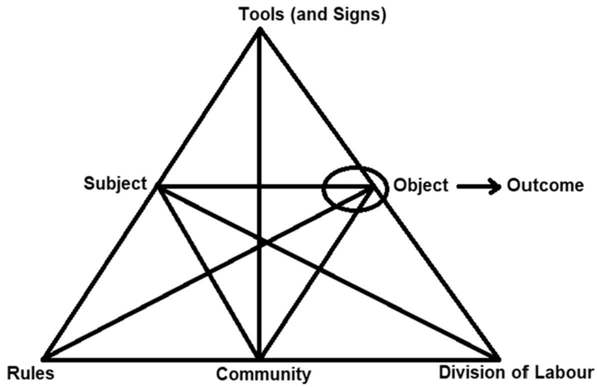

Fig. 1 Activity system (Engeström 2001, p. 135)

illustrated in Fig. 1 below. In this diagram, 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, thereby extending the earlier model to include social and collective activities as suggested by Leontiev. A side-wise flip of the triangle introduced rules that incorporate historical traditions, rituals, guiding values, etc. as a mediator between the subject and the community. A side-wise flip of the triangle to the opposite end introduced division of labour, which define 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 a potential for change" (Engeström 2001, p. 134). Finally, an activity outcome is added that could form the basis for starting a fresh new activity.

Engeström (2001, p. 136) articulated the need for a third wave of activity theory, wherein two or more interacting activity systems will have a common or shared object. In such cases, the activity theory can be summarized using five guiding principles. The *first principle* says that a collective, artifact-mediated, and object-oriented activity system should always be seen in its relationship with other neighboring activity systems. In other words, any action within an activity system will be understandable only if seen in the context of other related activity systems. The *second principle* is about the "multivoicedness" of activity systems. This means, actors of the same activity system may reflect "multiple points of view, traditions, and interests" (p.136). The *third principle* of "historicity" states that all activity systems will eventually get transformed over a lengthy time period and hence their problems and potential can only be understood when viewed against their own history. The *fourth principle* articulates the central role of "contradictions" as a source of change and development. Engestrom argues that in activity systems, contradictions are not the same as problems or conflicts, but historically accumulating structural tensions within and between activity systems. As and when these contradictions generate disturbances and conflicts, that will lead to innovative attempts to change the activity. The *fifth principle* proclaims the possibility of "expansive transformations" within activity systems. As and when contradictions within an activity system aggravate, individuals will be forced to reconceptualize the object and motive of the activity. Engestrom's five principles, especially the last two ones, i.e., the presence of contradictions and expansive transformations, feature prominently in many recent practical applications of the activity theory (Adamides, 2022; Baldwin, 2020).

In the following sections, we will discuss how and in what forms contradictions may manifest in an activity system and how expansive learning occurs when the actors within an activity system try to resolve these internal conflicts through cycles of constructing and implementing qualitatively new ways of functioning. As an example, we will consider the case of the shipboard learning activity system of seafarers and how contradictions arising out of the introduction of modern digitalized technologies lead to expansive learning.

3 Contradictions within an activity system

Human actions always form a part of the overall interacting context within an activity system. However, when some elements of the activity system undergo changes, it alters the conditions that may provoke users to experience problems, and that may also lead to a failure in achieving the intended outcome. Such misalignment among the actions is labeled as *contradictions* in an activity system. These may include events that manifest themselves as dilemmas, conflicts, mismatch, inner doubts, or double binds (Bligh & Flood, 2015; Virkkunen, 2013). Such misalignment could be represented by, for example, insufficiently trained users, any inadequacies in the design, or the introduction of a new tool or artifact. Whenever such contradictions appear, it will lead to disequilibrium within the activity system. When people strive to overcome such disturbances, it manifests itself as changes within other elements of the activity system. For example, the introduction of a new tool or artifact can cause a contradiction in the activity system that could lead to the introduction of some new rules or changes in community expectations.

Contradictions are important because they lead to changes and further development of the system (Engeström, 2001). In fact, they are "the main motive force leading to changes and development" (Engeström and Miettinen 1999, p. 9). Engeström (2001) explains how contradictions can eventually lead to innovation and transformation within an activity system,

> "As the contradictions of an activity system are aggravated, some individual participants begin to question and deviate from the established norms. In some cases, this escalates into collaborative envisioning and a deliberate collective change effort. An expansive transformation is accomplished when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity."
>
> (Engeström, 2001, p. 137)

Despite the potential for contradictions to result in the transformation of an activity system, such transformation does not always occur automatically. In fact, contradictions by themselves can neither "enable" nor "disable" learning to progress, depending on "whether or not they are acknowledged and resolved" (Nelson Jr, 2002, p. 34). Contradictions may not readily lead to transformation in cases where they may not be easily identifiable or they may not be easily acknowledged, visible, obvious, or even openly discussed by those experiencing them (Engeström, 2001; Murphy & Rodriguez-Manzanares, 2008). Thus, a proper analysis of the activity systems and identification of any systemic contradictions therein becomes necessary before taking steps to overcome those.

According to Engeström (2015), systemic contradictions can manifest in an activity system in four different forms:

- Primary contradictions, that may occur within the element(s) of an activity system.
- Secondary contradictions, that may occur between the elements of an activity system.
- Tertiary contradictions that occur between the existing form of an activity system and any attempts to introduce a new model.
- Quaternary contradictions, that may occur between two or more neighboring activity systems.

The numerical naming of the contradictions is implying an order based on how the changes are affected within the activity system. Changes to any one element of the activity system, for example, the introduction of a new tool or artifact, might aggravate primary contradictions by altering the ways in which it is used. Subsequently, participants' initial attempts to use the new tool might generate secondary contradictions because the newly introduced tools are now in contradiction with other existing elements of the system. Addressing such situations may require the creation of some new rule or roles or community within the activity system. But the actual implementation can still generate tertiary contradictions as and when people attempt to use a new model while many established practices still pertain to the earlier system. Furthermore, when the activity system is finally transformed, quaternary contradictions may crop up between the new system and other systems in the neighborhood that may functionally be dependent on the activity system acting in the same old way. For example, new tools introduced in the workplace may create the need for new expertise, but the vocational education activity system may continue to create expertise that was needed in the older activity system in the workplace.

4 Shipboard learning activity system

Until recently, apprenticeship was the most common means of developing maritime competencies. In such a system, newcomers learned new skills and knowledge in its social and functional context under the guidance and support of more experienced senior personnel (Emad, 2010). This process allowed juniors to gradually appropriate the various elements of the disciplinary knowledge, skills, and competencies needed in their sea-career ahead as they progress to more senior ranks. However, great disparity existed in the training standards globally, and attempts were made at IMO level to create a uniform global standard through the adoption of the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW Convention) (IMO, 2010). As per the mandates of this convention, the training period of seafarers was bifurcated into a shore-based phase conducted in maritime colleges and a shorter but mandatory phase of apprenticeship training onboard ships. The intention of making the onboard training mandatory was to help trainees develop the best part of their disciplinary knowledge and competencies by means of workplace learning through legitimate participation (Lave & Wenger, 1991) in real work done onboard ships (Emad, 2011, 2017). However, the effectiveness of the onboard phase of training also depends to a large extent on the opportunities available for trainees to participate in authentic work onboard, proper mentorship or guidance from the more experienced seniors, and most importantly, a beneficent onboard community of practice (Lave, 1991), comprising of fellow crew members. In this way, the trainees follow a structured, hierarchical progress from the periphery to the core. The shipboard work was mostly laborious, using physical tools and equipment and comprising of manual systems. The outcome of such training regime was seafarers with almost memorized knowledge and skills about conventional shipboard systems. A traditional shipboard learning activity system is depicted in Fig. 2 below.

The subject in this shipboard learning activity system is the seafarers undergoing practical training under the watchful guidance and mentorship of more experienced seniors onboard. Their objective of acquiring the professional competence required for the safe and efficient operation of ships is achieved through on-the-job learning and participation in social practices among the shipboard communities of officers and crew. Although the training curriculum of seafarers stipulated under the STCW Convention defines the global standards, equally important are the national

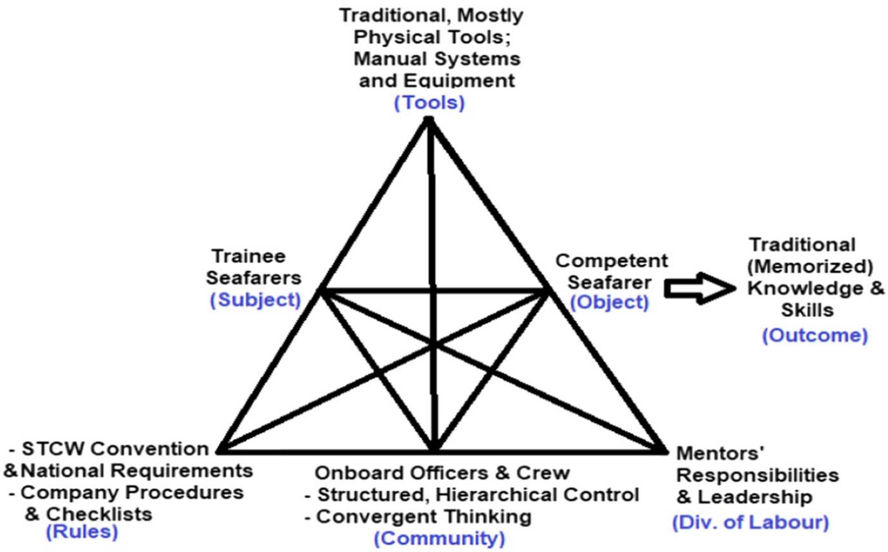

Fig. 2 Traditional shipboard learning activity system (source: authors)

and individual shipping company-specific requirements. This is because, the performance requirements, activities, and the social setup onboard each ship are unique. These factors are quite dynamic, and under the organizational and environmental influences, they keep changing with time and get accentuated due to the fast turnover of staff, which is another unique feature of the present-day merchant marine. All these aspects make the socio-technical setup aboard ships a unique and dynamic amalgam of varied levels of professional knowledge, skills, and experience, and the training of seafarers, challenging. The next section examines how the digitalization and automation of shipboard systems create certain contradictions and the ways to deal with those.

5 Contradictions introduced in the shipboard learning activity system by novel digitalized tools

The onboard phase of training of seafarers mandated by the STCW Convention is considered a critical part of their training. This is because it affords a learning environment characterized by situations, activities, and real-life challenges that the trainees will continue to face on board ships in the future (Emad and Roth, 2009). However, the recent influx of high technology is bringing rapid changes to the shipboard work environment, and that, to a great extent, is precluding many learning opportunities that existed earlier during the onboard apprenticeship (Emad, 2017). For example, digitalization can cause internalization or nontransparent and opaque systems, where the work and the decision-making processes directed by (hidden) algorithms may not be readily apparent to a bye-stander. This can affect the opportunities for learning through observation, which was a vital component of earlier apprenticeship training (Emad and Roth, 2016; Harteis, 2018).

Improvements in digital technologies are also facilitating an increase in the speed and processing power of the systems. This has led to more efficient (quicker or denser) processes, the merger of a few, and the introduction of a variety of new processes. On modern ships, a limited number of crew overseeing multiple and complex tasks in a shorter period of time often results in job intensification. This in turn can cause operator's cognitive overload, error in judgement, and, in many cases, lead to costly accidents. For example, Acejo et al. (2018) did a study of maritime accident investigation reports published by the UK Marine Accident Investigation Branch (MAIB), the Australian Transport Safety Bureau (ATSB), the US National Transportation Safety Board (NTSB), the Federal Bureau of Maritime Casualty Investigation in Germany, and the Danish Maritime Accident Investigation Board (DMAIB) between 2002 and 2016. Their report indicates that out of 693 accident reports analyzed, almost one-third can be directly attributed to the ineffective and improper use of technology. All such reports underscore the need for addressing cognitive human factors and the competence development of seafarers, relevant to the use of the modern technology and human-machine interactions.

The introduction of novel digitalized tools and systems onboard ships is gradually, but irreversibly obliterating the need for the traditional "expertise" over the earlier manual systems. In other words, automation is annihilating some part of the work activities that were dependent on the competences based on the experience of senior members of the crew (Harteis, 2018). Furthermore, it is also leading to situations wherein the appointed mentors sometimes lack adequate mastery over the newly introduced tools and systems, making them incapable of guiding the juniors in the use of such tools and equipment. This in turn can lead to unsatisfactory onboard training outcomes.

Digital technologies are introduced with the ultimate aim of extending human abilities and reducing the human efforts required to achieve the desired outcomes. Thus, the overall effectiveness of a fully implemented system will be a shared responsibility between an active subject and the technology designers (Blayone, 2019). From a subject perspective, the required human competences can be broadly classified as technical and operational competencies. Going ahead, along with the increasing digitalization, we can foresee a further reduction in the crew strength onboard ships. With only a limited number of personnel onboard ships in the future, and especially when vessels start getting remotely operated from ashore, there will be limited scope for the operators to undertake any labor-intensive tasks onboard, such as repair and maintenance (Lokuketagoda et al., 2017). Moreover, regular operators may need to gain only basic operational competences, leaving the fault diagnosis, rectification, etc. to specialists with adequate technical competence. All such changes call for a complete revamp of the present maritime syllabus and the removal of any redundant functions.

In modern, high-technology workplaces, there is an ever-widening gap between the knowledge and skills needed at work and those produced through formal vocational education (Tynjälä, 2008). Partly, this can be attributed to the fast pace of innovations and the introduction of novel technologies at the workplace, leaving the higher education to always perform a catch-up act. As and when new operating paradigms evolve and various types of ships start sharing the same waters (e.g., manned, unmanned, shore-side control, semi-autonomous, fully autonomous ships, etc.), vessel operators may need to develop a wider range of competences, comprising of both hard and soft skills (Mallam et al., 2019). This will require maritime education and training providers, shipping companies, and technology providers to develop optimized training programs and educational tools to meet the evolving demands of both existing as well as future maritime operations.

As stated earlier, digitalization and automation onboard ships are disrupting the traditional, almost unidirectional flow of competence and expertise, from the senior (master) to the junior (novice). With the onboard workspace getting more democratized, there is a new emphasis on team building and shared expertise. On modern ships, the trainees report better mentorship by junior officers belonging to generation Y or millennials, who in most cases are more at ease with digital technology and digitalized tools as compared to their more experienced seniors on board (Narayanan et al., 2023). This, in turn, has led to a situation wherein learning mostly happens through shared mentorship and leadership. As such, a team member could simultaneously be an expert in, and contribute towards a task, but a novice in, and ready to learn in the very next (Emad et al., 2022; Emad & Shahbakhsh, 2022,b).

In the overall, digitalization and automation process on ships are introducing many new contradictions and tensions among the constituent elements of an

Table 1 Examples of contradictions in the shipboard learning activity system caused by digitalization (source: authors)

Changes onboard ships introduced by modern technologies	Contradictions	Type
Disrupted onboard communities of practice	Community	Primary
Mentors lack necessary expertise to perform mentoring duties	Roles or ranks (representing division of labour onboard)	Primary
Many topics in the syllabus becomes redundant	Rules–object	Secondary
Internalization of tasks	Subject–tools	Secondary
Intensification of tasks	Subject–roles	Secondary
Manual systems replaced by automated system	Subject–tools–object	Tertiary
Higher ed no more able to produce the expertise required onboard	Higher ed. activity system vs onboard ed. activity system	Quaternary

onboard learning activity system comprising of the learners, mentors, technologies, pedagogical values, roles/identities, and rules/cultures as depicted in Table 1 below.

Next section explains Engeström's theory of expansive learning and how the contradictions within an activity system can become sources of change and further development.

6 Theory of expansive learning as a tool for change and development

Whenever an activity system tries to resolve its own internal conflicts through cycles of reconstructing and implementing a qualitatively new ways of functioning that will lead to expansive learning (Engeström, 2015; Engeström, 2016; Engestrom & Sannino, 2010,b). In other words, expansive learning involves transformative cycles of reconstruction and resolution of successively evolving contradictions over time (Engeström et al., 2013,b). However, expansive learning cycles seldom happen quickly, but may happen over weeks, months, or even years before being fully implemented in the workplace. Engeström describes these processes as micro-cycles of varying durations, involving intensive collaborative problem-solving (Engeström, 2003,b; Engestrom & Sannino, 2010,b).

The implementation of changes happens through a series of micro-cycles as described in Engeström et al. (2013,b). In step 1, the individual subject questions and criticizes any of the existing practices. In step 2, an analysis is done of the situation to identify any historical causes or other empirical inner relations that guide the elements in the activity system. In step 3, participants try to model new solutions to tackle the problematic situation. In step 4, the new model is closely examined to see how it functions and its potential and limitations. In step 5, the new model is implemented through practical actions and applications. Step 6 follows, involving any reflections and evaluations of the whole process. Finally, in step 7, participants consolidate the new practices into workplace routines. Knowledge creation is described as the object which emerges by accomplishing a collective zone of proximal development through adopting practices within a community (Engeström, 2015). Engeström through his experiments in different workplaces has shown that successful resolution of contradictions within or between activity systems, leads to effective development of new practices (Engeström & Sannino, 2017).

Figure 3 above shows how digitalization and automation are causing expansive transformation in the shipboard learning activity system. As and when the traditional, mostly manual systems and equipment onboard ships get replaced with digitalized tools, equipment, and automation, it generates some contradictions within the activity system. For example, the current national and international seafarer's training syllabus and curriculum, based on the STCW Convention, need to be thoroughly modified to cater to the new requirements of a digitalized shipboard workplace. With the crew strength onboard ships getting reduced further, and more specifically when the ships start getting operated remotely from ashore, that will make the traditional, structured, hierarchical community of officers and crew onboard ships obsolete. The present structure of the onboard community of officers and crew will be replaced with a more flexible, democratized community of operators with divergent thinking who are capable of operating across spatio-temporal boundaries (Emad et al., 2022). Moreover, the distributed expertise within an egalitarian community on modern ships will supersede the traditional mentor-mentee relationship. In lieu of that, there will be shared mentorship and an added focus on peer-to-peer learning. This means the team members will share their expertise as and when the need arises. The outcome of such an activity system will be vessel operators with digital problem-solving skills, whose competence will emerge from self-regulated collaborative ways of learning.

7 Conclusions

This paper presents CHAT as a novel, theoretical framework for modeling, analyzing, and redesigning the onboard learning of seafarers in view of the steadily increasing digitalization and automation onboard ships. En route to a fully autonomous future, the dynamically evolving ships and the changing nature of work

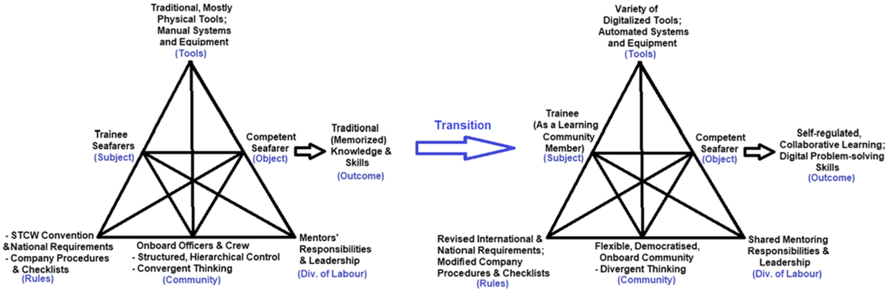

Fig. 3 Expansive transformation in the shipboard learning activity system (source: authors)

onboard call for the implementation of equally relevant education and training for seafarers. Although, fully autonomous vessel operations may still be many years or even decades away, the changes brought about by the proliferation of modern technology onboard thus far are already challenging the conventional practices of seafarers' work, learning, and development of competences. There is thus a need for a fresh conceptual approach that views the shipboard learning process of seafarers in a holistic, socio-cultural perspective, and CHAT fulfills that requirement. In addition, CHAT has also evolved as an ideal tool for analysis of people's actions in their everyday activity while collaborating with others, for example, the crew working onboard ships.

The versatility of activity theory makes it a malleable cognitive toolset affording its use for modelling, analyzing, and redesigning learning in a complex, fast-evolving workplaces, such as a shipboard environment. Its characteristics as a future-oriented tradition challenge individual-social dichotomies, and at the same time, address human-machine interactions as mediators of activity, development, and learning. It is our hope that this conceptual framework will provide maritime industry stakeholders a practical research tool for bringing reforms to future onboard learning programs and thereby meet the twenty-first century knowledge and skill requirements of the shipping industry.

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Declarations

Conflict of interest The authors declare no competing interests.

References

Acejo I, Sampson H, Turgo N, Ellis N, Tang L (2018) The causes of maritime accidents in the period 2002-2016. https://orca.cardiff.ac.uk/id/eprint/117481/1/Sampson_The%20causes%20of%20maritime%20accidents%20in%20the%20period%202002-2016.pdf Accessed on 15 Nov 2022

Adamides ED (2022) Activity theory for understanding and managing system innovations. Int J Innov Stud. https://doi.org/10.1016/j.ijis.2022.12.001

Baldwin CK (2020) Implementer learning in developmental evaluation: a cultural historical activity theory and expansive learning analysis. Evaluation 26(1):27–48. https://doi.org/10.1177/1356389019895033

Blayone TJB (2019) Theorising effective uses of digital technology with activity theory. Technol Pedagog Educ 28(4):447–462. https://doi.org/10.1080/1475939X.2019.1645728

Bligh B, Flood M (2015) The change laboratory in higher education: research-intervention using activity theory. In: Theory and Method in Higher Education Research, vol 1. Emerald Group Publishing Limited, pp 141–168. https://doi.org/10.1108/S2056-375220150000001007
Bodker S (1991) Through the interface: a human activity approach to user interface design CRC Press. https://doi.org/10.1201/9781003063971
Bertelsen OW, Bødker S (2003) Activity theory. In: Carroll JM (ed) HCI models, theories, and frameworks: toward a multidisciplinary science. Elsevier, pp 291–324. https://doi.org/10.1016/B978-155860808-5/50011-3
Cole M (1988) Cross-cultural research in the socio-historical tradition. In: Hildebrand-Nilshon M, Ruckriem G (eds) Activity theory: a look into a multidisciplinary research area, vol 1. Proceedings of the 1st Int. Congress on Activity Theory, Berlin
Cole M (2002) Alexander Luria, cultural psychology, and the resolution of the crisis in psychology. J Russ East Eur Psychol 40(1):4–16. https://doi.org/10.2753/RPO1061-040540014
Emad GR (2010) Introduction of technology into workplace and the need for change in pedagogy. Procedia Soc Behav Sci 2(2):875–879. https://doi.org/10.1016/j.sbspro.2010.03.119
Emad GR (2011) Rethinking adult and vocational education: hauling in from maritime domain. Ph.D. Dissertation. University of Victoria Retrieved from http://hdl.handle.net/1828/3285 Accessed 8 Nov 2022
Emad GR (2017) Improving maritime education and training for the sophisticated ships of today. Lloyds List, Australia (August 2017). http://ecite.utas.edu.au/122510/ Accessed 10 May 2022
Emad GR, Narayanan S, Kataria A (2022) On the road to autonomous maritime transport: a conceptual framework to meet training needs for future ship operations. In: Plant K, Praetorius G (eds) Human Factors in Transportation, vol 60. AHFE International. https://doi.org/10.54941/ahfe1002500
Emad GR, Shahbakhsh M (2022) In: Plant K, Praetorius G (eds) Digitalization transformation and its challenges in shipping operation: the case of seafarers cognitive human factor. AHFE International, pp 684–690. https://doi.org/10.54941/ahfe1002505
Emad G, Roth WM (2009) Policy as boundary object: a new way to look at educational policy design and implementation. Vocat Learn 2(1):19–35. https://doi.org/10.1007/s12186-008-9015-0
Emad GR, Roth WM (2016) Quasi-communities: rethinking learning in formal adult and vocational education. Instr Sci 44(6):583–600. https://doi.org/10.1007/s11251-016-9386-9
Engestrom Y (1987) Learning by expanding. Cambridge University Press
Engestrom Y (2000) Activity theory as a framework for analyzing and redesigning work. Ergonomics 43(7):960–974. https://doi.org/10.1080/001401300409143
Engeström Y (2001) Expansive learning at work: toward an activity theoretical reconceptualization. J Educ Work 14(1):133–156. https://doi.org/10.1080/13639080020028747
Engeström Y (2003) The horizontal dimension of expansive learning: weaving a texture of cognitive trails in the terrain of health care in Helsinki. Milestones Vocational Occup Educ Train 1:152–179
Engeström Y (2016) Studies in expansive learning: learning what is not yet there. Cambridge University Press, Cambridge
Engeström Y, Rantavuori J, Kerosuo H (2013) Expansive learning in a library: actions, cycles and deviations from instructional intentions. Vocat Learn 6(1):81–106. https://doi.org/10.1007/s12186-012-9089-6
Engestrom Y, Sannino A (2010) Studies of expansive learning: foundations, findings and future challenges. Educ Res Rev 5(1):1–24. https://doi.org/10.1016/j.edurev.2009.12.002
Engeström Y (2015) Learning by expanding: an activity-theoretical approach to developmental research, 2nd edn. Cambridge University Press
Engeström Y, Miettinen R (1999) Activity theory: a well-kept secret. In: Engeström Y, Miettinen R, Punamäki-Gitai R-L (eds) Perspectives on activity theory. Cambridge University Press, pp 1–16
Engeström Y, Sannino A (2017) Studies of expansive learning: foundations, findings and future challenges. Intro Vygotsky:100–146
Emad GR, Enshaei H, Ghosh S (2021) Identifying seafarer training needs for operating future autonomous ships: a systematic literature review [Article]. Aust J Marit Ocean Aff. https://doi.org/10.1080/18366503.2021.1941725
Fan C, Wróbel K, Montewka J, Gil M, Wan C, Zhang D (2020) A framework to identify factors influencing navigational risk for maritime autonomous surface ships. Ocean Eng 202:107188. https://doi.org/10.1016/j.oceaneng.2020.107188
Grech M, Horberry T, Koester T (2019) Human factors in the maritime domain. CRC press, Boca Raton

Harteis C (2018) Machines, change and work: an educational view on the digitalization of work. In: Harteis C (ed) The Impact of Digitalization in the Workplace - An Educational View, vol 21. Springer International Publishing AG, pp 1–12
Hopwood N, Stocks C (2008) Teaching development for doctoral students: what can we learn from activity theory? Int J Acad Dev 13(3):187–198
Ifenthaler D (2018) Digital workplace learning: bridging formal and informal learning with digital technologies. Springer International Publishing AG
IMO (2010) International convention on standards of training, certification and watchkeeping for seafarers. IMO https://www.imo.org/en/ourwork/humanelement/pages/stcw-conv-link.aspx
Janßen TJ, Baldauf M, Müller-Plath G, Kitada M (2021) The future of shipping: a shore-based experience? In: Bauk S, Ilčev SD (eds) The 1st International Conference on Maritime Education and Development. Springer, Cham. https://doi.org/10.1007/978-3-030-64088-0_5
Kaptelinin V, Nardi BA (2006) Acting with technology: activity theory and interaction design
Lave J (1991) Situating learning in communities of practice. In: Resnick LB, Levine JM, Teasley SD (eds) Perspectives on Socially Shared Cognition. American Psychological Association, pp 63–82
Lave J, Wenger E (1991) Situated learning: legitimate peripheral participation. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355
Leontiev AN (1997) On Vygotsky's creative development. In: The collected works of LS Vygotsky: Problems of the theory and history of psychology. Springer, pp 9–32
Lokuketagoda G, Miwa T, Ranmuthugala D, Jayasinghe S, Emad GR (2017) Moving the boundaries of MET with high fidelity ERS training. In: Global perspectives in MET: Towards Sustainable, Green and Integrated Maritime Transport
Lutzhoft M, Hynnekleiv A, Earthy JV, Petersen ES (2019) Human-centred maritime autonomy - an ethnography of the future. J Phys Conf Ser 1357(1):012032. https://doi.org/10.1088/1742-6596/1357/1/012032
Mallam SC, Nazir S, Renganayagalu SK (2019) Rethinking maritime education, training, and operations in the digital era: applications for emerging immersive technologies. J Mar Sci Eng 7(12). https://doi.org/10.3390/jmse7120428
Man Y, Lundh M, MacKinnon SN (2018) Facing the new technology landscape in the maritime domain: knowledge mobilisation, networks and management in human-machine collaboration. In: Stanton N (ed) Advances in Human Aspects of Transportation. AHFE 2018. Advances in Intelligent Systems and Computing, vol 786. Springer, Cham. https://doi.org/10.1007/978-3-319-93885-1_21
Murphy E, Rodriguez-Manzanares MA (2008) Using activity theory and its principle of contradictions to guide research in educational technology. Australas J Educ Technol 24(4). https://doi.org/10.14742/ajet.1203
Narayanan SC, Emad GR (2020) Impact of digital disruption in the workplace learning: a case of marine engineers. In: 31st Annual Conference of the Australasian Association for Engineering Education (AAEE 2020): Disrupting Business as Usual in Engineering Education. Engineers Australia, Barton, ACT, pp 1–8. https://doi.org/10.3316/informit.723704621829279
Narayanan SC, Emad GR, Fei J (2023) Key factors impacting women seafarers' participation in the evolving workplace: a qualitative exploration. Mar Policy 148:105407. https://doi.org/10.1016/j.marpol.2022.105407
Nardi BA (1996) Context and consciousness: activity theory and human-computer interaction. MIT Press
Nelson CP Jr (2002) Contradictions in learning to write in a second language classroom: insights from radical constructivism, activity theory, and complexity theory. The University of Texas at Austin
Porathe T, Prison J, Man Y (2014) Situation awareness in remote control centres for unmanned ships. In: Proceedings of Human Factors in Ship Design & Operation, 26-27 February 2014, London, UK, p 93 http://publications.lib.chalmers.se/records/fulltext/194797/local_194797.pdf
Pratt N, Tedder M, Boyask R, Kelly P (2015) Pedagogic relations and professional change: a sociocultural analysis of students' learning in a professional doctorate. Stud High Educ 40(1):43–59. https://doi.org/10.1080/03075079.2013.818640
Rajapakse A, Emad GR, Lützhöft M, Grech M (2019) A study on time constraints and task deviations at sea leading to accidents – a cultural-historical perspective. Marit Policy Manag 46(4):436–452. https://doi.org/10.1080/03088839.2019.1574407
Relling T, Lützhöft M, Ostnes R, Hildre HP (2018) A human perspective on maritime autonomy. In: International Conference on Augmented Cognition. Springer, Cham, pp 350–362. https://doi.org/10.1007/978-3-319-91467-1_27

Sellberg C, Viktorelius M (2020) From technical and non-technical skills to hybrid minds: reconceptualizing cognition and learning in semi-automated environments. In: International Conference on Applied Human Factors and Ergonomics. Springer, Cham, pp 191–197. https://doi.org/10.1007/978-3-030-50896-8_29

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 https://www.hvl.no/contentassets/64ae7d1b669c4d91ab5d8080ce76611e/catchingupwithtime_sharma.pdf

Toomela A (2000) Activity theory is a dead end for cultural-historical psychology. Cult Psychol 6(3):353–364

Toomela A (2008) Commentary: activity theory is a dead end for methodological thinking in cultural psychology too. Cult Psychol 14(3):289–303

Trowler PR, Turner GH (2002) Exploring the hermeneutic foundations of university life: deaf academics in a hybrid 'community of practice'. Higher Education, pp 227–256

Tynjälä P (2008) Perspective into learning in the workplace. Educ Res Rev 3:130–154. https://doi.org/10.1016/j.edurev.2007.12.001

Virkkunen J (2013) The change laboratory: a tool for collaborative development of work and education. SensePublishers

Vygotsky LS (1978) Mind in society: The development of higher psychological processes. In: Cole M, John-Steiner V, Scribner S, Souberman E (eds). Harvard University Press, Cambridge

Vygotsky LS (1997) The instrumental method in psychology. In: Reiber RW, Wollock J (eds) The collected works of L.S. Vygotsky: Problems of the theory and history of psychology. Springer, pp 85–89

Wertsch JV (1991) Voices of the mind: a sociocultural approach to mediated action. Harvard University Press

Wiser F, Durst C, Wickramasinghe N (2018) Activity theory: a comparison of HCI theories for the analysis of healthcare technology. In: Wickramasinghe N, Schaffer JL (eds) Theories to inform superior health informatics research and practice. Springer International Publishing, pp 235–249. https://doi.org/10.1007/978-3-319-72287-0_15