

# **Integration of Latest Teaching Learning Tools for Multidisciplinary Marine Engineering Curriculum on Autonomous Ships**

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## **Abstract:**

In this review paper, we explore the integration of Modern Teaching and Learning Tools into a Multidisciplinary Marine Engineering Curriculum, in particular, focusing on Autonomous Ships. Indeed, the evolution of the Maritime industry goes hand in hand with technological development, which in this case includes the advent of Autonomous technologies. Therefore, there needs to be a change in approach in order to educate students in a realistic setting. In this way, it is possible to conduct simulations and improve skills in decision-making and technical capabilities. This review paper will focus on the benefits of using/integration of Modern Teaching and Learning Tools, particularly in terms of safety, cost-effectiveness, and the variety of simulation capabilities. It is important to adapt traditional curricula to new technologies and methodologies. As the emergence of autonomous ships imposes multidisciplinary requirements, modern teaching tools such as VR (Virtual Reality), AR (Augmented Reality), MR (Mixed Reality), as well as full mission engine room simulators need to be incorporated into teaching curricula. This paper will explore Latest Tools and Methodologies, their Implementation, and Impact.

**Keywords:** Marine Engineering, Autonomous Ships, Teaching Tools, Learning Methods, Multidisciplinary Curriculum

## **1. Introduction**

The Maritime Industry is undergoing a significant transformation with the advent of Autonomous Ships - Maritime Autonomous Surface Ships (MASS)<sup>1</sup>. These advancements necessitate a re-evaluation of Marine Engineering Education to equip future Engineers with the necessary skills and knowledge. This review aims to explore the Integration of the Latest Teaching and Learning Tools in a Multidisciplinary Marine Engineering Curriculum, focusing on Autonomous Ships.

As per IMO the degrees of autonomy<sup>1</sup> in Autonomous Ships - Maritime Autonomous Surface Ships (MASS) identified for the purpose of the scoping exercise are:

- Degree one: Ship with automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control<sup>1</sup>.

- Degree two: Remotely controlled ship with seafarers on board. The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions<sup>1</sup>.
- Degree three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board<sup>1</sup>.
- Degree four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself<sup>1</sup>.

## 2. Background and Importance

The emergence of Autonomous Shipping offers both challenges and possibilities for Marine Engineering Education. It is imperative that the existing Curricula adapt to meet the requirements of New Technologies and Methods.

The usual methods employed by marine engineering curricula depend significantly upon lectures, an approach that may not necessarily engage the learners and develop their skills. The inclusion of new methods currently involves the use of technologies like Information & Communication Technology (ICT), Computational Fluid Dynamics (CFD). The following are the various aspects of these methodologies.

### 2.1 Innovation in Teaching Methodologies

Autonomous Shipping requires significant changes in Marine Engineering Education, including changes in Curricula to include innovative Technologies and methodologies.

- **Blended Learning:** This methodology includes the use of both online and offline teaching methods, thereby providing flexibility and personalization of the education process. Students get an opportunity to study at their own pace, but still, interact directly with the teachers and classmates
- **Project-Based Learning:** Participation in projects involving analysis and design of ships through use of CFD tools allows for developing students' thinking skills and abilities to work independently in a project-oriented manner. This methodology provides a learning by doing approach, which makes learning relevant and effective.

### 2.2 Emphasis on Developing Specific Skills

- **Skill-based Methods:** It has been found that approaches aimed at developing skills like reading, writing, and oral communication are successful with students of different levels<sup>2</sup>. Thus, emphasis should be placed on skills to ensure the successful application of theoretical knowledge.
- **Sustainable Development Goals (SDG):** SDG-related curricula contribute to sustainable development, preparing specialists to tackle contemporary challenges<sup>3</sup>. Therefore, SDGs can become an important part of the curriculum, encouraging students to think about their actions' environmental consequences.

Despite the benefits of the above methodologies, some teachers may prefer traditional methods of teaching. However, innovation becomes necessary due to the nature of modern marine engineering.

### **3. Latest Teaching and Learning Tools**

#### **3.1 Simulation-Based Learning**

Simulation-based learning has been introduced as an important teaching tool in marine engineering education. Modern simulations give students practical experience of controlling autonomous ships in a risk-free and highly realistic setting. They improve understanding and knowledge acquisition of complex theories thanks to practice in a controlled environment<sup>4</sup>.

#### **3.2 Virtual and Augmented Reality**

Virtual Reality (VR) and Augmented Reality (AR) have started to change the way marine engineering courses are delivered. VR and AR offer interactive lessons where one can immerse oneself into a virtual environment and perform activities that involve the use of VR headset and gloves to simulate handling shipboard machinery or performing certain actions in the Engine Control Room (ECR). In addition, the interaction provides a good understanding of spatial relationships and operations involved<sup>5</sup>.

For example - With the use of state-of-the-art VR technology, a realistic virtual Engine Control Room ECR will be recreated to provide hands-on training on the simulation of generator parallel operations, performed both manually and automatically with the opportunity to control parameters and settings and analyse changes in performance. Moreover, using VR, students will get instructions and guidance on how to prepare the main engine for operation and how to perform a safe start up procedure.

#### **3.3 Online Learning Platforms**

The emergence of online learning platforms has been an important milestone in marine engineering education as it made studying more accessible than ever before. It became the source for educational materials for aspiring marine engineers or even experienced workers who wanted to further their expertise. An evident benefit is the fact that the online method offers flexibility. Learners have the freedom to access materials at their convenient pace and time and integrate their studying and education with other activities such as working on ships in the maritime industry. Moreover, learning in the online space is useful for lifelong education, which allows staying up-to-date with the most recent developments in marine engineering<sup>6</sup>

#### **3.4 Collaborative Learning Tools**

Apart from learning through the web, another important aspect of modern technological progress is the use of collaborative learning tools. Collaboration is facilitated by the use of special applications such as digital whiteboards and software for managing group projects. They allow the exchange of information between peers and encourage the creation of a positive learning environment<sup>13</sup> that fosters the cooperation of students with diverse engineering backgrounds<sup>6</sup>.

Collaboration tools are vital for the development of students' team-working skills and preparation for future career in the maritime industry. Indeed, marine engineering requires collaboration between employees in mechanical, electrical and software engineering disciplines. Therefore, participating in group work and discussion prepares students for the challenges of their job in the field.

#### **3.5 Digital Twin Technology**

One of the newest innovations in marine engineering is the application of digital twin technology in the process of learning. The term 'digital twin' denotes the digital replication or simulation of a physical object,

system, process, or even environment. It adds new opportunities to enhance learning by employing interactive technologies based on the analysis of real-time data to create a virtual representation of a subject matter.

For example, simulation of dynamic operation systems such as cranes<sup>14</sup> used aboard ships enables practice of complex operations in a risk-free immersive environment<sup>14</sup>. Such an opportunity allows gaining experience in dealing with different scenarios and improving one's skills in critical situations<sup>7</sup>.

## **4. Multidisciplinary Approach in Marine Engineering Education**

### **4.1 Interdisciplinary Curriculum Design**

Interdisciplinary Curriculum Design plays an important role in preparing students for the challenges and complexity involved in autonomous shipping. Interdisciplinary Curriculum Design involves approaches in designing a curriculum that incorporates elements of mechanical engineering, electrical engineering, electronics and communications engineering, and software engineering.

### **4.2 Industry Partnerships**

Another important aspect of a good marine engineering education program includes collaboration between educational institutions and industry partners. Forming partnerships with maritime businesses and organizations ensures that students get to learn about the latest technologies and methods used in the industry. Such industry partnerships come in different forms including internships and guest lectures.

This collaboration enhances the curriculum and enables the students to acquire first-hand information about the industry that is very useful in complementing their academic knowledge.

## **5. Challenges and Future Directions**

While there are various advantages associated with the integration of advanced technology into marine engineering education, there are also some challenges that need to be considered. These challenges include technological and pedagogical issues and will be discussed in this section.

### **5.1 Technological Challenges**

Introducing state-of-the-art educational tools for the training of future marine engineers is associated with certain technological problems. First of all, there is the problem of purchasing appropriate hardware and software as well as compatibility. Institutions will have to invest in the proper infrastructure to facilitate the integration of technology.

#### **5.1.1 Understanding the technology:**

The introduction of new technologies requires that teachers learn how to use the latter. Furthermore, they need to understand how to apply these tools during the learning process. The knowledge about the application of new tools is vital to design engaging lessons.

#### **5.1.2 Tech divide**

There is another important issue that needs to be addressed before introducing new technologies. This issue refers to the availability of technologies for students and ensuring equal access to them. Educational institutions need to find ways to overcome the digital divide.

## **5.2 Pedagogical Challenges**

Apart from technological challenges, there are certain pedagogical challenges that teachers will have to address while trying to use innovative methods and techniques. For example, the problem of professional development should be mentioned.

### **5.2.1 Continuous Professional Development**

In today's fast-changing world of education, particularly in marine engineering, professional development is an integral part. It is vital that there is continuous professional development for the teacher in order for him/her to be updated in terms of the use of various tools and approaches to teach effectively. It is important that professional development continues as it affects greatly the education of students and how they would meet the challenges in the maritime industry in the future

### **5.2.2 Support and Continuous Improvement**

In order for the education to be of high quality, the teachers should take part in continuous professional development practices. These practices are very diverse and may include participation in seminars, workshops, online courses, or collaboration in learning communities. In this case, teachers will keep up with the latest developments in technology and pedagogy. Teachers are expected to know about the latest innovations used in the field of education, for example, simulation software and advanced assessments tools. Professional development must not be seen as something that happens only once, but something that happens constantly and promotes self-reflection among educators, who are expected to discuss and come up with solutions to any challenges they face. Such an environment allows teachers to always search for fresh approaches and ideas which will make their work better and ultimately benefit their students.

### **5.2.3 Innovative Activities to Engage Students:**

The element of engagement is significant when considering productive learning in such ever-changing subjects as marine engineering. The instructors will have to develop activities that involve using advanced technology and engaging students' interest for gaining more profound insight into complicated topics. It can be done through the application of multimedia presentations, simulation techniques, and practical assignments that would enable students to apply acquired theory.

For instance, incorporating such innovative approaches like VR/AR can provide opportunities to make learners involved in creative processes, helping them comprehend some difficult notions. Using these technologies, instructors will be able to present material in such a way that it will become more comprehensible for students. It means that by adopting innovative approaches, instructors will ensure a more engaging and active learning process among students.

### **5.2.4 Assessment Methodology for New Tools**

In light of changes in education, it is necessary to develop innovative assessment methods because traditional assessments such as quizzes and tests may no longer reflect student learning. Therefore, it becomes essential to create a mechanism by which one will be able to measure the effectiveness of innovations introduced in the classroom. It will help assess the understanding of students, evaluate their progress, and determine their readiness to move to a higher level.

Student work evaluation can be conducted through the process of assessing work in class, implementing projects, peer-assessment. Such techniques allow evaluating student learning. In case when teachers apply

such techniques, they are provided with the opportunity to assess the students' comprehension of the topic and its application in practice. As we can see, student learning is what needs to be assessed and what these assessment strategies are about. With the help of these methods, one will be able to measure student learning and evaluate the knowledge that students have gained.

### **5.2.5 From learning to team projects:**

The transition from study activities to cooperation during project work is one of the major changes in education. Being able to collaborate with others has become an indispensable part of working life in modern society, which makes it important that students majoring in marine engineering be taught this ability during their studies. The use of online communication platforms can help educators create conditions under which students can help each other by working in teams and exchanging knowledge.

With the help of features such as discussion forums, common workspace and video conferences, educators can foster collaboration and problem solving within groups.

Such platforms will allow students to interact with each other better and prepare for collaboration which might become necessary later during their career. Marine engineering students need to learn teamwork skills through projects. Teamwork is essential in the industry.

Online platforms are useful for marine engineering students to learn from each other. They can use tools, for group work and knowledge sharing. This helps them prepare for their jobs.

### **5.3 Future Trends in Multidisciplinary Marine Engineering Education**

The future trends in marine engineering education will revolve around innovation and adaptation. The suggestion is to concentrate on applying simulators, VR, AR, and digital twins combined with artificial intelligence (AI) and machine learning (ML) tools for the simulation of the process of operating autonomous vessels. Thus, it will be necessary to keep training programs up-to-date and relevant. In addition, the future trends include the rapid development of various courses to ensure the preparation for working with the Maritime Autonomous Surface Ships (MASS).

It will be extremely important to rapidly develop many new courses for preparing for the operation of MASS. As many topics connected to the operation of such ships are not included in the STCW (Standards of Training, Certification and Watchkeeping for Seafarers) requirements at all, there is an obvious need to introduce new themes into the curricula of marine engineering programs<sup>8</sup>.

## **6. Conclusion**

The use of the most advanced technology within teaching and learning process at universities in the sphere of marine engineering is critical to ensure future readiness of students for the upcoming era of autonomous vessels. By using multidisciplinary approach and the power of technology, educational establishments can prepare professionals who will successfully operate in that sphere.

## **References:**

1. <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx>.
2. Bhatt, J. "Marine curriculum: A pragmatic learning technique." OCEANS 82. IEEE, 1982.

3. Zincir, Burak. "Analyzing marine engineering curriculum from the perspective of the sustainable development goals." *Marine Science and Technology Bulletin* 11.2 (2022): 158-168.
4. Nejad, Amir R., Yuriko Aoyanagi, and Michaela Ibrion. "Team and Research Based Learning Methods applied in multidisciplinary marine engineering education." *Journal of Physics: Conference Series*. Vol. 1357. No. 1. IOP Publishing, 2019.
5. Meštrović, Toni, et al. "Challenges for the Education and Training of Seafarers in the Context of Autonomous Shipping: Bibliometric Analysis and Systematic Literature Review." *Applied Sciences* 14.8 (2024): 3173.
6. Bogusławski, K., Gil, M., Nasur, J., & Wróbel, K. (2022). Implications of autonomous shipping for maritime education and training: The cadet's perspective. *Maritime Economics and Logistics*, 24(2), 327–343. <https://doi.org/10.1057/s41278-022-00217-x>.
7. Liu, Z., Chu, Y., Li, G., Hildre, H. P., & Zhang, H. (2024). Shipboard crane digital twin: An empirical study on R/V Gunnerus. *Ocean Engineering*. <https://doi.org/10.1016/j.oceaneng.2024.117675>.
8. Deling, W., Dongkui, W., Changhai, H., & Changyue, W. (2020). Marine Autonomous Surface Ship - A Great Challenge to Maritime Education and 221 Training. *American Journal of Water Science and Engineering*, 6(1), 10. <https://doi.org/10.11648/J.AJWSE.20200601.12>.
9. Dewan, M.H.; Godina, R.; Chowdhury, M.R.K.; Noor, C.W.M.; Wan Nik, W.M.N.; Man, M. Immersive and Non-Immersive Simulators for the Education and Training in Maritime Domain—A Review. *J. Mar. Sci. Eng.* 2023, 11, 147. <https://doi.org/10.3390/jmse11010147>.
10. Kim, Tae-eun, et al. "The continuum of simulator-based maritime training and education." *WMU Journal of Maritime Affairs* 20.2 (2021): 135-150.
11. Mangga, Charles, Paul Tibo-oc, and Ronnie Montaño. "Impact Of Engine Room Simulator As a Tool For Training and Assessing Bsmare Students' performance In Engine Watchkeeping." *Pedagogy/Pedagogika* (0861-3982) 93 (2021).
12. Laskowski, R., Chybowski, L., Gawdzińska, K. (2015). An Engine Room Simulator as a Tool for Environmental Education of Marine Engineers. In: Rocha, A., Correia, A., Costanzo, S., Reis, L. (eds) *New Contributions in Information Systems and Technologies. Advances in Intelligent Systems and Computing*, vol 354. Springer, Cham. [https://doi.org/10.1007/978-3-319-16528-8\\_29](https://doi.org/10.1007/978-3-319-16528-8_29).
13. Nikhilesh, N., Sukesan, R. (2026). Regulatory Challenges of Maritime Autonomous Surface Ships (MASS): Advancing Towards a New Legal Framework. In: Venkatesan, R., Roselyn, J.P., Vijayakumar, K., Sugumaran, V. (eds) *Artificial Intelligence for the Oceans. ICAIO 2025. Lecture Notes in Networks and Systems*, vol 1696. Springer, Singapore. [https://doi.org/10.1007/978-981-95-3978-9\\_18](https://doi.org/10.1007/978-981-95-3978-9_18)
14. Zizheng Liu, Yingguang Chu, Guoyuan Li, Hans Peter Hildre, Houxiang Zhang, Shipboard crane digital twin: An empirical study on R/V Gunnerus, *Ocean Engineering*, Volume 302, 2024, 117675, ISSN 0029-8018, <https://doi.org/10.1016/j.oceaneng.2024.117675>.