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Forming the environmental professional competence of future specialists in ship technical systems and complex operation

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Abstract. The maritime industry contributes to pollution, including oil spills, air emissions (such as sulphur oxides and nitrogen oxides), and ballast water discharge, negatively impacting marine ecosystems. As the global maritime industry continues to move towards stricter environmental regulations, endorsed by the International Maritime Organisation's (IMO) MARPOL Convention (which mandates the reduction of pollution from ships), and more sustainable practices, future ship engineers with environmental competence are crucially needed to meet the demands of the evolving industry. This study explored the use of e-learning facilitated by the LMS Moodle platform for future specialists in ship technical systems and complex operations, particularly in developing environmental professional competence during the Maritime English course. To achieve the research objective, a survey method was employed to collect and analyse information on the development of environmental professional competence among students during discussions in English for Specific Purposes (ESP) classes. The findings indicated that the use of e-courses on the LMS Moodle platform and e-learning through Zoom video conferences significantly contributes to the formation of professional competence among future seafarers. The combination of these technologies provided an interactive approach to learning, allowing students to access educational materials at a time convenient for them and actively participate in distance learning. This method fostered the development of independent work skills, critical thinking, and enhances understanding of specialised topics through interactive discussions and real-time exchange of ideas. The practical value of this research lies in its potential application by teachers when preparing lessons for English for Specific Purposes (ESP), literature, history, and other subjects

Keywords: maritime institutions; marine environment; digitalisation; LMS Moodle; Maritime English; e-learning

INTRODUCTION

Ecology plays a crucial role in the life of every individual, and its significance has only increased in modern times, given the alarming state of the world's oceans and the catastrophic damage caused by harmful emissions from industrial production, oil rigs, and military aggression. The depletion of natural resources, oil spills, and chemical pollutants have resulted in the destruction of ecosystems, endangering marine life and contributing to climate change. The marine industry is deeply intertwined with these environmental issues, as modern ships, while essential for global trade and transportation, contribute significantly to the problem. Large vessels release harmful gases, such as sulphur oxides and nitrogen oxides, which pollute the atmosphere, and their operations often involve discharging ballast water and fuel residues that harm marine species and delicate ecosystems. Furthermore, ship-based accidents, oil spills, and the improper disposal of waste materials have devastating effects on marine biodiversity. As the shipping industry continues to grow and adapt to meet global demand, it faces the challenge of reducing its environmental footprint. Modern ships, particularly those involved in the transportation of goods and resources, must comply with stricter international environmental regulations, such as those set by the International Maritime Organisation (IMO). This compliance necessitates implementing greener technologies, such as cleaner fuels, energy-efficient designs, and more sustainable waste management practices, to minimise the environmental damage caused by the industry.

The role of marine specialists familiar with modern environmental challenges is vital in addressing these issues and preventing negative consequences. Third-year cadets of the ship engineering department study the main components of environmental protection, including the prevention of sea pollution by ship waste and methods for addressing oil spills in the sea. They also identify the causes and consequences of marine pollution, as well as actions for preventing and mitigating marine pollution from ships (Tsimplis, 2020).

Scientists emphasise the importance of seafarer training, focusing on energy-efficient ship operations through the integration of digital tools, addressing knowledge gaps, and enhancing environmental awareness to mitigate climate change (Dewan & Godina, 2024). O. Oloruntobi *et al.* (2023) explore the growing challenges and expectations in the maritime industry driven by technological advancements, analysing the causes and consequences of this revolution with projections beyond 2030. Key findings highlight the development of smart devices, unmanned vessels, and digital transformation in ports, which enhance operational flexibility, energy efficiency, and support the industry's transition towards low-emission systems.

In-water hull cleaning can help reduce fuel consumption and prevent the spread of non-native species by removing foulants from ship hulls, but it also risks releasing toxic antifouling paint residues into the environment. Analysis of cleaning effluents revealed significant levels of suspended solids and metals like copper and zinc, highlighting the need for recovery or treatment to mitigate environmental risks in ports (Soon *et al.,* 2021). A. Loh *et al.* (2020) found that suspended particulate matter (SPM) enhances the dispersion and stability of both mechanically and chemically dispersed oil, preventing recoalescence and improving long-term stability, particularly when smaller particles are present. Oil spill dispersant (OSD) is commonly used to manage marine oil spills by breaking oil into smaller droplets, aiding biodegradation.

This study aimed to describe the e-learning of future specialists in ship technical systems and complex operations on the LMS Moodle platform, specifically to develop environmental professional competence in the Maritime English course.

MATERIALS AND METHODS

The research presents a case study of the Maritime Applied College at Kherson State Maritime Academy. The Maritime English educational programme for future specialists in ship technical systems and complex operation e-learning includes a module devoted to the marine environment. This module covers various topics, such as MARPOL Annexes, SOPEP equipment, prevention of oil spills on deck or in the engine room, and the application and operation of shipboard machines (incinerators, compactors, comminutors).

The experiment was conducted over one academic year – from September to May – and included several key stages: preparatory, ascertaining, formative, and control. Each stage involved the application of various research methods and tools to collect, analyse, and interpret the results. At the preparatory stage (1-2 months), the purpose, tasks, and hypotheses of the research were formulated, and educational and methodological materials were developed for the integration of ecological components into the educational process. Educational groups participating in the experiment were determined, and tools were created for the initial diagnosis of the level of environmental competence, including questionnaires, tests, and control tasks. At the ascertaining stage (3-4 months), an initial diagnosis of the level of environmental knowledge and competencies of students was carried out. The survey and testing enabled the identification of the initial level of environmental awareness, attitudes towards environmental problems, and the ability to apply environmental knowledge in the context of ship technical systems management.

The formative stage (6-8 months) involved the implementation of various teaching methods, particularly electronic courses on the LMS Moodle platform and interactive video conferences on Zoom. Particular attention was paid to the use of group discussions, case methods, and project activities, with an emphasis on the environmental aspects of shipping. During this phase, students engaged in interdisciplinary lectures, analysed real-world situations, and developed environmental strategies for ship operations. At the control stage (1-2 months), a final diagnosis was carried out to assess the effectiveness of the implemented methods.

The collected data facilitated comparisons between the experimental and control groups and helped identify changes in the level of environmental professional competence of future ship specialists.

The experiment involved 120 cadets specialising in maritime disciplines, enrolled in the "Management of Ship Technical Systems and Complexes" programme. Participants were divided into two groups: control (60 students) and experimental (60 students). The selection of groups was based on the principle of random sampling, which ensured the reliability of the results and minimised the possibility of systematic errors in the study. Various research methods were used to achieve the study's objectives. Questionnaires and surveys (conducted via a Google Form, where students answered anonymously) enabled the collection of data on the initial level of environmental awareness, knowledge, and attitudes of students towards ecological problems. Testing was employed to evaluate theoretical knowledge of ecology at various stages of the experiment, allowing an objective assessment of the dynamics of changes. The case method was utilised during practical sessions, where students analysed real-world situations related to environmental challenges in shipping, enhancing their critical thinking and ability to make informed decisions. Observation of the educational process provided insight into the behaviour of students during discussions and active interactions in classes. Zoom video conferences contributed to the development of communication skills in the format of interactive learning.

All procedures performed during the research complied with ethical norms, respecting the honour and dignity of the respondents. Age characteristics were also taken into account. During the pedagogical experiment, no individual's rights were violated, anonymity was maintained, and the research adhered to the developed recommendations regarding the ethical conduct of pedagogical studies provided by authoritative organisations (Declaration of Helsinki, 2013). The main source of materials was drawn from the LMS Moodle platform of Kherson State Maritime Academy, Ukraine (the online course "Maritime English" developed for future specialists in ship technical systems and complex operations). Figure 1 presents the name of the module, along with the corresponding topic, objectives, essential competencies, and the first task.

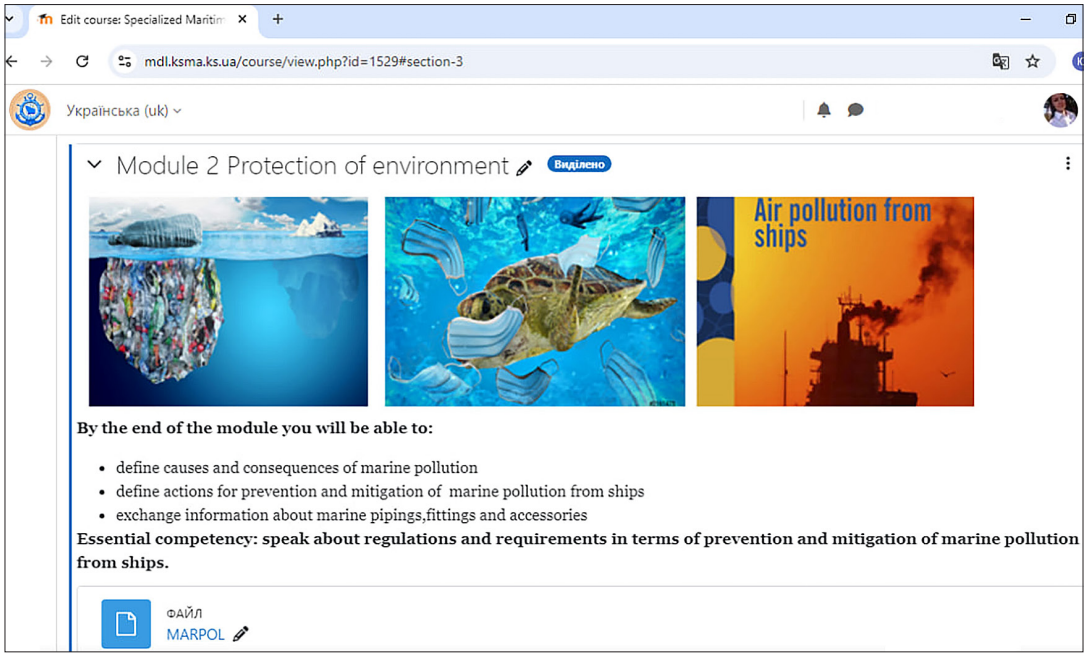


Figure 1. "Protection of Environment" module on LMS Moodle
Source: Maritime English course on LMS Moodle of Kherson State Maritime Academy

RESULTS AND DISCUSSION

The maritime industry is undergoing significant transformation as it adapts to the growing demand for sustainable practices. Ecological competence, or the ability to understand and apply environmentally responsible behaviours, has become increasingly crucial for professionals within this sector, particularly for specialists in ship technical systems and complex operations. This shift is largely driven by several key factors, including the tightening of environmental regulations and the global emphasis on sustainability (Kurban, 2018). The international maritime community has seen a surge in environmental regulations aimed at mitigating the industry's impact on the planet. Organisations such as the IMO have introduced stringent guidelines to address various environmental issues, including pollution, emissions, and waste management (Official website of the International…, n.d.). Notable among these is the MARPOL (Marine Pollution) Convention, which governs the prevention of pollution from ships. MARPOL Annex VI, for example, sets limits on sulphur oxide (SOx) and

nitrogen oxide (NOx) emissions from ship exhausts, pushing the industry towards cleaner fuels and technologies.

Compliance with these regulations is not optional; it is mandatory and enforceable by law. Non-compliance can lead to severe penalties, including fines, detention of vessels, and even criminal charges in some jurisdictions. As a result, specialists in ship technical systems and complex operations must possess a deep understanding of these regulations and the technical expertise to ensure their vessels operate within legal environmental parameters. This need for compliance underscores the importance of ecological competence as a core component of a seafarer's professional skill set. Companies within the maritime sector are now expected to adopt sustainable practices not only as a matter of regulatory compliance but also as part of their corporate social responsibility (CSR). This includes the adoption of cleaner technologies, such as the use of LNG (liquefied natural gas) as a more environmentally friendly fuel alternative, the development of energy-efficient ship designs, and the implementation of comprehensive waste management systems onboard vessels. As key players in the operation and maintenance of maritime vessels, specialists in ship technical systems and complex operations are at the forefront of implementing and managing these ecological practices. Their role extends beyond technical proficiency; they are responsible for ensuring that the ship's systems are not only efficient but also environmentally compliant. This involves understanding the environmental impacts of various shipboard operations, from fuel consumption and emissions to ballast water management and waste disposal.

The development of ecological competence of specialists in ship technical systems and complex operations is therefore critical. It equips them with the knowledge and skills necessary to innovate and adapt to new technologies and practices that minimise environmental harm. Furthermore, as the industry continues to evolve, ecologically competent engineers will be better positioned to contribute to the design and operation of next-generation vessels that meet the highest environmental standards. Moodle is a popular learning management system (LMS) used to create and deliver online courses during e-learning. It provides a wide range of tools for instructors and students to organise the learning process, share materials, conduct tests, and interact within a learning community (Lytvynova, 2015). In Moodle, one can create a variety of exercises that promote interactive and effective learning. Additionally, Moodle supports exercises with pictures, enabling activities related to graphic materials (Mezentseva, 2020). The main types of exercises that can be created on the Moodle platform include:

"Quizzes", which include various types of questions: multiple choice (where answers are presented in the form of images), fill-in-the-blank, matching pairs (useful for subjects requiring visual perception), short answer, ordering (students arrange images in the correct order), extended answer, and others. Images, audio, and video can be added to questions (Mohan, 2018). "Polls", which can also incorporate graphics, enhancing interactivity and engagement. "Assignments", involve activities where students upload their work as text documents, presentations, videos, images, diagrams, or charts. These submissions can be graded and commented upon (Rasool & Dawod, 2021). The benefits of using drawings in Moodle exercises include improved understanding of material, and helping learners grasp complex concepts more effectively. Interactive graphics make learning more engaging and dynamic (Schaffzin, 2016). In Moodle, the "Glossary" activity serves as a collaborative tool for building a collection of terms and definitions relevant to a particular course or subject. It functions like a dictionary, where each entry can include a term, its corresponding definition, examples, and pictures (Fig. 2). Students can contribute to the glossary, making it a dynamic and evolving resource. Teachers can control whether students can add, edit, or delete entries (Striuk & Semerikov, 2022).

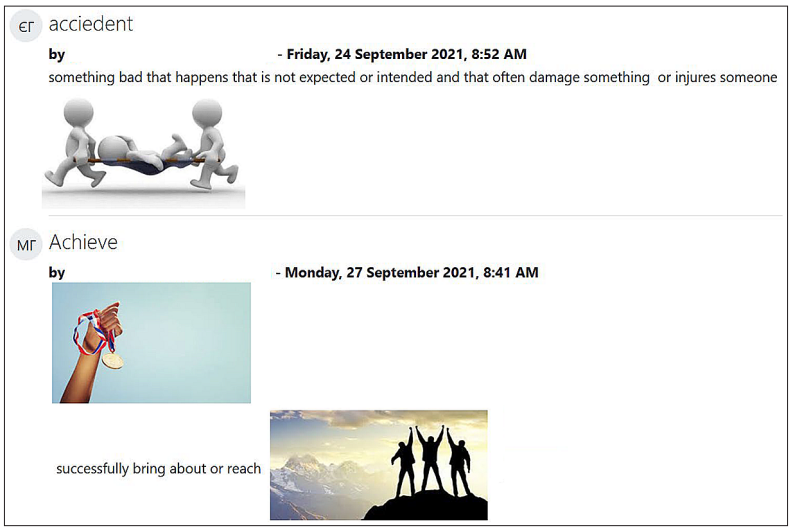
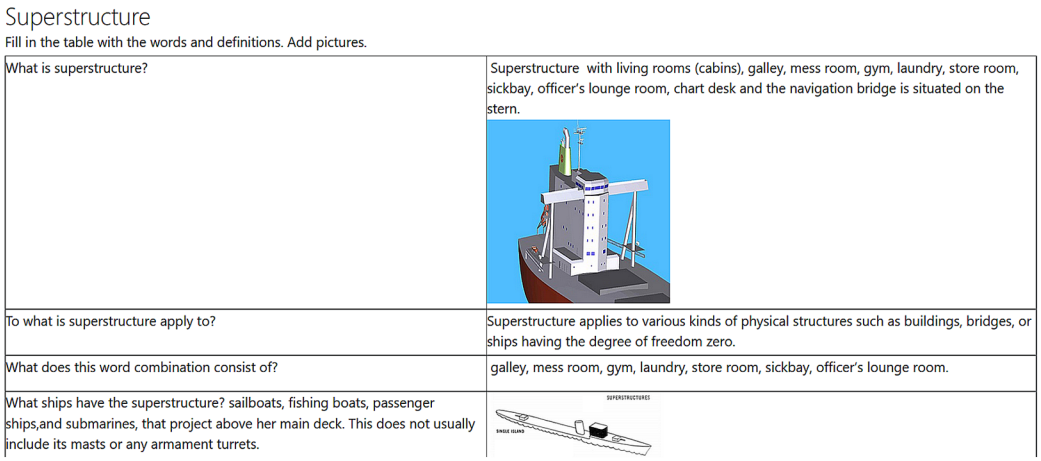


Figure 2. Glossary to the topic "Career Awareness"
Source: Maritime English course on LMS Moodle of KSMA

In Moodle, the "Wiki" activity is a collaborative tool that allows students and teachers to create and edit a collection of interlinked web pages directly within a course (Valko *et al.*, 2021). A Wiki is particularly effective for group projects, where students can work together to develop content, such as a research project, a knowledge base, or a course manual (Yakhontova, 2003). Each participant can add, modify, or delete content, and the Wiki keeps a history of all changes, allowing users to track revisions and contributions. This activity promotes teamwork, encourages collaborative learning, and provides a dynamic platform for creating shared knowledge within a course (Fig. 3).



Superstructure

Fill in the table with the words and definitions. Add pictures.

What is superstructure?	Superstructure with living rooms (cabins), galley, mess room, gym, laundry, store room, sickbay, officer's lounge room, chart desk and the navigation bridge is situated on the stern.
To what is superstructure apply to?	Superstructure applies to various kinds of physical structures such as buildings, bridges, or ships having the degree of freedom zero.
What does this word combination consist of?	galley, mess room, gym, laundry, store room, sickbay, officer's lounge room.
What ships have the superstructure? sailboats, fishing boats, passenger ships,and submarines, that project above her main deck. This does not usually include its masts or any armament turrets.	

Figure 3. Students in a group completing the "Wiki" activity
Source: Maritime English course on LMS Moodle of KSMA

The "Interactive Videos" feature (enabled by H5P integration) allows teachers to create and share rich, interactive content directly within their courses. H5P (HTML5 Package) offers a wide range of content types, including quizzes, interactive videos, presentations, games, and simulations. This tool enables instructors to design engaging learning experiences without requiring advanced technical skills (Zaitseva *et al.*, 2022). The integration seamlessly embeds these activities into Moodle, making them accessible across devices. Additionally, students can interact dynamically with content, such as answering questions within videos or participating in interactive timelines. H5P also supports the inclusion of images from the internet, enabling the creation of visually rich and engaging educational materials. Examples include videos embedded with clickable hotspots, quizzes, and informational popups. For instance, a video tutorial on a topic could pause to ask a question, display images related to the content, or include an image with multiple clickable areas that reveal additional information when clicked. This feature is particularly effective for educational diagrams or maps (Zinchenko *et al.*, 2022).

Additionally, teachers can design slide presentations with integrated multimedia, quizzes, and interactive elements. Images from the internet can be incorporated to create visually appealing and educational slides. These activities can be combined to develop complete courses, including diverse tasks aimed at enhancing both theoretical knowledge and practical skills (Yakhontova, 2003). The use of pictures and graphic tasks contributes to more effective learning, the development of visual literacy, and increased student motivation. At the end of the module devoted to the marine environment, students take a test to demonstrate essential competencies and discuss regulations and requirements related to the prevention and mitigation of marine pollution from ships. Practical lessons and professional training further enhance understanding, particularly through in-depth exploration of environmental aspects specific to maritime work. This includes comprehension of international standards and regulations concerning marine ecology, as well as the organisation of interactions with relevant international organisations and bodies responsible for environmental safety in maritime transport (Liashenko, 2024).

In addition to the methods used (survey, testing, case studies, video conferences, and e-courses on the LMS Moodle platform), several other approaches can further support the development of environmental competence. Engaging students in the creation of practical environmental projects is an especially effective method for enhancing their environmental competence, particularly within the shipping industry (Bekteshi, 2021). This approach enables students to apply theoretical knowledge to real-world scenarios, fostering problem-solving skills through hands-on solutions to current environmental challenges. For instance, one key area for student research is the reduction of emissions from ships. This may involve the development of innovative systems or processes aimed at reducing emissions of harmful substances, such as sulphur oxides (SOx) and nitrogen oxides (NOx), which are critical pollutants linked to shipping. Students can also explore the integration of scrubbers or other emission control technologies into ship operations, analysing the cost-effectiveness and efficiency of these solutions. Another promising area for project work (Fig. 4) is the optimisation of energy consumption aboard ships.

Students may analyse energy use patterns in various ship systems, ranging from propulsion to auxiliary machinery, and propose strategies to reduce fuel consumption. This could include investigating energy-efficient designs, hybrid propulsion systems, or the implementation of waste heat recovery technologies. Projects like these not only improve technical competence but also encourage future specialists to think critically about eco-friendly energy management.

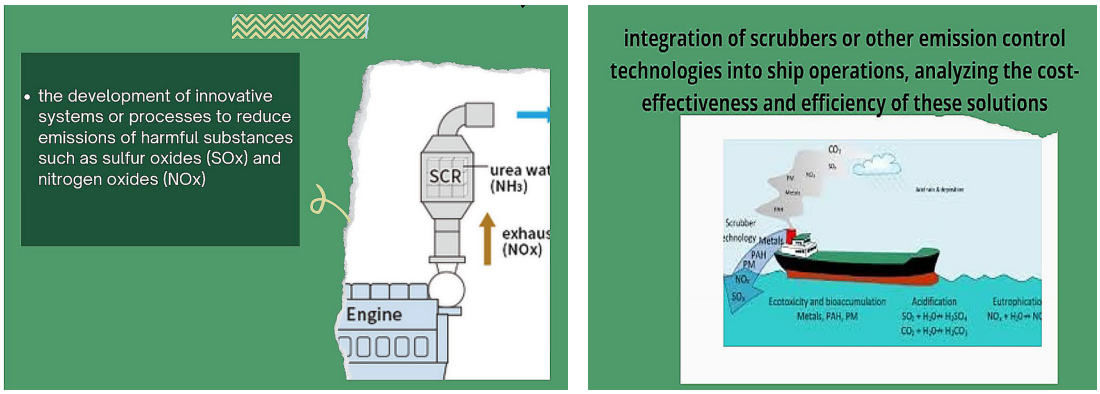


Figure 4. Students' project work
Source: Maritime English course on LMS Moodle of KSMA

In addition, students can work on projects focused on the implementation of alternative energy sources in maritime operations (Semerikov *et al.*, 2020). With the growing importance of sustainability, exploring the use of renewable energy, such as wind, solar, or hydrogen fuel, in shipping provides valuable insights. For example, students might design or evaluate systems for integrating solar panels into ship structures, assess the feasibility of wind-assisted propulsion, or analyse the potential of hydrogen as a clean fuel alternative. These projects encourage innovation and forward-thinking, preparing students to contribute to the decarbonisation of the maritime industry (Sherman *et al.*, 2020). Moreover, project-based training extends beyond technical solutions. Students can be involved in developing environmental policies and frameworks that support sustainable practices within shipping companies or port authorities. They might explore the implementation of green shipping practices or work on establishing guidelines for zero-waste operations aboard vessels. Such activities enable students to understand not only the technical but also the regulatory and managerial aspects of environmental sustainability in shipping.

Project-based learning encourages students to engage in collaborative, interdisciplinary projects (Shintial *et al.*, 2024). For example, they can work alongside professionals from other sectors, such as marine biology, environmental law, or maritime logistics, to create comprehensive solutions to environmental challenges. This approach not only broadens their perspective but also enhances teamwork and communication skills, both of which are essential for future careers in the global maritime industry. Project-based training provides a rich, multifaceted approach to fostering environmental competence. By engaging in real-world projects, students deepen their understanding of sustainability, improve their technical and managerial skills, and contribute to the advancement of greener practices in the maritime sector. The use of computer simulations and ship simulators with an emphasis on environmental aspects enables students to practise practical skills in virtual conditions. These simulations may include practising emergency responses to situations such as oil spills or managing emissions cleaning systems on ships (Kondratenko *et al.*, 2021).

One of the primary advantages of using simulations is the ability to model emergencies, such as oil spills or chemical leakages, that may occur during ship operations. Through these simulations, students gain hands-on experience in managing complex environmental crises, practising the appropriate protocols for containing spills, minimising environmental damage, and coordinating with environmental response teams. This training not only builds their technical expertise but also fosters a deeper understanding of the ecological consequences of maritime accidents and the importance of swift and effective action. Moreover, simulators offer students the chance to explore the use of alternative propulsion systems, such as hybrid or electric engines, and assess their impact on reducing emissions and fuel consumption. By adjusting different variables, such as engine speed, power output, and fuel type, students can observe how these factors influence the overall environmental footprint of a ship's operations. This hands-on experience helps students grasp the complexities of balancing operational efficiency with environmental sustainability (Tyron *et al.*, 2020).

Ecological masterclasses and workshops are essential components of hands-on learning that provide future maritime specialists with the opportunity to directly apply theoretical knowledge in realworld scenarios. By engaging in practical activities focused on waste management, energy efficiency, and environmental technologies, students develop the skills and insights needed to implement sustainable practices aboard ships and in maritime operations. During various classes, students are taught to handle hazardous

and recyclable materials, reduce waste, and use treatment technologies like incineration and sewage systems in compliance with maritime regulations. Additionally, students explore energy-saving strategies, optimise ship systems, and learn about fuel efficiency and renewable energy sources such as solar and hybrid power. Practical sessions introduce students to technologies like ballast water treatment, exhaust gas cleaning, and advanced hull coatings, providing insight into their environmental benefits and maintenance. Workshops also cover environmental impact assessments and ensure students understand international regulations, such as those from the IMO, with exercises on compliance audits and inspections (Official website of the International…, n.d.).

Involving students in scientific research related to marine transport ecology significantly contributes to the development of their environmental competence. Through participation in various research projects, students engage directly with real-world environmental issues, helping them develop a deeper understanding of the ecological challenges within the maritime industry. For example, students participate in pollution monitoring, where they measure levels of air and water pollutants emitted by ships. Using advanced tools and methodologies, they gather data on harmful substances such as sulphur oxides (SOx) and nitrogen oxides (NOx) or track the spread of oil spills (Volkova, 2021). This experience allows them to gain practical skills in environmental monitoring, while also learning how to interpret the data and propose solutions for reducing pollution. Additionally, students conduct research on new environmental standards and analyse their impact on maritime operations (including international conventions like MARPOL). Furthermore, students evaluate the effectiveness of the latest technologies in minimising environmental harm, such as the use of scrubbers, ballast water treatment systems, and alternative fuels. The integration of these methods into the educational process allows for the comprehensive development of environmental competence in future specialists, enhancing their readiness to address modern environmental challenges in the field of shipping.

CONCLUSIONS

In this context, specialists in the operation of ship technical systems and complexes with strong ecological competence are invaluable. They are responsible for implementing sustainable technologies and practices that not only meet regulatory requirements but also align with the environmental expectations of customers and stakeholders. As such, ecological competence is not just a regulatory necessity but also a competitive advantage in the maritime industry. In summary, the growing importance of ecological competence in the maritime industry arises from a confluence of factors, including tightening environmental regulations, global sustainability goals, and evolving industry expectations. For future specialists in ship technical systems and complex operations, developing this competence is essential, as it enables them to navigate the complexities of modern maritime operations while contributing to the industry's sustainable transformation.

The development of ecological competence enhances the level of ecological knowledge, environmental thinking, environmental awareness, and environmentally safe behaviour among future seafarers. The prospects for further research lie in the analysis of external tools (e.g. VR, AR, AI) to develop the environmental professional competence of future specialists in ship technical systems and complex operations. The results of the pedagogical experiment showed that the integration of environmental components into the educational process had a positive effect on the formation of this competence among future specialists in the management of ship technical systems and complexes. Students participating in the experiment demonstrated a significant improvement in their knowledge of environmental standards and their practical application, particularly in areas such as emissions management, energy conservation, and the minimisation of marine pollution.

Further research could focus on identifying the most effective methods of integrating environmental topics into the training of ship technical systems specialists using technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI). These innovations have the potential to significantly improve the absorption of environmental knowledge, increase environmental awareness, and promote environmentally responsible behaviour.

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None.

CONFLICT OF INTEREST

None.

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Формування екологічної професійної компетентності майбутніх фахівців управління судновими технічними системами і комплексами

Анотація. Морська галузь є основним джерелом забруднення, включаючи розливи нафти, викиди в повітря (наприклад, оксиди сірки та оксиди азоту) і скидання баластних вод, що впливає на морські екосистеми. Оскільки світова морська галузь продовжує рухатися до більш суворих екологічних норм, схвалених Конвенцією МАРПОЛ Міжнародної морської організації (ІМО), яка зобов'язує зменшувати забруднення з суден) і більш стійких практик, майбутні суднові механіки повинні бути краще підготовлені з екологічної компетентності, щоб відповідати вимогам галузі, що розвивається. Це дослідження було зосереджено на вивченні використання електронного навчання за допомогою платформи LMS MOODLE для майбутніх спеціалістів у галузі суднових технічних систем і складних операцій, зокрема на розвитку екологічної професійної компетентності під час курсу морської англійської мови. Для досягнення поставленої мети було застосовано метод опитування для збору та аналізу інформації про розвиток екологічної професійної компетентності студентів під час бесід на заняттях з дисципліни «Англійська мова за професійним спрямуванням». Зроблено висновок, що використання електронних курсів на платформі LMS MOODLE та електронного навчання за допомогою відеоконференцій Zoom значно сприяє формуванню професійної компетентності майбутніх моряків. Поєднання цих технологій забезпечує інтерактивний підхід до навчання, дозволяючи студентам отримувати доступ до навчальних матеріалів у зручний для них час та брати активну участь у дистанційному навчанні. Це сприяє розвитку навичок самостійної роботи, критичного мислення та поглиблює розуміння спеціалізованих тем через інтерактивні дискусії та обмін ідеями в реальному часі. Практична цінність даного дослідження полягає в можливості його застосування вчителів у підготовці занять з англійської мови за професійним спрямуванням, літератури, історії та інших спеціальних дисциплін

Ключові слова: морські заклади освіти; морське середовище; діджиталізація; LMS MOODLE; морська англійська; електронне навчання