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Investigating educational solutions in the field of autonomous shipping at Finnish Universities

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ABSTRACT

The transformative impact of autonomous shipping requires a call for changes in the workforce and necessitates a shift in curricula. This study explores the state of higher education in Finland within the context of autonomous shipping and Maritime Autonomous Surface Ships (MASS). The research presented in this article is based on the collaboration among several educational institutions in the focal country and examines the landscape for MASS-related education and related pedagogical approaches and tools. Based on 19 interviews of educators in six Finnish universities, the article investigates predominant learning frameworks, pedagogical approaches and digital solutions while discussing the preparedness of the Finnish higher education system to address the emerging needs of the autonomous shipping domain. The findings of the presented research indicate that while a variety of digital solutions and hands-on activities, such as simulations and programming exercises, are employed, the lack of standardization across institutions poses challenges for collaboration and multi-disciplinary learning. These insights lead to a proposal of a pedagogical framework emphasizing experiential and challenge-based learning.

1. Introduction

The technological revolution affects the society as a whole, influencing the required skill sets and ways of leading new types of work communities. The increasing automation emphasizes the need for continuous learning. Rapid technological advancements and the resulting complexity require the workforce to adapt and possess innovative problem-solving skills, critical thinking, and creativity.

Existing research on MASS-related education focuses largely on identifying the skills and knowledge required for autonomous shipping, such as leadership, cybersecurity, and interdisciplinary understanding (Bolbot et al., 2022; Sharma and Kim, 2022; Björkroth, 2021). However, there is limited exploration of the educational frameworks and solutions needed to implement these changes effectively. This study addresses this gap by examining current educational practices and proposing strategies to enhance collaboration, interdisciplinarity, and readiness for the evolving demands of the autonomous shipping industry.

This study is the result of a research project devoted to the development of higher education to accommodate the future autonomous shipping and digitalization needs in the maritime sector, considering education in Finland as a case. Through the collaboration among higher education institutions, the project aimed to develop related multidisciplinary expertise and create innovative learning environments.

The aim of the study presented in this paper is twofold. First, it aims to identify common learning frameworks and approaches, as well as supporting digital tools, in teaching subjects that are directly or indirectly relevant for education related to Maritime Autonomous Surface Ships (MASS) and autonomous shipping in a wider sense in Finland at the moment. MASS has been defined as ships which, to a varying degree, can operate independently of human interaction, ranging from partly automated conventional ships, remotely controlled, to fully autonomous and unmanned ships (International Maritime Organisation, 2018). Second, based on these findings, commonalities in learning solutions and current preparedness of education in the focal country is discussed in light of the specific educational needs identified from the literature review on the impact of introducing MASS and corresponding knowledge needs. The study addresses the following research questions:

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- What is the portfolio of educational solutions currently used in MASS-related education in Finland?
- How do these solutions support the development of a nation-wide educational offering to address the emerging knowledge needs in the realm of MASS and autonomous shipping?

This entails an interest in learning solutions and supporting digital tools used, both on a subject and course level. To explore the current portfolio of education solutions related to MASS and autonomous shipping, we conducted semi-structured interviews with 19 educators from six Finnish universities, using thematic content analysis to extract insights aligned with the study's key questions. The study also has a specific normative knowledge interest regarding what an overall pedagogical framework and platform across Finland should look like from the perspective of MASS education.

This paper is structured as follows. In Section 2, a literature review presents the recent knowledge on the impact of the introduction of MASS on business and society, the corresponding new educational needs, and the overview of several pedagogical approaches that are further discussed in the paper. In Section 3, the research methodology is elaborated and the subsequent choices are explained. Section 4 describes the context in more detail, namely which subjects related to autonomous shipping and MASS within the current curriculum in the studied universities and contains the main results of this study, while Section 5 discusses the results and proposes a pedagogical framework for future MASS-related education. Section 6 concludes the study.

2. Literature review

2.1. The impact of introducing MASS and corresponding knowledge needs

The growing digitalization and the implementation of MASS are transforming the roles of seafarers and other professionals in the maritime industry. When it comes to seafarers, it has been discussed that operating MASS through remote operation centres will require a different skill set compared to the current situation (Sharma and Kim, 2022). The need for specialized knowledge in a specific area will be replaced by the demand for creativity and swift problem-solving abilities (Björkroth, 2021). Leadership has also been identified as a critical skill for seafarers to acquire in the future (Seatrade-maritime, 2018). With the increasing technological complexity of ships due to automation, skills related to cybersecurity, machine learning algorithms, remote and autonomous systems troubleshooting, and software development will need to be rehearsed among seafarers (Bolbot et al., 2022). Considering seafarers' perspective, Bogusławski et al. (2022) conducted a global survey assessing maritime cadets' attitudes towards autonomous shipping and its job market implications. The study found that cadets consider the current Maritime Education and Training (MET) curricula insufficient in covering automation and autonomous systems. However, cadets demonstrated an understanding of industry expectations, identifying essential future skills such as remote situation awareness, IT proficiency, and multitasking across global assets.

Furthermore, in addition to the changes directly affecting the shipbuilding and operation professions, maritime professionals will need to obtain a better understanding of how MASS function. Having a cross-sectoral and interdisciplinary understanding of autonomous shipping will prove beneficial for various professionals involved in MASS design, construction, and operation (Bolbot et al., 2022). The increased autonomy levels necessitate significant changes in many sectors related to maritime transportation and face substantial legal and business obstacles. Future education must address these challenges among others. Specifically, comprehending the legal foundations and current barriers for MASS is crucial for further policy development (e.g., how should regulations be modified?) and guiding technological innovation (e.g., how can the safety of specific technologies enabling MASS be proven to achieve regulatory compliance?). Skills related to cybersecurity and autonomous systems design will be in demand in the future from Original Equipment Manufacturers due to the increased threat vector against autonomous solutions. Moreover, as highlighted by Khan et al. (2024), 80% of survey respondents emphasized the necessity of cybersecurity regulations in autonomous vehicle operations.

The area of autonomous shipping is evolving rapidly with several autonomous vessels already launched (Yara, 2021) and multiple small autonomous ships on the market (Patterson et al., 2022). The accompanying automation and digitalization are increasingly adopted in the realm of maritime transportation (Heilig and Voß, 2017; Inkinen et al., 2019; Baldauf et al., 2018; Alsos et al., 2024) (Alsos et al., 2024). Yet, the implementation of MASS in commercial shipping remains a complex and uncertain concept. While some benefits of MASS, such as cost reduction through reduced manpower, are evident and well-understood, there are also barriers to overcome, including legal issues surrounding autonomous shipping (Ringbom, 2019), challenges with demonstrating an adequate level of safety (Negenborn et al., 2023) and the difficulties with building a viable business case (Wright, 2020; Ziajka-Poznańska and Montewka, 2021). Moreover, the introduction of MASS represents a system innovation that extends beyond mere cost reduction and individual business cases, profoundly impacting supply chains and logistics. This transformative innovation is also influenced by barriers related to the current organizational structure of maritime logistics, which could potentially reshape the entire institutional framework of the shipping industry (Tsvetkova et al., 2021; Munim, 2019; Ghaderi, 2020). For instance, shippers, as the end-users of logistics services, can gain unprecedented control over their goods' transportation in a fully automated and transparent supply chain that relies on MASS, automated ports, and other enabling innovations (Negenborn et al., 2023).

The previously mentioned challenges might postpone wide deployment of MASS. This, in turn, will influence the extent to which novel skills related to MASS are in demand currently and will be in demand in the future. This calls for educational solutions for MASS that are both flexible and adaptable to the demand but also specific and robust, and promoting the adoption of MASS by addressing the previously mentioned challenges. This would also require continuous collaboration with the industry when defining new skills and jobs required to address the evolving maritime sector needs due to autonomous shipping. The systemic change brought on by a wider introduction of MASS (Tsvetkova et al., 2021; Tsvetkova and Hellström, 2022), in turn, calls for more cross- and interdisciplinary approaches in teaching, which, among other measures, can be facilitated by the interdisciplinary exchange of educational solutions and the use of digital technologies, in particular.

2.2. Overview of pedagogical approaches

Didactic teaching refers to a traditional instructional method in which the teacher assumes a central role in the classroom, delivering knowledge and information to students in a direct, structured manner (Entwistle, 2005). Didactic teaching can be considered an efficient approach for disseminating factual information to a substantial number of students, making it an economically viable instructional method. However, it is crucial to acknowledge that the mere transmission of information does not ensure effective learning outcomes (Walkin, 2000). The concept of experiential learning was introduced by David A. Kolb in the 1970s and further developed in his book in 1984 (Kolb, 1984). Experiential learning theory, as opposed to didactic teaching, is learner-centred and focuses on a process of acquiring knowledge, skills, and understanding through direct experiences and reflection on those experiences. It emphasizes the importance of hands-on, active learning that engages learners in real-world contexts. Learning, in this paradigm, occurs in a four-stage cycle, namely (1) concrete experience; (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation. While often experiential learning is put in contrast to didactic teaching, there is evidence of the benefits of combining those approaches (Birnbaum, 1984). In relation to this study, we believe that a certain combination of both approaches is needed. However, since the two approaches require different learning solutions in the classroom, the correct combination of different solutions can reinforce the benefits of didactic teaching and experiential learning.

Problem-based learning (PBL), on the other hand, is a specific pedagogical approach that falls under the umbrella of experiential learning. It is a student-centred, enquiry-based method that involves presenting learners with authentic, complex problems or scenarios to solve. Students work collaboratively to explore the problem, identify relevant information, generate hypotheses, and develop solutions. PBL aligns with the principles of experiential learning by providing learners with opportunities to engage in hands-on experiences, reflection, and the application of knowledge (Shreeve, 2008).

Another example of student-centred learning is the flipped classroom approach. The flipped classroom is an instructional model that involves students accessing pre-recorded content independently before class, and using class time for interactive and collaborative activities. This approach aims to reverse the traditional sequence of learning, promoting active engagement and application of knowledge during face-to-face sessions (Milman, 2012). While the flipped classroom primarily focuses on restructuring the use of class time and the delivery of content, thereby aiding didactic teaching, it can be integrated with experiential learning and PBL to create a more comprehensive and immersive learning experience.

In this paper, the focus is on exploring the pedagogical approaches and educational solutions in the context of MASS-related education. To better understand the current portfolio of available educational solutions and their alignment with student-centred or teacher-centred learning paradigms, it is useful to consider Bloom's taxonomy of learning goals. Bloom's Taxonomy categorizes learning objectives into six levels, namely remembering, understanding, applying, analysing, evaluating, and creating (Bloom and Krathwohl, 1956). By employing this taxonomy, educators can design instructional strategies and assessments that foster higher-order thinking skills and promote deeper learning. By incorporating Bloom's taxonomy, the paper further analyzes how different pedagogical approaches, such as didactic teaching, experiential learning, PBL, and the flipped classroom, align with the different levels of learning identified in the taxonomy. This analysis will help identify the strengths and limitations of each approach and explore the potential benefits of combining them to create a more comprehensive and immersive learning experience for MASS-related education.

3. Research approach and study design

To explore the current portfolio of education solutions, we interviewed educators at six Finnish universities that teach courses that relate to MASS and autonomous shipping. The universities which are part of this study include Aalto University (Aalto), University of Turku (UTU), Åbo Akademi University (AAU), Novia University of Applied Sciences (Novia), Turku University of Applied Sciences (TUAS), South-Eastern Finland University of Applied Sciences (XAMK). The educational offerings of these higher education institutions collectively cover educational needs in terms of navigation, naval architecture, maritime law, maritime business and economics, mechanical engineering, IT and other fields relevant in the advent of MASS.

3.1. Selection of interviewees

The selection of interviewees was made among educators in the higher education institutions mentioned above with the aim of having at least one university representative to respond the interview questions. The other criteria was that the interviewees acknowledged that a course or several courses they teach can be considered MASS-related education. As a result, the total of 19 teachers were interviewed in these six institutions.

3.2. Data collection and analysis

We used Semi-Structured Interviews (SSI) for collecting data in our study. In a semi-structured interview, the interviewer poses questions designed to spark candid discussions and provide participants with the chance to bring up significant issues (Schmidt, 2004). SSIs discover participants' opinions regarding their experiences linked to the specified topic, which can be explored further to yield new insights (McIntosh and Morse, 2015).

We created an interview protocol (see Appendix) for the interviews based on our evaluation of the key issues underlying the main study questions, listed in Section 1. The interviews were open-ended and semi-structured, meaning that the respondents were free to provide greater detail on the subjects than was provided in the immediate response. The interviews lasted 20–60 min each and were conducted in February and March 2023. The interviews were recorded with structured notes. To analyse the data, we partially employed theme content analysis to extract relevant findings (Gubrium and Holstein, 2002). The themes essentially adhered to the interview protocol's framework within the results section.

4. Results

4.1. Current educational offering in terms of MASS and autonomous shipping

This section presents the main results of the research and aims at giving guidelines to the universities in Finland and outside on the needs and potential solutions to education. The key interviewees were selected based on the project partners' recommendations and their areas of expertise. We therefore had specialists in law, economics, cybersecurity, and IT together with many ship-related topics such as ship operations or ship design.

The topics that are related to or included in MASS-related education are subjective depending on the existing applicability. There are not yet any clear regulations of what MASS-related curricula should include for different professions, nor are there defined learning paths to follow. Half of the interviewed teachers mentioned that MASS-related topics are covered or partially mentioned within the curriculum. One of the interviewees pointed out that they are raising awareness on MASS while others mentioned no availability within curricula to add extra courses specifically devoted to MASS. One reason is that navigational education is strongly regulated by the STCW (The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers). A planned education will come in the future with a master's programme named, at TUAS, while others already have master's on MASS at Novia. At Aalto, a dedicated elective study path connected to smart shipping is offered.

MASS brings new challenges to the industry such as making it necessary to train personnel with additional or perhaps different skills compared to present ones, such as remote manoeuvring, navigation, ship engineering, maritime business safety, and decision-making.

MASS-related education is implemented in various ways at different schools and by different teachers. Out of 19 responses, 13 interviewees mentioned not having a dedicated teaching of MASS, while the rest have been teaching MASS-related subjects for several years. Eight responses were recorded mentioning having MASS-related topics only as chapters or small parts of some of the courses.

The courses that were mentioned in the interviews were grouped into seven wide subject areas (see Table 1). Many courses, not surprisingly, belonged to the field of naval architecture, navigation and other maritime studies, while other courses belonged to IT or business and social studies. Thus, it was expected that the pedagogical approaches and educational solutions would be different for these courses. Next, we present the characteristics of these courses in more detail, as regards the learning goals, average student number, pedagogical approach, and so forth.

Table 1
MASS-dedicated courses(*) and MASS-related courses explored in the study, grouped in subject groups.

1. Naval Architecture and Design	2. Navigation	3. Ship Operations and Management	4. Maritime Business and Law	5. Automation and AI Systems	6. Safety and Security	7. Networks and Communication
• Marine and ship systems engineering • Principles of naval architecture • Ship design portfolio	• Celestial navigation • Navigation systems • Manoeuvring • Navigation handling • Navigational Aids: Electronic Chart Display and Information Systems • Navigational Aids: Integrated Navigation Systems (*) • Route planning • Terrestrial navigation and collision regulations	• Ship types and cargo handling • Safety management; Occupational safety • Search and rescue • MRM (maritime resource management) • Ship maintenance, deck department	• Smart and sustainable maritime business • Maritime law • Law and legislation	• Autonomic software and systems • Safety and security management • Cyber security • Ship's automation systems (*) • Intelligent ships (*) • Autonomous systems architecture (*) • Perception and navigation in mobile robotics • Algorithmic foundation of robotic and AI systems • AI & Cybersecurity • Data analysis and knowledge discovery • Machine learning and pattern recognition • Electronics and automation (*)	• Communications and data transmission networks, cyber security (*) • Security engineering • Network infrastructure technology and security • Systems and application security • Firewall and IPS technologies • Marine risk and safety	• Communication GOC • Networks • Networking management

4.2. Legislation that affects or will affect MASS teaching

In response to the interview question about legislation affecting MASS-related courses, it is clear that in Finland, the development of MASS-related legislation is guided by STCW and Traficom (Traficom, 2019). The use of certain areas in the Finnish archipelago for testing autonomous ships is also ongoing. The Collision Regulations, COLREG (IMO, 1972), offers instructions for establishing safe speeds, evaluating collision risks, and managing vessel conduct in or around traffic separation schemes while at sea. Legislation is present and will continue to be developed to accommodate MASS developments, although issues and risks associated with remote piloting are a hot topic. STCW and IMO are working on updating regulations to include lower-level MASS ships (International Maritime Organisation, 2023), and DNV has produced a report on the topic for the European Maritime Safety Agency (EMSA, 2019). Science universities may have different regulations regarding testing autonomous vessels compared to applied science universities, and collaborations between the two may require additional work. Additionally, environmental legislation and cyber security regulations are important considerations for MASS. Coastal countries have their regulations regarding where MASS systems can be tested and used, and the IMO and classification societies have their own rules for MASS. Finally, the safety framework and pollution prevention for ships outlined in SOLAS (IMO, 1998b), MARPOL (IMO, 1998a), and IMO regulations (IMO, 2021) are relevant to MASS, particularly regarding watch-keeping and engine departments. These regulations affect MASS-related education in terms of, among others, requirements for seafarers' education, safety and security considerations of systems designed for MASS, and the possibilities for hands-on activities related to e.g. testing prototypes for MASS. As the legislative updates are constantly updated with the increase in automation and expectations of wider MASS adoption, it is crucial to harmonize the education related to autonomous shipping with these evolving requirements.

4.3. Learning goals

Bloom's Taxonomy (Bloom and Krathwohl, 1956) is a framework that helps educators categorize learning objectives according to different levels of cognitive complexity. Based on the data collected from the interviews regarding the primary learning goals for different courses explored, it appears that most courses aim for middle and higher-order learning goals (see Table 2). The most commonly mentioned goal is "evaluate", with six learning objectives categorized at this level, followed by "analyse" with five learning objectives identified. "Create" and "understand" were mentioned three times each. Interestingly, learning objectives categorized as "remember" were not mentioned by interviewees, indicating that the focus is on higher-order thinking skills rather than simply memorization. Overall, these statistics offer insights into the types of learning objectives that are emphasized in Bloom's Taxonomy and how they are distributed across different levels of cognitive complexity (see Fig. 1).

Apart from the primary learning goals, there were several other learning goals mentioned for each course. Further, the courses aimed at different learning goals also depend on the subject. As demonstrated in Table 2, the majority of courses have learning goals within the middle range of Bloom's taxonomy. However, certain subjects such as 'Safety and security', 'Automation and AI systems' and 'Naval engineering and design' aim at higher-order goals of evaluating and creating, which is rather natural for engineering sciences.

4.4. Pedagogical approach

Based on the collected data, it appears that several pedagogical approaches are employed for teaching. Table 3 demonstrates the prevalence of different pedagogical approaches for the MASS-related courses in the seven subject categories. The darker shade of green indicates the weighted average of the use of one or another pedagogical approach in the courses within one subject. First, didactic teaching still prevails in many courses, manifested in direct instruction by the teacher, demonstrations, and other activities. This finding is consistent throughout the subjects. Flipped classroom was mentioned sparingly only regarding the course in 'Automation and AI systems' and 'Maritime business and law'. Experiential learning was also mentioned rather often, and the same courses often combined didactic teaching and experiential learning. Interestingly, PBL was mentioned within every subject group, often interchangeably with Challenge-Based Learning.

4.5. Multi or cross disciplinarity

Adopting multi- or cross-disciplinary teaching approaches is perceived in various ways. Approximately half of the interviewed teachers classified their courses as cross-disciplinary or multi-disciplinary courses. When asked to elaborate, the educators were able to provide their view on what is a cross-disciplinary or multi-disciplinary teaching. In some instances, they rather meant foundational subjects, such as automation or security engineering, which are relevant for different applications. In these case, autonomous shipping was one of the application contexts studied during the course. Other courses, such as those devoted to smart and sustainable maritime business, included insights from several disciplines such as business, law, engineering and marine biology. Thus, only few interviewed educators have implemented multi or cross-disciplinarity, even though some recognize their advantages.

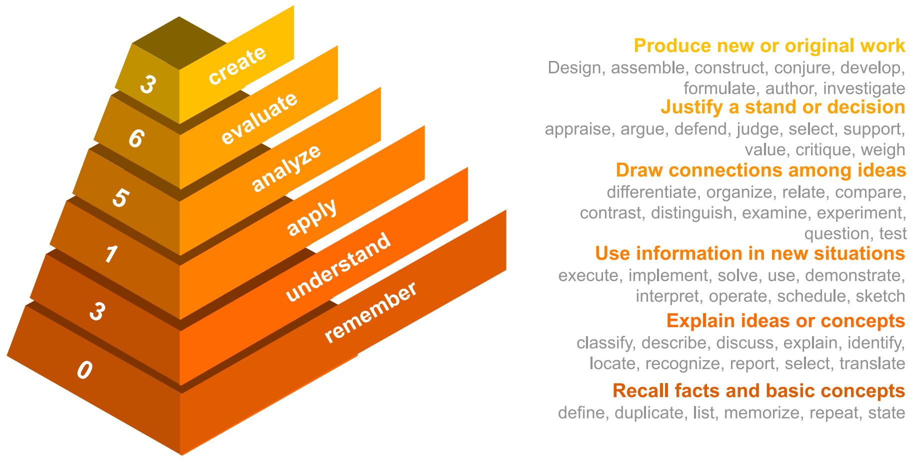

Fig. 1. Bloom Taxonomy: the prevalence of learning goals in MASS-related education.

Table 2
The prevalence of learning goals for different subjects in MASS-related education.

	Remember	Understand	Apply	Analyse	Evaluate	Create
1. Naval engineering and design	0	0	0	1	3	3
2. Navigation	0	2	4	2	0	0
3. Ship operations and management	0	1	1	2	1	0
4. Maritime business and law	0	1	1	1	1	0
5. Automation and AI systems	0	1	0	3	4	4
6. Safety and security	0	0	0	0	5	0
7. Networks and communication	0	0	1	0	2	0

Table 3
The use of selected pedagogical approaches in teaching MASS-related courses within different subjects.

	Didactic teaching	Flipped classroom	Experiential learning	Problem-based
1. Naval engineering and design				
2. Navigation				
3. Ship operations and management				
4. Maritime business and law				
5. Automation and AI systems				
6. Safety and security				
7. Networks and communication				

Table 4
The modality of teaching courses in different subject groups.

	Classroom	Hybrid	Online
1. Naval engineering and design	3	1	
2. Navigation	4	6	4
3. Ship operations and management	2	4	1
4. Maritime business and law	1	2	2
5. Automation and AI systems	3	11	1
6. Safety and security	3	3	
7. Networks and communication	1	3	1
TOTAL	17	30	9
Share of all courses studied	44%	77%	23%

4.6. Teaching medium

The modality of teaching is a crucial consideration when discussing common educational offerings across several universities located across the country. Many respondents noted having class courses where many offer the possibility of hybrid participation (see Table 4). It applies to students in working life, located in other regions of the country, or when requested. A few courses were offered completely online and as recorded classes. The Table 4 percentages exceed 100% because the teaching modalities have changed over the years. For example, some courses were affected by COVID-19 and shifted from classroom to online to a hybrid format before returning to classroom teaching.

One interviewee mentioned that interesting content during courses motivates students to come to classes. Joining online comes as a benefit for students having extended visa waiting times or living in other locations than where the lectures are given. However, online interaction has the drawback of potentially reducing interactions between students and teachers. The students can also be distracted more easily during online sessions. One significant remark was that more in-depth discussions are possible in on-site classes and that simulations or laboratory exercises are required to have students on-site. As regards the pace of study, more than half of respondents shared that courses happen in real-time while the rest mentioned possibilities for mixed or self-study modes.

4.7. Learning platforms used for teaching and the perspectives on potential common digital platform

Considering the need for multi-disciplinary education in the field of autonomous shipping, a number of ideas that could shed light on the requirements for a shared platform for MASS-related education appeared during the interviews. In particular, there is a plan to create a digital learning platform where all the Finnish higher education institutions are collaborating on enabling an easy and flexible common study path and course offering on specific subjects and qualifications. This platform has been discussed by the interviewees as a viable option for MASS-related education if a standardized set of courses is available at this platform and a common learning platform for all universities, such as Moodle, is utilized for different courses. Students might benefit from a shared learning experience as well as the chance to study under specialists in many fields. It was mentioned that every university needs to showcase its specialized areas within this digital platform to avoid administrative problems.

The same educational tools, including Microsoft Word, Microsoft Teams, and simulations, should be used throughout the platform, and students who are only partially present in class should be encouraged to work independently. While creating courses, content creators should have access to teacher support. Finally, basic content should be available to professionals who need to start at the beginning, and more advanced content may be subject to an additional charge. Lastly, the platform should be easy to use and not overly complicated to guarantee a good user experience.

It can be concluded that while various platforms are used, the lack of standardization can hinder the integration of MASS-related education across institutions. A unified platform with shared content and tools could enable collaboration and provide students with a cohesive learning experience, which is crucial for enabling cross- and multi-disciplinary education for the new jobs in autonomous shipping.

4.8. Current teaching and learning solutions

Through the discussions with educators about more specific educational solutions, we identified five distinct categories of such solutions that emerged as common themes in their responses: instructional methods, hands-on activities, reflective activities, collaborative activities, and assessment.

Under instructional methods, teachers employed a range of educational solutions including lectures, external speakers, live demonstrations, videos, and reading materials. These methods were utilized to deliver foundational knowledge and introduce key concepts to students. Technological solutions for these activities included, for example, streaming and video sharing platforms like *Panopto*, *Youtube* and *Microsoft Stream*. There were mentions of other platforms used for communication or streaming live lectures such as *Microsoft Teams*, *Zoom*, and *Echo360*. Hands-on activities played a prominent role in the teaching strategies discussed by the educators. They mentioned laboratory work, simulations, programming exercises, practical exercises, and case studies as effective means of engaging students and promoting experiential learning. Given the focus of MASS-related education on IT and automation, practical tools that were mentioned included programmable robots and programmable logic controllers, simulators such as *VTS Simulator* for vessel traffic management, *CARLA* for autonomous driving simulations and research, and a web-based interactive computing platform for code and data *Jupyter Notebook*.

Reflective activities were also highlighted by the teachers as valuable components of their courses. Students were encouraged to keep

Table 5
The use of educational solutions for achieving different levels of learning goals.

	Instructional methods					Hands-on activities					Reflective activities					Collaborative activities				Assess-ment	
	Lectures	External speakers	Live demonstrations	Videos	Reading	Calculations	Laboratory work	Simulations	Programming	Practical excercise	Case studies	Learning journal	Reflective report	Essays	Research	Student conference	Group work	Peer reviews	Discussions	Quizzes	Presentations
Understand	5	2	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	2	0
Apply	0	0	0	0	0	0	0	8	0	0	8	0	0	0	0	0	0	0	8	8	0
Analyse	8	1	1	2	1	0	0	5	1	6	0	0	2	5	1	0	2	0	0	6	2
Evaluate	12	1	2	3	2	3	3	5	4	8	0	8	1	4	3	3	4	0	0	6	3
Create	7	0	0	0	0	0	0	5	4	4	0	3	0	0	0	3	4	0	0	1	0

learning journals, write reflective reports, and engage in essay writing, research, and self-evaluation. These activities facilitated deeper understanding, critical thinking, and independent work. No specific technological solutions for these activities were mentioned.

Collaborative activities emerged as an essential aspect of the learning process, with group work, peer reviews, discussions, and student conferences being commonly mentioned by the educators. These activities promoted teamwork, communication skills, and the exchange of ideas among students. These activities could be performed using learning platforms' capabilities or with the help of, for example, interactive whiteboards.

Lastly, assessment methods were recognized as crucial for evaluating student progress and understanding. Teachers mentioned the use of quizzes, presentations given by students, and various assessment techniques to estimate students' knowledge and provide feedback. The most commonly mentioned method of assessment combined with exercising and building a better connection with the students were quiz solutions such as *Kahoot*, *Socrative*, and *Mentimeter*.

The educational solutions described above were used to achieve the learning goals on all levels of Bloom's taxonomy. Table 5 illustrates how often particular educational solutions were used in the courses that are associated with one or another learning goal. It can be noted that lecturing, simulations and quizzes are commonly used teaching activities for all types of learning goals. Practical exercises are also critical especially for higher-order learning goals aimed at analysing, evaluating and creating knowledge. It can also be noticed that courses with lower-level goals are not characterized by a wide range of learning solutions used, while different kinds of solutions were used across the courses that had goals such as 'evaluate'.

Further, the use of educational solutions was compared across the course subjects (see Table 6). No clear patterns emerged besides ubiquitous use of lecturing and a high use of simulations in the courses across the subjects.

The findings point to the importance of hands-on activities, such as simulations and programming, for seafarers and professionals in autonomous shipping. While reflective and collaborative methods support critical thinking, hands-on approaches are vital for addressing the practical and technical demands of MASS operations, which are challenging to replicate fully online or through didactical approaches.

4.9. Educational tools expected to be used in the future

Based on the interview data, a variety of techniques are being considered for future teaching. With five occurrences each, Canvas, Miro board, and Teams integrated education are the most frequently mentioned technologies to be included in the range of educational solutions. Two respondents also highlighted *ChatGPT* - text-based instruction, emphasizing the expanding significance of AI in the education industry. Nine interviewees highlighted the need for improved online connections and more complex simulation scenarios to raise the standard of online learning. Both AmROC (Remote Operation Center) and Discord were mentioned as potential instruments for future education. In two cases, the significance of real-world test applications in education was emphasized, and in two others, the potential for gaming, the incorporation of AR/VR into real-world situations, and container/dokker-based scenarios to enhance the learning experience was noted. It was also mentioned that emerging technologies can already be used to update and maintain professional competences in virtual reality training scenarios. Examples include MarISOT solution for a virtual maritime simulator (Tarkkanen et al., 2023) and Virtual Training Center (Luimula et al., 2020). It is expected that higher education institutes will continue utilizing hybrid teaching methods with more immersive solutions to enhance social communication with tools for hands-on-training and with digital twin integrations (Kontio et al., 2023). This can be achieved developing new learning management solutions where metaverse will be widely applied. Finally, digital twins and real-life integrations in metaverse will open new opportunities to focus on ROC training (Kaarlela et al., 2023).

According to the feedback from the interviewees, there are several factors that should be taken into account when teaching MASS-related courses. Real-world examples can significantly enhance teaching subjects, and it might be advantageous to add extra lab classes or hardware to the curriculum. One technique that can be used within MASS teaching is simulation, albeit using simulation infrastructure remotely, especially cloud simulation, which might be difficult. It could be required to use collaborative technologies in the same field to solve this obstacle.

Programmable robots in scientific settings might be helpful in addressing this. Important considerations to take into account include cyber security, simulation platforms, maritime courses with general and legal STCW (Standards of Training, Certification and Watchkeeping for Seafarers) assistance, and real-world applications in the development stage. Potential teaching aids for MASS-related education include a simulated testing environment, remote controlling and monitoring, and laboratory instruction.

The interviews highlight the need for new and targeted educational solutions tailored to the unique requirements of MASS. Instruments, such as digital twins and simulators should be designed to address the specific challenges of MASS, such as remote operation, cybersecurity, and complex system integration, ensuring that students and professionals are well-prepared for the evolving demands of the industry.

5. Discussion

5.1. Current portfolio of educational solutions for MASS-related education

This study analyses the current educational solutions employed in MASS-related courses and explores their implications for implementing a joint educational offering across Finnish universities. The findings

Table 6
The use of educational solutions within different subject groups.

	Instructional methods					Hands-on activities					Reflective activities					Collaborative activities				Assess-ment	
	Lectures	External speakers	Live demonstrations	Videos	Reading	Calculations	Laboratory work	Simulations	Programming	Practical excercise	Case studies	Learning journal	Reflective report	Essays	Research	Student conference	Group work	Peer reviews	Discussions	Quizzes	Presentations
1. Naval engineering and design	4	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	1	0
2. Navigation	4	0	0	0	0	0	0	8	0	2	4	0	0	2	0	0	0	4	4	6	0
3. Ship operations and management	3	1	0	0	0	0	0	5	0	1	1	0	1	1	0	0	1	1	1	3	1
4. Maritime business and law	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	0	0	1	1	2	1
5. Automation and AI systems	8	1	1	1	1	1	1	10	6	8	1	0	0	2	0	0	5	1	1	5	0
6. Safety and security	5	0	0	0	0	1	1	1	1	3	0	4	0	2	2	0	2	0	0	3	2
7. Networks and communication	2	0	1	1	1	1	1	2	1	2	1	1	0	1	0	0	1	1	1	2	0

reveal a variety of learning platforms, instructional methods, hands-on activities, collaborative approaches, and assessment techniques. While platforms like Moodle are widely used, the lack of standardization across institutions poses challenges for integrating and connecting MASS-related educational offerings. A unified platform with shared tools and content would facilitate collaboration, resource sharing, and enable multidisciplinary education in autonomous shipping.

The identified educational solutions emphasize the use of hands-on activities and practical tools to engage students and promote experiential learning (Kolb, 1984). Such hands-on activities, including simulations, programming exercises, and practical case studies, are critical for engaging students and preparing them for the technical demands of autonomous systems. These approaches are particularly important given the identified need for skills like cybersecurity, machine learning, and autonomous systems troubleshooting in MASS (Bolbot et al., 2022; Bogusławski et al., 2022) Also, problem based learning (PBL) was a commonly used pedagogical approach across the subjects, providing students with opportunities to tackle real-world problems in a controlled environment. However, the fragmented use of platforms and tools can hinder the integration of interdisciplinary knowledge crucial for MASS education. For example, while reflective and collaborative activities encourage critical thinking and teamwork, their implementation often depends on the capabilities of specific platforms. Addressing this gap with a standardized platform would support the interdisciplinary and practical learning necessary to prepare students for the evolving job market dictated by the diffusion of autonomous shipping.

5.2. Implications for the pedagogical framework for MASS-related education

The findings of this paper point out that experiential learning is a primary focal area for the development of pedagogical frameworks for MASS related education. Universities are already heavily employing PBL in this field. The educational needs are constantly evolving as it is unclear when and how MASS will actually be deployed and at which level(s) of autonomous capability. This aligns with the findings of Bolbot et al. (2022), who highlight the dynamic nature of MASS-related skill requirements, such as cybersecurity and autonomous system design. There is an ever-growing need to incorporate more and more interdisciplinary knowledge into curricula, resulting in a need to revise the curricula more often than feasible in educational institutions. Traditional problem based learning with targeted solutions and outcomes may reach its limitations in this rapidly changing ecosystem where the problems become more complex and open-ended. A targeted solution that was valid one year may already be obsolete in the next year.

To alleviate this issue, we propose the adoption of challenge based learning and education frameworks for MASS. Challenge based learning (CBL) shares some characteristics witfh PBL, but with focus not on the target solution and the kind of learning associated with reaching the particular target, but on the problem or challenge itself without an expected solution (that is, an open-ended challenge). In CBL, the students receive the learning experience in the process of solving a real-world sociotechnical and multidisciplinary challenge that does not have an exact predictable outcome. To ensure the real-world nature as well as the current topicality and relevance of the challenges, they should come from the MASS industry and stakeholders. Close collaboration with industry is necessary for defining the skills and knowledge required for MASS, as emphasized by Sharma and Kim (2022) and Björkroth (2021). The students or student groups must define the details of the initial challenge and identify the knowledge needed to tackle the challenge and progress towards a solution in three main phases: (1) Engage — start from the conceptual challenge and proceed to define a concrete and actionable challenge; (2) Investigate — apply and acquire knowledge and skills to conduct activities that lead towards possible solutions; simulations, experiments, research and subprojects; and (3) Act — develop and implement solutions in an authentic real-world environment, and evaluate the obtained solutions and results. When considering an educational paradigm rather than an implementation style, we propose the use of the term Challenge Based Education (CBE).

We propose that CBE and the use of digital tools in teaching jointly address evolving educational demands in terms of MASS and autonomous shipping, which include the increasing need for multi- and interdisciplinary education, adaptation of the curriculum to evolving education needs, and the focus on experiential learning. This aligns with Kolb's experiential learning framework (1984) and reflects the systemic need for interdisciplinary solutions discussed by Tsvetkova et al. (2021). Fig. 2 demonstrates examples of how CBE and digitalization can contribute to addressing the requirements for future MASS-related education.

6. Conclusions

This study analysed educational solutions for MASS-related education in Finland, with the aim of identifying common learning frameworks, approaches, and digital tools, as well as assessing their readiness to support a nation-wide educational offering. The findings indicate a diverse but converging portfolio of educational solutions that emphasize experiential and multidisciplinary learning. A unified educational platform that could integrate shared courses and resources, can support the multi-disciplinary demands of autonomous shipping.

Another key finding is that hands-on activities, such as simulations, programming exercises, and case studies, are essential for preparing students for the technical and operational challenges of MASS. Reflective and collaborative methods further enhance critical thinking and teamwork, which are critical in the new jobs enabled by autonomous shipping. Building on these insights, the adoption of challenge-based education (CBE) emerges as a promising pedagogical framework. CBE can address the open-ended, real-world challenges inherent to MASS.

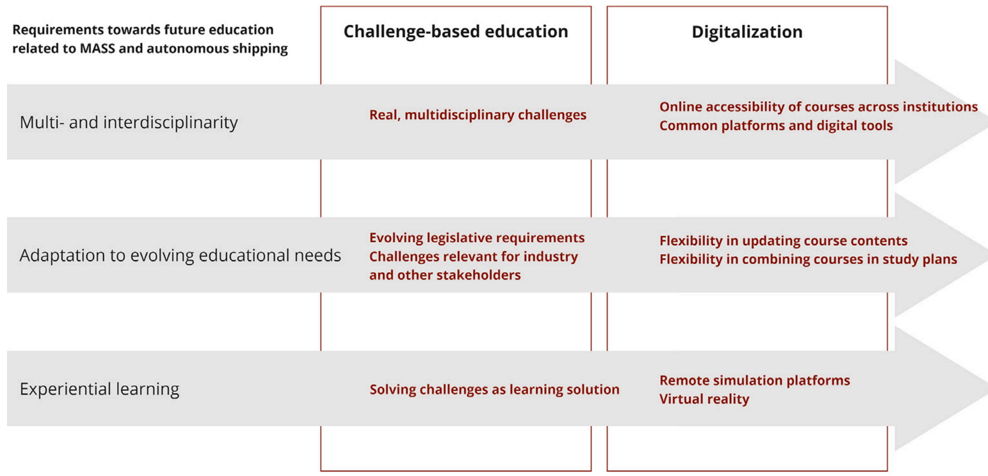

Fig. 2. The role of CBE and digitalization in addressing requirements towards future education related to MASS and autonomous shipping.

It requires close collaboration with industry stakeholders and allows adjusting the teaching content at a faster pace.

The objectives of the study were achieved by identifying the current portfolio of educational solutions and demonstrating their alignment with the emerging knowledge needs of MASS. The findings provide concrete recommendations for advancing MASS-related education, including the need for standardization of teaching tools across universities, interdisciplinary approaches, and the integration of industry-relevant challenges into curricula. Although the study focuses on Finland, its implications are globally relevant, given Finland's leadership in maritime innovation and its progressive educational system. Future research should explore the detailed implementation and scalability of CBE and other frameworks in MASS-related education.

CRediT authorship contribution statement

Andrei-Raoul Morariu: Writing – original draft, Investigation, Data curation. **Anastasia Tsvetkova:** Writing – review & editing, Writing – original draft, Methodology, Data curation. **Magnus Hellström:** Writing – original draft, Validation. **Victor Bolbot:** Writing – review & editing, Writing – original draft, Visualization, Validation, Data curation. **Seppo Virtanen:** Writing – review & editing, Writing – original draft, Methodology, Investigation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Morariu Andrei-Raoul reports financial support was provided by Abo Akademi University Faculty of Science and Engineering. Morariu Andrei-Raoul reports a relationship with Abo Akademi University Faculty of Science and Engineering that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Interview protocol

1. How well do you think the current curriculum supports MASS? What should be improved?
2. For how long have you been teaching MASS-related subjects?
3. What learning platform are you using (Moodle, Teams, Canvas, etc.)?
4. Can you name up to 1–3 MASS-related courses are you teaching?
   (a) What type of course is it?
      i. What kind of subject?
      ii. What kind of learners (undergraduates, adult learners etc.)?
      iii. Average number of students
      iv. What are learning goals?
      v. At which level of Bloom's taxonomy are the learning goals?
      vi. Is it multi- or cross-disciplinary?
   (b) What pedagogical approach is used?
      i. Lectures
      ii. Blended learning (elements of classroom and online/web-based)
      iii. Flipped classroom
      iv. Problem-based (challenge-based)
      v. Anything else?
   (c) What medium do you use? How are you attracting students to come to the classroom? (online, hybrid, offline classroom)
   (d) What tools are you using for planning the course; assignments; training; communication with students; lecturing; assessments; engaging students (simulators, games, quizzes, polls, blogs, other)
   (e) Real-time or self-paced?
5. What are the digital tools that you foresee will be used in your course(s)/future education?
6. What suggestion do you have for an online course platform available across the country for training professionals?
7. Is teaching a MASS course need any special approach and tools for making it happen?
8. What kind of feedback (KPIs) are you collecting from the courses?

(a) What tools are used for course improvement and funding?
(b) Do you have some personal KPIs for other purposes?

9. Is there any legislation that affects or will affect MASS-related courses?
10. How to make learners reflect back to the course and keep them engaged in learning the subject?
11. Do you have any extra ideas that may help our research into MASS teaching solutions?

Data availability

The data that has been used is confidential.

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