

INTEGRATING ECODESIGN AND AI IN YACHT DESIGN EDUCATION: A WORKSHOP CASE STUDY

Massimo PICCIONI, Ludovico RUGGIERO and Arianna BIONDA
Politecnico di Milano, Italy

ABSTRACT

Yacht design is increasingly influenced by the need for sustainability and technological advancement. As environmental concerns grow and regulations tighten, the maritime industry faces pressure to adopt more sustainable practices. At the same time, advancements in Artificial Intelligence (AI) are transforming creative processes and decision-making, presenting new opportunities for innovation. This convergence offers a unique chance to redefine yacht design approaches.

This paper explores the integration of sustainability considerations and AI tools within yacht design education. A design workshop was conducted with 24 students tasked with developing a concept for a 50-foot charter catamaran, using a generic Ecodesign method alongside generative AI tools.

While acknowledging opportunities for future refinement, the study shows the potential of using both the method and tools in early design phases, revealing synergies that can encourage more sustainable projects.

Keywords: Yacht design, Ecodesign, artificial intelligence, sustainability, MPDS

1 INTRODUCTION

The adoption of sustainable design practices is increasingly becoming a critical priority for companies operating within the maritime industry [1], with yacht shipyards being no exception [2]. This shift is driven by market demand for greener products and stricter regulations aimed at reducing environmental impacts. Companies are now recognising that sustainability is no longer a peripheral concern but a central pillar of their operational and strategic approaches. This shift underscores a broader acknowledgement of the environmental and societal repercussions associated with traditional production processes and operational models. Addressing these challenges effectively requires innovative, forward-thinking strategies that embrace sustainability as a core principle rather than an afterthought.

The design phase is especially significant in this context, as research suggests that over 80% of a product's environmental footprint is determined at this stage [3,4]. This highlights the responsibility held by designers to make informed, sustainable choices during the conceptualisation and development processes.

In the field of yacht design, the integration of sustainability principles has historically been overlooked, with limited efforts made to embed these considerations into both industry practices and academic education. The complexity of yachts, involving multiple stakeholders and diverse materials, further complicates its adoption, slowing progress in the field.

Parallel to the growing emphasis on sustainability, Artificial Intelligence (AI) is emerging as a transformative technology with significant implications for the design industry. In recent years, AI has demonstrated remarkable potential to enhance creative processes, expedite early design stages, and support decision-making. Generative AI tools, in particular, enable designers to explore a broader range of solutions through rapid ideation and complex problem-solving [5,6,7]. Due to these advantages, AI's role in education is also expanding [8,9], demanding a reconsideration on how design approaches are taught. This integration not only can accelerate learning but also could prepare future designers to adapt to evolving industry practices.

Following trends observed across creative sectors, yacht design is now confronting the disruptive influence of these emerging tools. Although still in an experimental phase, several professionals are exploring the potential of generative AI tools to develop exterior and interior yacht concepts [10].

Building on the rising interest in both areas, recent research is increasingly exploring the potential synergies between generative AI and sustainability, suggesting that the use of these novel technologies can be beneficial in minimising the environmental impact of products [11,12].

The purpose of this study is to contribute to the preliminary integration of both environmental sustainability considerations and AI into training programmes for yacht design.

Design for Sustainability (DfS) approaches encompass a range of systemic levels, from individual components to broader socio-technical systems. Yacht design, as a profession, predominantly emphasises the product level. As highlighted by Ceschin and Gaziulusoy [13], Ecodesign provides a comprehensive framework for addressing sustainability specifically at this level. Consequently, Ecodesign was selected as the primary approach due to its alignment with the core responsibilities and focus areas of nautical designers. At the same time, a series of AI tools were selected with the primary objective of assisting yacht designers in their workflow.

To explore these aspects in a practical context, a design workshop was conducted in which students focused on the concept design of a 50 ft charter yacht. They were tasked with integrating AI tools into their workflow while adopting an Ecodesign method to enhance the project's environmental profile. The workshop served as a testing ground to investigate the potential and constraints of both approaches, evaluating their individual contributions to the design process as well as their possible interactions and complementarities.

2 MATERIALS AND METHODS

2.1 Workshop structure

The workshop was designed to provide masters' yacht design students with preliminary knowledge and hands-on experience regarding the integration of AI tools and sustainability considerations into the concept design phase of yacht development. A total of 24 students participated, organised into six groups of four members each. Spanning seven days, the workshop centred on developing a 50-foot charter catamaran yacht, intended for the "Albergo Nautico Diffuso" service-oriented model, which envisions yachts more as floating hospitality spaces [14]. The focus was exclusively on the early stages of the design process, emphasising conceptual development rather than detailed engineering. This approach was chosen to encourage creative exploration and problem-solving towards innovative sustainable solutions.

On Day 1, students were provided with all necessary materials and introduced to the tools they used throughout the workshop. This included guidance on how to effectively utilise the selected AI tools and an overview of the Ecodesign method, ensuring that all participants were equipped with the foundational knowledge required for the subsequent design phases.

To guide the design activities effectively, the students' work during the workshop was structured into four distinct phases: Exploration & Inspiration, Creation, Implementation & Refinement, and Finalisation & Delivery. Each phase was crafted to support the progressive evolution of ideas, allowing students to navigate from initial inspiration to well-defined concept proposals. Throughout these stages, continuous guidance and support were provided through design reviews.

- Exploration & Inspiration - Day 2: This phase involved familiarisation with the tools provided and the project theme. Attendees were expected to conduct preliminary research to identify relevant trends, explore opportunities for integrating environmental sustainability principles into the design brief, and investigate innovative solutions for charter yachts. Additionally, the analysis of case studies was encouraged to examine competitors within the industry and therefore to inspire creative thinking.
- Creation - Day 3: Building on the insights gained during the previous phase, this stage focused on defining the design brief. Participants were tasked with developing moodboards and evocative images to establish the key ideas that would guide the project, aiming to solidify the vision and direction.
- Implementation & Refinement - Day 4/5: During this phase, conceptual ideas were translated into design deliverables. The groups were expected to begin with space compartmentalisation and preliminary sketches, gradually advancing to the development of the general arrangement and more detailed drawings through continuous iterations.
- Finalisation & Delivery - Day 6: The final phase involved fully developing and finalising the design concepts. Students were required to produce rendered views and presentation graphics to effectively communicate their design proposals.

Throughout these stages, continuous guidance and support were provided through design reviews. Additionally, these reviews served as a valuable means of gathering feedback on the effectiveness of both the Ecodesign method and the AI tools used during the workshop. The workshop ends on Day 7 with project presentations from all participant groups. After showcasing their work, attendees completed an evaluation survey examining how effectively they incorporated both Ecodesign strategies and AI applications throughout the yacht development process. The assessment explored these tools' usability, their role in shaping design choices, and their overall effectiveness. This feedback helped gauge the applicability of sustainable design methods and identified potential refinements for future implementation.

2.2 Ecodesign method

The ecodesign method selected for the workshop is the Method for Product Design for environmental Sustainability (MPDS), developed by the Design and System Innovation for Sustainability (DIS) research unit at the Design Department of Politecnico di Milano [15]. This method was chosen for its alignment with the UNI ISO/TR 14062:2007 standard and its proven effectiveness, demonstrated through over 20 years of application in Practical projects. MPDS integrates a variety of tools and is systematically structured to support the product design process with the aim of developing environmentally sustainable solutions.

It is organised into three main phases: Product Strategic Analysis and Brief, Concept Design, and Product Design and Engineering. Each phase is directly linked to a specific stage of the product development process. Since the workshop focused on the concept design phase, only the instruction and tools relevant to this stage were applied. Following the MPDS approach, participants were encouraged to generate ideas that integrate sustainable practices into their design proposals. To guide this process, the workshop adopted six Ecodesign strategies outlined by the MPDS method:

1. Use extension/intensification
2. Material consumption reduction
3. Energy consumption reduction
4. Material life extension
5. Toxicity reduction
6. Resources conservation/biocompatibility

To facilitate the application of these strategies, participants were provided with eco-ideas boards, a tool within the MPDS framework that offers practical guidelines for each Ecodesign strategy. These boards present a series of actionable insights across various sub-processes, which are often highly specific. Consequently, each group was required to carefully select the most relevant guidelines that could be potentially applicable to the context of yacht design.

2.3 AI tools

In this workshop, various AI tools were made available to the students to examine their applicability within yacht design education, assessing not only their effectiveness in accelerating the early design phases but also their capability to support the integration of Ecodesign strategies. To cover the most common applications of generative AI in design, a selection of tools was provided, each representing a different approach to AI-assisted creativity:

- Text to text – ChatGPT: this AI chatbot is built on large language models that engage in conversational dialogue and help users with various tasks like writing, coding, analysis, and creative projects.
- Text to image – Midjourney: this is an AI image generation tool that creates detailed artwork and illustrations from text descriptions. Users input text prompts describing their desired image, and the AI produces unique visuals by combining elements from its training data.
- Image to image – Vizcom: this tool is specialised in transforming rough sketches and basic drawings into more refined product design visualisations, proving useful for concept illustrations.

All AI applications offered a free-to-use plan, except for Midjourney, for which licenses were provided on the first day of the workshop.

3 RESULTS

3.1 Ecodesign method

The analysis of survey responses and feedback gathered during design reviews revealed insights into

the perceived ease of integration, influence on the design process and output, as well as the applicability and scope of the method.

3.1.1 Easiness

- Which Ecodesign strategies did you find easiest to apply during your project?
- How easy or difficult was it to integrate Ecodesign strategies into your existing design process?
- Were there any Ecodesign strategies that you found difficult or impractical to implement? If so, why?

The integration of Ecodesign strategies was generally perceived as manageable. Half of the groups rated the integration as neutral, two groups found it relatively easy, while one group reported moderate difficulty. Among the six Ecodesign strategies, “use extension/intensification” was consistently identified as the easiest to implement, with five out of six groups indicating its straightforward application. Conversely, material-related strategies and toxicity reduction were perceived as the most challenging. Participants attributed these difficulties to limited knowledge of sustainable materials and the technical complexities involved in yacht production. Specifically, the toxicity reduction strategy required expertise beyond the participants' familiarity, leading to its non-implementation by any group.

3.1.2 Influence on design process and output

- How did the Ecodesign strategies influence your overall yacht design process?
- How did the application of Ecodesign strategies affect the decision-making process in your design?
- To what extent did you feel that Ecodesign strategies limited or expanded your design options?

All groups acknowledged that the Ecodesign strategies influenced their design process by enhancing the focus on sustainability, particularly in material selection and production methods. Four groups reported substantial changes in their design approach from the early stages, while the remaining two groups noted moderate to minor adjustments. Notably, the integration of MPDS tools did not significantly impact project timelines, as confirmed by all groups. Regarding the influence on design options, only two groups perceived an expansion of possibilities, whereas the majority reported a neutral impact.

3.1.3 Applicability and scope

Feedback gathered during design reviews highlighted the key strengths and limitations of the MPDS method. On the positive side, several eco-ideas board suggestions were easily implementable, enabling immediate integration of sustainability considerations. Additionally, the method required minimal prior knowledge of sustainability, facilitating its use by novice designers. However, significant challenges were identified concerning the scope and applicability of the guidelines. For complex products such as yachts, the extensive number of guidelines made it difficult for participants to simultaneously address all aspects. Furthermore, many guidelines were perceived as overly detailed and more relevant to later stages of product development rather than the conceptual phase targeted in this workshop. Participants also noted that certain Ecodesign strategies fell outside the scope of a nautical designer's responsibilities.

3.2 AI tools

The analysis of survey responses revealed insights into the perceived usefulness and intuitiveness of the AI tools.

3.2.1 Usefulness

- How would you rate the overall usefulness of AI tools in your project?
- Which AI tools proved to be the most useful?

Five out of six groups rated the AI tools as moderately useful, while one group considered them slightly useful. The primary reason for this assessment was the gap between expectations and actual results. Although participants found the tools valuable for a range of tasks, they consistently encountered limitations in controlling the desired outputs. According to the survey, ChatGPT proved to be most useful, followed by Midjourney and then Vizcom, which was used by only four groups.

3.2.2 Intuitiveness

- How intuitive did you find the use of AI tools?
- Did you face any challenges when using the AI tools? If so, which ones?

ChatGPT was perceived as the most intuitive tool, with most groups reporting no significant issues. Midjourney was mostly rated neutral, with prompt engineering being the main challenge. Participants

struggled to craft effective prompts, often requiring multiple iterations to obtain the desired outputs. Among the four groups that used Vizcom, half found it quite challenging, as the tool struggled to accurately interpret sketches unless they were highly precise. As a result, some groups resorted to post-processing the outputs using Photoshop to better align them with their design intentions.

3.3 Potential synergies between ecodesign method and AI tools

During the design reviews conducted throughout the workshop, the integration of the MPDS method and AI tools was closely monitored at various project stages to explore potential synergies identified by participants.

In the Exploration & Inspiration phase, students experimented with eco-ideas boards and used ChatGPT for preliminary research on target audiences, trends, and creative concepts related to catamaran design. A particularly effective approach involved combining ChatGPT with the eco-ideas boards by inputting the boards' content into the AI tool. This strategy helped participants to better interpret the guidelines and identify those most relevant to their design context.

Midjourney was predominantly used during the Creation phase, aiding in the generation of initial concept visuals and moodboard imagery. By incorporating elements from the eco-ideas boards into the prompts, students were able to translate the design suggestions into visual outputs, effectively guiding the spatial planning and conceptualisation process.

As reported by the participants, Vizcom was mainly utilised in the final stages of the concept development. Although it helped accelerate the rendering of sketch images, participants noted challenges in integrating its use with the MPDS method. They pointed out that by this stage, their focus was primarily on refining the aesthetics, leaving limited opportunities to incorporate sustainability considerations.

4 DISCUSSION AND CONCLUSIONS

The present study investigates the integration of a generic Ecodesign method and AI tools within a yacht design workshop, exploring their effectiveness and potential synergies in this discipline. The findings highlight both opportunities and challenges in the implementation of these approaches, providing insights for future improvements in yacht design education.

The results of the workshop indicate that while the ecodesign method provided a structured framework to incorporate sustainability into the design process, some challenges emerged in its application. Survey responses and design reviews revealed that students encountered difficulties in implementing material-related ecodesign strategies, particularly those involving toxicity reduction and sustainable material selection. This difficulty stems from the limited availability of sector-specific databases on sustainable materials for yacht design. Consequently, the development of dedicated material repositories for the maritime industry emerges as a crucial step toward facilitating the application of ecodesign principles. Participants highlighted that certain ecodesign strategies were too detailed for the concept phase, while others extended beyond the typical role of a yacht designer. This suggests the importance of structuring the guidelines to better align with the specific phases of the yacht design process. At the same time, incorporating multidisciplinary teams in ecodesign courses for the nautical sector could enhance learning by fostering knowledge exchange among students with diverse backgrounds, ultimately providing a more comprehensive perspective on sustainable yacht design.

The integration of AI tools in the workshop highlighted the necessity of structured guidance to maximise their potential in yacht design. The challenges encountered in controlling outputs and adapting AI-generated content to specific design needs suggest that these tools should not be introduced as standalone solutions but rather as complementary instruments within a well-defined workflow. Without prior training, their benefits remain limited, as users may struggle to fully exploit their capabilities.

To enhance their effectiveness in future applications, it would be beneficial to develop targeted educational materials specifically designed for the yacht design context. This would allow students to approach AI with a clearer understanding of its constraints and possibilities, ultimately fostering a more strategic use of these tools in early-stage design processes.

The findings suggest that AI's potential in ecodesign for yacht design lies in augmenting the creative and research phases. However, to be truly effective, AI tools must be better structured within the design workflow, with clearer guidance on their strategic use. Future implementations should focus on developing tailored AI applications that directly support ecodesign strategies, such as material selection databases or automated sustainability assessments, bridging the gap between conceptual ideation and

practical application. Our insights are intended to encourage further advancements in yacht design education, where AI tools and ecodesign methodologies can evolve beyond their current roles. By refining their integration and developing more specialised resources, future workshops and academic programmes should foster a more seamless adoption of sustainability principles, equipping designers with the skills needed to navigate the complex challenges of sustainable yacht design.

ACKNOWLEDGEMENTS

The paper is part of the research conducted for the NEMO project, funded by PNRR Made in Italy Circolare e Sostenibile (MICS), grant number PE_00000004.

REFERENCES

- [1] Jacquet L., le Duigou A. and Kerbrat O. A systematic literature review on holistic lifecycle assessments as a basis to create a standard in maritime industry. *Int J Life Cycle Assess*, 2024, 29, 683–705.
- [2] Ansaloni G. M. M., Bionda A. and Ratti A. The Evolution of Yacht: From Status-Symbol to Values' Source. In: Zanella, F., et al. *Multidisciplinary Aspects of Design. Design! OPEN 2022*. Springer Series in Design and Innovation, vol 37, 2024, (Springer, Cham).
- [3] Directorate-General for Communication (European Commission). Circular economy action plan: For a cleaner and more competitive Europe. *Publications Office of the European Union*, 2020.
- [4] Hauschild M. Z., Rosenbaum R. K. and Olsen S. I. *Life Cycle Assessment: Theory and Practice*, 2018 (Springer, Cham).
- [5] Yin H., Zhang Z. and Liu Y. The Exploration of Integrating the Midjourney Artificial Intelligence Generated Content Tool into Design Systems to Direct Designers towards Future-Oriented Innovation. *Systems*, 2023, 11(12), Article 566.
- [6] Shin D.-Y. The Role and Utilisation of AI: An Integrated Approach with ChatGPT and DALL.E in Architectural Design, *Journal of the Architectural Institute of Korea*, 2024, 40(2), 67-76.
- [7] Kaljun K. K. and Kaljun J. Enhancing Creativity in Sustainable Product Design: The Impact of Generative AI Tools at the Conceptual Stage. *Proceedings of the 47th ICT and Electronics Convention*, MIPRO 2024, Opatija, 451 - 456.
- [8] Kasneci E. et al. ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 2023, 103, 102274.
- [9] Popenici S.A. and Kerr S. Exploring the Impact of Artificial Intelligence on Teaching and Learning in Higher Education. *Research and Practice in Technology Enhanced Learning*, 2017, 12(1), 1-13.
- [10] Zaltman J. Using AI in yacht design: the pitfalls and potential. Available: <https://www.boatinternational.com/yachts/yacht-design/ai-yacht-design> [Accessed on 2025, 26 February], (2023, 20 December).
- [11] Rane N. Roles and challenges of ChatGPT and similar generative artificial intelligence for achieving the sustainable development goals (SDGs). Available at SSRN 4603244, 2023.
- [12] Li M. et al. (2024). Generative AI for Sustainable Design: A Case Study in Design Education Practices. In: Kurosu, M., Hashizume, A. (eds) *Human-Computer Interaction. HCII 2024. Lecture Notes in Computer Science*, 2024, vol 14687 (Springer, Cham).
- [13] Ceschin F. and Gaziulusoy I. *Design for Sustainability: A Multi-level Framework from Products to Socio-technical Systems*, 1st ed., 2021 (Routledge, London).
- [14] Regione Autonoma della Sardegna. *Legge regionale n. 13 del 21 giugno 2021: Riconoscimento dell'albergo nautico diffuso. Modifiche alla legge regionale n. 16 del 2017*. Bollettino Ufficiale della Regione Autonoma della Sardegna (BURAS), n. 37, Parte Prima.
- [15] Vezzoli C. *Design for Environmental Sustainability: Life Cycle Design of Products*, 2nd ed., 2018 (Springer, Cham).