A CHALLENGE BASED EDUCATION FRAMEWORK FOR AUTONOMOUS SHIPPING

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ABSTRACT

Due to expected profound changes in the maritime industry caused by the introduction of Maritime Autonomous Surface Shipping (MASS), the education in this field is in clear need of development. Cross-sectoral and inter-disciplinary understanding of the premises of autonomous shipping is required of professionals connected to MASS design, construction and operation. There is a gap in aligning education to technological developments in MASS, as existing approaches fail to specify the type of training required or to propose a framework for developing the future skills of seafarers. This paper addresses this gap by developing a framework for challenge-based education, emphasizing interdisciplinary knowledge and 21st-century skills such as critical thinking, problem solving, digital literacy, creativity, and communication. This framework allows for agile adjustments to meet the evolving and emerging needs of the maritime sector. The framework utilises genuine challenges of the maritime cluster that are defined in cooperation with maritime stakeholders and industry. The framework is customisable and it can be generalised to other fields of education.

KEYWORDS

Challenge Based Learning, Autonomous Maritime, Shipping, CDIO Standards: 1–3, 5–8

INTRODUCTION

Due to expected changes in the maritime industry caused by a wider introduction of Maritime Autonomous Surface Shipping (MASS) (Ghaderi, 2020), professionals in other sectors besides shipbuilding and operation will require an increasing understanding of how MASS operate. Cross-sectoral and inter-disciplinary understanding of the premises of autonomous shipping at large might also be beneficial for different kinds of professionals connected to MASS design, construction and operation. Higher degrees of autonomy requires bigger changes in many sectors connected to maritime transportation and face higher legal and business barriers (Tsvetkova et al., 2021). Future education needs to address these challenges as well. Namely, the understanding of legal foundations and current barriers for MASS is important both for further policy development (for example, how regulation should be changed) and for directing technological innovation (for example, how to prove the safety of certain technologies enabling MASS in order to reach regulatory compliance) (Bolbot et al., 2022). Also, given the uncertainty regarding the development of the maritime sector with a more abundant introduction of MASS, it is necessary to develop flexible teaching and learning frameworks, which would allow for agile adjustments and modifications according to emerging needs. In line with this, maritime experts expect a shift towards personalised training adapted to individual needs and an interdisciplinary approach integrating simulator-based and computer-based training, 3D simulations, and gamification (Nguyen, 2018).

The perspective of students, apprentices, seafarers at the beginning of early careers or in the maritime industry (cadets) and future maritime professionals have also been explored (Tsvetkova et al., 2024). With regard to seafarers, Bogusławski et al. (2022) conducted a worldwide survey to assess maritime cadets' attitudes towards autonomous shipping and its job market implications. The findings reveal that cadets feel current Maritime Education and Training curricula inadequately cover automation and autonomous systems. Despite this, cadets successfully identified essential skills for future shipping, such as remote situation awareness, IT proficiency, and multitasking across global assets. This indicates that cadets understand industry expectations and are optimistic about adapting to future challenges, including transitioning to shore-based roles if sea-going opportunities decline.

In an extensive literature review, Emad et al. (2022) evaluated the current state of knowledge on maritime education and training of future operators of autonomous and unmanned ships. Through comparing the maritime industry with other industries that have seen increased levels of automation such as mining and aviation, the authors suggested that the lack of an existing framework for training on MASS can be overcome through learning from these industries. In particular, the training of operators of automated equipment in these sectors has focused on developing cognitive skills, communicative abilities, analytical thinking, effective communication and taking efficient action. However, the authors concluded that there is a research gap in aligning seafarers' training to technological developments in MASS, as existing papers reiterate the need but fail to specify the type of training required or propose a framework for developing the future skills of seafarers.

This paper addresses this gap by developing a framework for challenge-based education, which emphasises interdisciplinary knowledge and 21st-century skills such as critical thinking, problem solving, digital literacy, creativity, and communication. This framework allows for agile adjustments to meet the evolving needs of the maritime sector, particularly in the context of MASS. The framework for Challenge Based Education (CBE) developed in this paper is based on recognised educational needs in the MASS context (Bolbot et al., 2022). In education based on this framework, student teams seek creative solutions for current and future challenges in the field. The framework utilises genuine challenges of the maritime cluster that are defined in cooperation with working life representatives, that is, maritime stakeholders and industry. The framework is customisable and can also be generalised to other fields of education beyond the MASS context. The presented pedagogical framework and learning design for challenge based learning and other forms of learning design enable agile adjustments and modification of the content according to emerging needs.

The development of the CBE framework presented in this paper started in the AutoMare EduNet project funded by the Ministry of Education and Culture in Finland during 2021-2023. In AutoMare EduNet, a multidisciplinary collaboration network between universities was built to ensure the delivery of high-quality education to meet the emerging educational needs of MASS.

THE AUTOMARE FRAMEWORK FOR CHALLENGE BASED EDUCATION

The presented scalable AutoMare Challenge Based Education framework makes it possible for higher education institutions to dynamically offer up-to-date engagement between students and industry related to MASS solutions. Naturally, companies and industrial actors do not have sufficient incentives to take care of knowledge and information transfer on their own. Higher education institutions should make a long-term decision by selecting relevant faculties and disciplines to carry out "living lab" activities, which integrate working with experimentation and research. In the AutoMare framework, the higher educational institutes are assumed to have existing industry collaboration which gets more focused and emphasised towards the field of autonomous maritime if the institute adopts the AutoMare framework. In principle, this requires that participating higher educational institutes:

1. have existing relevant expertise that can currently be connected to visions related to MASS (technology, business and operations, regulations, and so on). Most likely this is determined by each institute's management themselves.
2. are willing to allocate teaching resources, especially in the MASS context, and also resources to coordinative work and industry collaboration.
3. also participate in R&D projects related to MASS, prepares new project proposals and participates in related networks.

Depending on the scale of teaching close to topics of MASS, the living lab can vary from being a part-time task of an individual teacher to being a stream of a larger university-industry collaboration team which interacts with companies in R&D projects.

Figure 1 summarises the AutoMare framework and its main sections. On the left side of the figure, the main phases of the framework related to the respective industry and students are shown. On the right side of the figure, the related activities of the living lab functions suggested for higher education institutes are shown. Each main phase is described in detail in separate sections.

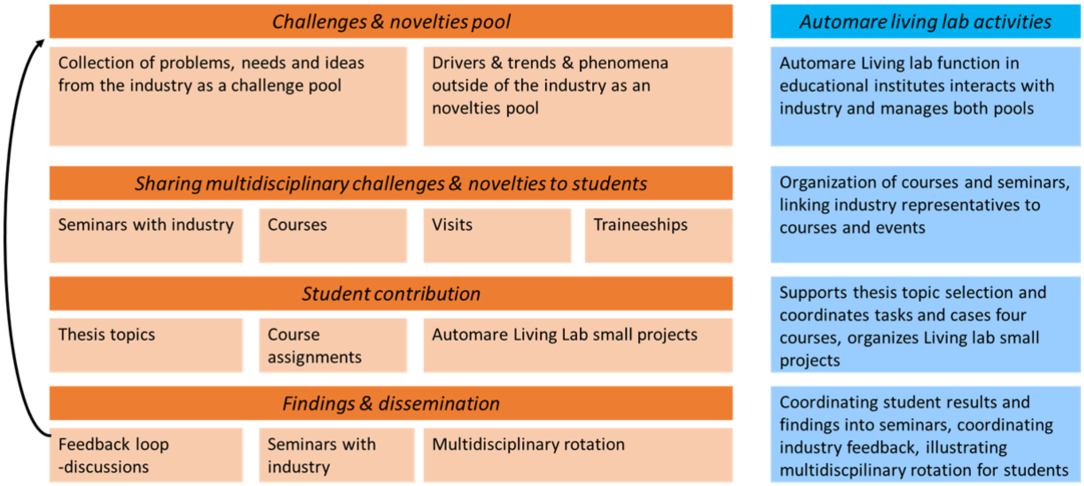

Figure 1. Automare Challenge Based Education Framework

Challenges and novelties pool

Each higher education institute interacts with different industries and stakeholders according to their own goals, resources, etc. At least in the case of Finland, the backbone for collaboration already exists. The question is whether the topic of MASS will be considered among the collaborations with feasible focus and expertise. The second question is whether, even if researchers engage in MASS research, the research results will also be transported to education.

In the AutoMare framework, the first phase covers activities that manage the collection of both challenges and novelties that could potentially reshape technologies, business and regulation related to the set context – MASS. In the framework, challenges refer to problems, needs or sleeping ideas within the core industry. Industry actors and start-ups especially often need to put their effort into immediate business goals and focus on generating concrete outcomes. However, they often run into broad and multidisciplinary challenges and questions that will have a longer-term effect with, for example, technology adoption. The AutoMare framework seeks to establish a sufficient dialogue between the parties in which higher education institutes could capture observations and thoughts on the challenges and convey them bit-by-bit to students and scholars to generate new knowledge and solutions. Challenges could include for example:

- improving sensor fusion techniques
- addressing poor connectivity issues in coastal areas
- business model scenarios related to, for example, remote operations or equipment maintenance
- ethics evaluation of different algorithmic decision-making outcomes
- investigating alternative supply chains relying on autonomous technologies and ecosystems
- scenarios that could be tested in a ship simulator environment

When developing radically new technology and surrounding sociotechnical regimes, the industry and educational sector need to take into account also other factors beyond challenges rising from inside a certain set of actors. Both technological and industrial boundaries are always in motion even if there are rather broadly accepted visions of what autonomous maritime solutions might be in the future. It is likely that not all the elements needed are yet fully detected. Path dependency on how maritime technologies have evolved before or which are the currently active actors can lead to missing some potential coming from elsewhere. Therefore, in parallel with the pool of challenges, the AutoMare framework introduces a novelties pool. Novelties refer to drivers, trends and phenomena outside the current industry boundary that might shape the technological, operative and institutional development of MASS. Novelties include:

- positioning of remote work practices and culture in near future and impact on, for example, remote-operation technologies
- green transition demand impact for technologies and operations as well as investment financing
- possibility of superapps as tools for individuals managing their every day partly on their behalf
- collaborative robots joining in configuring new processes
- mass escape and career shifts from routine jobs

In practice, individuals or teams allocated to AutoMare living lab activities participate in collaboration with relevant companies and stakeholders and seek to pick up challenges and novelties from the field. Depending on the scale chosen, this collection can be passive observing or more actively pursued in dedicated events. Companies may choose whether they wish to be listed as the owner of the challenge or novelty, or if the topic should be listed in the pool anonymously.

Sharing challenges and novelties to the students

Industry collaboration and education have their own goals and they are often met separately. Therefore, in the AutoMare framework, the second phase of the higher education institutes' AutoMare living lab team members is to share challenges and novelties that get collected in the respective pools. Four basic methods for sharing are identified in the framework. The first one is the organisation of different seminars and events bringing together industry experts and students. Secondly, visiting lectures and thirdly, site visits to companies generate interaction in different courses. Fourthly, coordination with traineeships in MASS companies contributes to the accumulation of students' understanding of topics and opportunities, including the possibility of future employment.

During the third phase, the students contribute by familiarising themselves with the topic, discovering new research results and findings, and gradually generating new knowledge for themselves and the industry. Primary knowledge is obtained directly through tackling challenges, but also the importance of applied and generated tacit knowledge through interest and engagement with stakeholders must be recognised. In addition to project work, students can contribute by doing their theses on commission by stakeholders and have parts of the challenges or novelties solved as course assignments.

Students have diverse perspectives on how course material affects their motivation to attend classes. Some people live in remote regions, so access to online classes is useful. However, there is concern about the potential decrease in contacts between students and teachers during virtual sessions, which may hinder engagement, particularly owing to distractions (e.g., social media). Students stress the value of on-site presence during activities like simulations and laboratory exercises.

Some courses that use project work, particularly in phase four of the presented framework, as a form of assessment allowing students to choose the technology they will use to execute the specified activity. With enough available time to experiment and test various technologies, students can fail and learn from their mistakes to improve their final project. Structured feedback mechanisms from peers, teachers and industry stakeholders can enhance the learning process and improve project outcomes. This assessment is relevant to CBE because students must investigate the novelty of technology or procedures that they have not before used.

EXPERIMENTS IN THE IMPLEMENTATION OF CHALLENGE BASED LEARNING

Challenge Based Learning can be implemented in different levels of abstractions depending on the challenge in question and on the learning goals of the study module incorporating the challenge. We define the key abstraction levels as three scopes for challenge based learning as follows.

1. "Course": in this scope, "design sprint" style innovation processes are applied in the student groups. The basic idea in the process is to generate a high number of raw ideas, and then collect feedback on them. Based on the feedback, the best raw ideas are selected for further development. In this kind of scoping the whole challenge-based learning approach can be utilised: stakeholders, for example companies, benefit from the students producing a high number and variety of ideas, then experts representing the stakeholders have the opportunity to consider the ideas, evaluate their realism and direct the forthcoming work of the student groups to suitable directions. Students will learn from the feedback and are able to utilise it in tackling the challenge but still the chance for fresh angles and solving strategies to appear remains strong.
2. "Topic/Development area": in this scope, the challenges would represent various development areas within autonomous maritime development, for example, various systems and their interoperability. Among the authors, there is recent experience in applying challenge based learning in this scope in innovation processes on topics like automation of container lashing and tanker berthing as a pre-step of remote pilotage. At this level of scoping it becomes evident to students that the operational environment in maritime always includes several actors with conflicting interests. Tackling the challenge requires understanding of all the actor's goals and the involved processes.
3. "Discipline": in this scope, the challenges include a predefined selection of different disciplines from which students are brought together for multidisciplinary perspectives to tackling a challenge. Investigating the different perspectives helps students grasp a broader sense of how to carry out multidisciplinary development for challenges in autonomous maritime. A selection of disciplines could cover, for example, different technical approaches (machine vision, data transfer, cyber security, automation algorithms, etc.) with business legal aspects. The development needs of the stakeholders might vary and situations could change during the challenge, potentially highlighting challenge based learning as a mechanism for participating higher education institutions to bring together experts in different fields to support the student teams, facilitating the building and growth of collaboration between various research groups and companies.

In the following, we discuss three experiments in challenge based learning from the higher education institutions represented by the authors, and consider how they align with the scopes defined above.

Challenge as a student project

As part of applying the CBE framework in Figure 1, and advancing autonomous ships' educational development at Aalto University, a small autonomous ship model was developed. The concept ship model constituted a miniature copy of an Icebreaker ship model. The model was developed in stages, where three Master students (Two summer workers and one thesis worker) addressed the general problem of designing, selecting and retrofitting the ship model with the necessary equipment as well as developing the relevant software code in Arduino and ROS2 software.

In each case, a set of problems for each student was specified based on the general and specific needs of the overall project plan for ship model design, similar to the one encountered in industry and academia. The project in each case had some specific aims, tasks and deadlines to be implemented by the students, and students were given freedom in adressing the tasks. Additionally, the position with a clear task description was advertised through the Aalto network, so that interested students could make the relevant application as per their interest.

The project execution was implemented under the close supervision of one Postdoc, one PhD student, Aalto Ice and Wave tank manager, and two Aalto professors. All of the students reported positive feedback to their engagement to the project and the Master thesis student (employed for 6 months contrary to 3 months and 1.5 months for the other two) received an offer from project industrial partners, where he continued applying the skills that he learnt during his Master thesis work. Additionally, the research conducted by the students had an academic impact, with students contributing to one journal and one conference paper, and with some research still ongoing, receiving good feedback from the industry.

Challenge as a course assignment

CBE can be integrated into both the activity design and assessment strategies within individual courses, providing students with opportunities for engagement and practical application. For instance, a challenge-based approach was incorporated into the assignment design of the course 'Smart and Sustainable Maritime Business' at the Laboratory of Industrial Management, Åbo Akademi University. In this main course assignment, students are tasked with selecting a problem or phenomenon within the maritime sector, analyzing it through the lens of wicked or potentially wicked problems. Autonomous shipping is provided as one of the phenomena that can be chosen by students for their course assignment.

The assignment begins with students defining the problem, focusing on potential risks and the interconnected aspects of sustainability involved. This initial step encourages them to consider the different dimensions of sustainability and the complexity of the issues related to autonomous shipping, such as legal considerations, impact on jobs in the maritime sector, and the potential environmental benefits of autonomous shipping. This way, the students are directed to identify the potential contentions and challenges that have emerged or will emerge as autonomous ships are increasingly introduced. Further, students investigate relevant digital and clean technologies that could play a role in addressing the challenges they have identified.

Finally, students attempt to provide solutions and recommendations for how the maritime sector needs to develop further to be able to benefit from and mitigate potential negative impacts of autonomous shipping. Given that the students come from various engineering backgrounds, such as computer science, energy technology, and marine biology, discussions within groups allow them to gain a multidisciplinary perspective on the problem.

In this particular case of a challenge-based learning type of assignment, the idea of having a challenge and novelty pool (see Figure 1) is utilised (top level), which is further shared with students in a course (second level), and is then analyzed by students as part of a course assignment (level 3). What still needs to be developed, is creating a feedback loop as implied at level 4. Although the final seminar in the 'Smart and Sustainable Maritime Business' course, where students present their assignments, brings together the students and some of the researchers at the Laboratory of Industrial Management, the involvement of industry representatives would be beneficial.

Innovation camp process with students as a research project facilitation method

Another type of approach has been tested by adding CBE activities into a research and development project rather than taking the education curriculum as the starting point. In this type of approach CBE activity is a tool for increasing a research project's co-operational and dissemination elements by integrating a challenge-based innovation process aboard. University of Turku (UTU) applied this approach in connection to autonomous maritime development in a project which general topic involved the advancement of intelligent fairways and remote pilotage. UTU had a pre-existing innovation process (Business Innovation Camp) based on design sprint which was applied for the project.

The innovation process supported the research project in two ways. Firstly, the part of UTU's business research was to explore the roadmap of international scaling for remote pilotage solutions. There an existing collaboration with the Singapore Maritime Institute was applied to relevant Singaporean organizations for pilotage aboard among Singaporean universities' researchers and students. This enabled in the process eye-opening discussions reflecting the contrasts between two very different operational environments for pilotage between Finland and Singapore. Secondly, the innovation process aim was to introduce a further detailed real-life challenge from the roadmap from today's pilotage operations on the way to remote operations. The chosen challenge was considering possible solutions for tanker berthing if automation or remote operations would be added. The process was supported by maritime educators from Novia University of Applied Sciences and a few technology supplier representatives.

The innovation camp process is a different research-originated approach which enables the students to get involved in really state-of-art discussions from the industry related to different needs and ideas. It doesn't require attributes related to traditional educational courses in the curriculum, but it can introduce opportunities for pioneering dialogues and interaction possibilities for selected students. Therefore it's most beneficial for students who for example have almost completed their studies and are planning for their thesis work or such. However, carrying out the process requires considerably more tailored planning and isn't easy to replicate. But as part of the curriculum for selected students such a CBE framework can offer very detailed, impactful and network-expansive experience as one of the final milestones in any degree.

CONCLUSION

The role of Challenge-Based Education (CBE) extends far beyond a single course; it is a continuous, transformative process that shapes the framework for interaction and drives a cultural revolution in education delivery. In the AutoMare framework, this transformation is reinforced through a feedback loop that shares findings and results. Organized events, such as industry seminars, provide platforms where students present their contributions to stakeholders, creating opportunities to refine and generate new challenges. A key feature of this loop is multidisciplinary rotation, where students are briefly rotated between different disciplines and stakeholders, such as technology developers, operators, and authorities, to broaden their perspectives. This approach not only enriches the learning experience but also fosters continuous innovation and collaboration across fields.

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