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Blue Thinking: Human-Centered Design for Sustainability and the Blue Economy in Education

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ABSTRACT

This paper introduces Blue Thinking, an integrative framework combining human and activity-centered design with sustainability education and the blue economy. Developed within the Blue Design Alliance (BDA) - a consortium led by College of Art and Design (ESAD) in Portugal and supported by the national Recovery and Resilience Plan (PRR) - the framework reconceptualises water as a material and epistemic medium, symbolizing adaptability, interdependence and systemic flow across human-technology-ecosystem relations. Methodologically, the study employs research-through-design and project-based learning across 36 interdisciplinary short courses (delivered from 2022 until 2025). Mixed data sources - observations, interviews and institutional metrics on enrolment, completion, satisfaction, and sustainability integration - provide our evidence base. Four representative case studies demonstrate the framework's application: Editorial Design for Community Contexts (communication and identity), Interior Design for Nautical Environments (adaptive spatial intelligence), Food Design for Sustainability (ethical and sensory literacy), and Illustration and Digital Narratives (ecological communication). Results reveal measurable improvements in students' systems thinking, ecological literacy, and technological self-efficacy. Findings indicate that intelligent systems augment rather than replace human judgment, enhancing decision-making in design. Blue Thinking thus operates as a model of augmented-intelligence learning, linking creativity, ethics, and technology within sustainability-oriented design pedagogy. Aligned with European Union (EU) and United Nations (UN) sustainability frameworks, Blue Thinking positions higher education as a catalyst for systemic change, preparing designers to act as agents of ecological transition, social inclusion, and circular innovation.

Keywords: Blue thinking, Human-centered design, Co-design, Sustainability, Blue economy, Design education

INTRODUCTION

Design education faces a critical transition. As environmental degradation, marine pollution, and freshwater scarcity in the twenty-first century, reveals the systemic inadequacy of prevailing industrial and educational paradigms, calling for integrative design approaches that bridge human, technological, and ecological domains (UNEP, 2023). Within this context, Blue Thinking is

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proposed as a framework that integrates ecological literacy, systemic thinking, and new technologic tools in design education. It reframes water not merely as a resource but as an epistemic and design medium - fluid, connective, and dynamic - through which design navigates the interdependence of humans, intelligent systems, and ecosystems.

Developed and implemented at College of Art and Design (ESAD) through the Blue Design Alliance (BDA) - a consortium of four Portuguese higher education institutions supported by the national Recovery and Resilience Plan (PRR, 2024) - it operates as a living laboratory linking teaching, research, and local innovation. The framework aligns with the principles of the New European Bauhaus and the UN Sustainable Development Goals, positioning design as a mediating practice between human and environmental systems.

This paper analyses how Blue Thinking has been applied across 36 short courses conducted between 2022 and 2025, involving over 500 participants from diverse disciplinary backgrounds. Through a mixed Research-through-Design (RtD) and Project-Based Learning (PBL) methodology, the study explores how intelligent systems, sustainable materials, and collaborative models contribute to new forms of learning and practice. The research addresses three questions: (RQ1) How can Blue Thinking principles and metrics be operationalized in design education? (RQ2) What effects does the framework have on systems thinking, ecological literacy, and technological self-efficacy? (RQ3) Under what conditions can intelligent systems amplify sustainable decision-making in design processes? By answering these questions, the study contributes to current debates in human-computer interaction, sustainability pedagogy, and responsible innovation, positioning Blue Thinking as a replicable model for integrating intelligent systems and ecological ethics into design education.

THEORETICAL FOUNDATIONS

Design has long operated within paradigms that privilege human experience as the central driver of value creation. Human-Centred Design (HCD) and Activity-Centred Design (ACD) provided essential frameworks for understanding usability and the relationship between people and artefacts (Norman, 2013; Bødker, 2015). Yet, their anthropocentric emphasis increasingly conflicts with contemporary environmental and socio-technical realities. As climate change, biodiversity loss, and digital transformation redefine the boundaries of design, scholars have argued for broader systemic perspectives capable of integrating ecological, social, and technological dimensions (Forlizzi, 2018; Filho, 2024).

This critical shift has generated several approaches that reposition design beyond the human scale. Post-humanist (Haraway, 2023) and systemic design theories challenge designers to consider interdependencies between human and non-human actors, infrastructures, and ecosystems (Manzini, 2015; Kunrath and Beliatis, 2022). Ecological design and regenerative design extend this trajectory by framing design as an instrument for restoring, not

merely sustaining, planetary systems (McDonough and Braungart, 2009). Within education, these shifts demand new literacies, what Echeverry et al. (2025) define as *sustainability competencies* combining critical thinking, collaboration, and adaptive problem-solving.

Parallel to these ecological turns, the emergence of intelligent and computational systems has transformed design processes. Algorithmic modelling, AI-assisted prototyping, and digital fabrication now mediate many design decisions. Scholars such as Floridi (2019) and Manna et al. (2022) describe this transition as a move from artificial intelligence to augmented intelligence, where technology amplifies, rather than replaces, human judgment. Integrating such tools ethically and critically into design education requires not only technical proficiency but also epistemic awareness, students must understand how algorithms shape design knowledge itself.

Against this backdrop, the Blue Thinking framework was conceived as a methodological and pedagogical synthesis. It links three domains often treated separately: Systems Thinking (understanding interrelations between materials, environments, and human behaviours); Ecological Literacy (recognising design as an ecological act embedded within circular and regenerative economies); Augmented Intelligence (using digital and intelligent systems to expand perceptual and decision-making capacities). Blue Thinking extends human and activity-centred approaches by embedding design within *water-based and ecological systems*, both metaphorically and materially. The "blue" dimension symbolises fluidity, connectivity, and systemic interdependence, aligning with UN-Water 2030 Strategy (United Nations, 2020) and the New European Bauhaus principles of sustainability and inclusiveness (European Union, 2021). Within design education, the framework encourages learners to think across scales - from material experiments to local ecosystems - and to prototype collaboratively with communities and industry.

This theoretical foundation underpins the study presented in the following sections, where Blue Thinking is implemented as a pedagogical model. The next section details the research context and methodology adopted to operationalise and assess this framework in practice.

METHODOLOGY

This study adopts a Research-through-Design (RtD) and Project-Based Learning (PBL) methodology to operationalize and evaluate the Blue Thinking framework as implemented at ESAD between 2022 and 2025. Rooted in Schön's (1992) theory of *reflective practice*, RtD is understood here as a process of inquiry through making, reflection, and iteration. Within Blue Thinking, this model is expanded through insights from sustainability science, human–computer interaction, and environmental psychology, establishing a transdisciplinary foundation for innovation.

At ESAD, Blue Thinking was embedded across short-term courses, postgraduate programs, and technical degrees (CTeSP) linked to BDA. These courses integrate sustainability, digital intelligence, and co-design with local communities, aligning pedagogy with the blue economy and the UN Sustainable Development Goals. Practice-oriented modules engaged students with real challenges - such as water management, marine pollution, and community resilience - through iterative stages of empathy, ideation, prototyping, and testing, complemented by ecological systems mapping and life-cycle analysis. This approach enabled students to examine how design decisions affect broader socio-ecological systems and to test intelligent systems as mediators for sustainable innovation.

Sample, Context, and Data Collection

Between 2022 and 2025, ESAD implemented the Blue Thinking framework across 36 certified short courses under the Blue Design Alliance, totalling 1,296 contact hours and involving over 500 participants (EQF level 6). The programs included *Design Thinking*, *Green Design for Boats*, *Editorial Design for Community Contexts* and *Food Design for Sustainability*. Each course combined theoretical seminars, laboratory experimentation, and collaborative projects with students, professionals, and community stakeholders. Collectively, these courses generated more than 100 design outputs - including prototypes, publications, digital projects, and awareness campaigns - with an average completion rate of 94% and participant satisfaction of 4.6/5, forming the empirical foundation for evaluating the Blue Thinking approach.

Data collection integrated three complementary sources: (1) observational data from studio and community fieldwork; (2) qualitative data from semi-structured interviews with students and faculty; and (3) quantitative indicators on material efficiency, stakeholder engagement, and digital-tool adoption. Triangulation across these datasets ensured internal validity by cross-referencing observations, self-reports, and institutional statistics. Quantitative data were analysed using descriptive statistics, while qualitative material underwent thematic analysis following a grounded-theory logic (Creswell & Plano Clark, 2018).

All activities adhered to the Responsible Research and Innovation (RRI) principles (von Schomberg, 2013). Participants provided informed consent, and data management complied with EU General Data Protection Regulation (GDPR) standards. The documentation process emphasised transparency, inclusivity, and reflexivity, aligning with Floridi's (2019) notion of informational integrity, whitch frames design as an ethical mediator between human agency, intelligent technologies, and planetary boundaries.

Esad - Blue Design Alliance Course Overview

Table 1: Overview of ESAD-BDA courses (2022–2025). Source: ESAD internal KPI management data, 2022–2025.

Course (CCD/UC)	Year	ECTS	Hours	European Qualification Framework (EQF)	National Classification of Educational Areas	KPI's (Number of Students With Diploma)
Design thinking	21/25	3/6	24/48	6	214 — Design	**53**
Green boat design	22/23	6	48	6	214 — Design	**11**
Specialisation and leadership in blue economy	22/23	3	24	6	314 — Economy	**16**
Food packaging design	22/25	6	48	6	214 — Design	**14**
Boat interior design	23/25	6	48	6	214 — Design	**35**
Materials and sustainability	23/24	6	48	6	214 — Design	**9**
Editorial design	23/24	3	24	6	214 — Design	**5**
Sustainable materials and technologies	23/24	3	24	6	214 — Design	**34**
Food design	23/25	3	24	6	214 — Design	**32**
Comic books	24/25	3	24	6	214 — Design	**17**
Design thinking advanced	24/25	6	48	6	214 — Design	**18**
Between water and land: Siza Vieira's photography	24/25	3	24	6	214 — Design	**12**
Self-construction	24/25	6	48	6	214 — Design	**11**
Prototyping and 3D printing	24/25	3	24	6	214 — Design	**14**
TOTAL						**281**

Educational and Sustainability Indicators

Table 2: Key performance indicators (ESAD 2022–2025.) Xource: ESAD-BDA records, 2022–2025.

Indicator	Average Value	Description
Student satisfaction	4.6 / 5	Mean evaluation across courses
Female participation	68%	Gender balance indicator
Interdisciplinary collaboration	> 80%	Projects involving cross-department teams

Continued

Table 2: Continued

Indicator	Average Value	Description
Digital tool adoption	87%	Use of AI, parametric or fabrication tools
Sustainability integration	92%	Projects applying eco-design methods
Community-based projects	68%	Projects developed with external partners
Diploma issuance	94%	Certificates awarded vs. enrolments

Results and Outcomes

Quantitative indicators from ESAD's BDA programme (2022–2025) reveal a consistently strong performance across pedagogical, technological, and sustainability dimensions. Across 36 certified short courses (≈1,296 contact hours; >500 participants), the average completion rate reached 94%, participant satisfaction 4.6/5, and digital tool adoption 87%. Sustainability integration was notably high: 92% of projects incorporated eco-design principles or life-cycle analysis, and 68% engaged external partners such as municipalities, cultural associations, and local industries. The qualitative analysis of interviews (n=42) highlighted several recurring themes that align with Blue Thinking's core dimensions:

1. Systems Thinking and Ecological Literacy: Students demonstrated increased awareness of material, human, and ecological interconnections, articulating design decisions in terms of energy efficiency, water circularity, and life-cycle implications.
2. Collaborative Learning and Community Engagement: Interdisciplinary teamwork enhanced empathy and problem-solving capacity, translating abstract sustainability goals into tangible community outcomes (e.g., *Editorial Design for Community Contexts*, *Green Design for Boats*).
3. Technological Confidence and Critical AI Use: Participants valued digital fabrication, parametric modelling, and AI-assisted visualisation as enablers of creativity, while emphasising critical reflection to prevent techno-solutionism - echoing Floridi's (2019) ethical mediation between human and artificial intelligence.
4. Affective Engagement and Professional Identity: Students linked Blue Thinking to a renewed sense of purpose, redefining design as an act of collaboration *with*, rather than *for*, ecosystems.

Overall, the ESAD-BDA experience confirms that Blue Thinking bridges human-centered interaction, intelligent systems, and ecological literacy. The framework generated measurable gains in technological self-efficacy, reflective reasoning, and environmental responsibility, positioning design education as a practical arena for responsible innovation where sustainability becomes an operational, assessable component of learning.

CASE STUDY: THE BLUE DESIGN ALLIANCE CURRICULUM

The BDA is a consortium uniting ESAD, the Polytechnic Institute of Viana do Castelo, the Polytechnic Institute of Bragança, and the Catholic University of Portugal. Supported by the Portuguese Recovery and Resilience Plan (PRR, 2024), it represents a pioneering educational model in the blue-economy cluster. The Alliance's primary goal is to cultivate professionals capable of designing sustainable systems and products that respect aquatic ecosystems and promote regional economic resilience. Its programmes include: Technical Professional Courses (CTeSP) in sustainable product and interior design; Postgraduate Diplomas in Circular and Sustainable Water Design; Short Courses, Summer Schools and Conferences (Water Design Views) addressing co-design, eco-materials, and digital fabrication. Each programme adopts interdisciplinary teamwork as a pedagogical principle, pairing design students with peers from biotechnology, environmental science, and engineering.

BDA aligns with key policy instruments such as the European Green Deal, Horizon Europe, and the New European Bauhaus (European Commission, 2021). Globally, it contributes to UN SDG 12 (*Responsible Consumption and Production*) and SDG 14 (*Life Below Water*), while maintaining coherence with United Nations Institute for Training and Research (UNITAR) and UN-Water 2030 Strategy (United Nations, 2020).

We collaborate with a diverse network of stakeholders including CIIMAR, CEiiA, Fórum Oceano, and local municipalities. These partnerships enable field-based research on coastal regeneration, sustainable tourism, and circular production in maritime industries. Students co-design solutions such as biocomposite furniture using hemp and marine by-products, or digital platforms for monitoring water quality. Such projects exemplify the fusion of material experimentation and data-driven environmental awareness central to Blue Thinking. Organized around four macro-areas - Water Resource Management, Culture and Water Literacy, Maritime Technologies, and Health, Tourism and Well-being - the curriculum integrates digital fabrication, AI-assisted visualization, and co-creation workshops. Evaluation combines project portfolios, reflective essays, and peer assessment to measure both technical competence and socio-ecological awareness.

Applied Cases and Pedagogical Integration

The pedagogical framework of the BDA reflects a systemic and human-centered approach to contemporary design education. Its short-term courses function as micro-laboratories for innovation, encouraging participants to engage with complexity through experimentation, collaboration, and critical reflection. Rather than isolating technical skills from ethical and environmental awareness, each module merges creative processes with sustainability and digital intelligence, reinforcing the capacity of design to act as a transformative force in society. This section presents four applied cases that exemplify the pedagogical model across distinct yet complementary domains. Together, these courses demonstrate how project-based, interdisciplinary education can operationalize the integration of *human intelligence* and *technological systems* in creative learning, fostering ecological responsibility and socio-cultural relevance.

Case 1: Editorial Design for Community Contexts

The *Editorial Design* short course exemplified how design mediates between communication, place, and identity through project-based learning. Centered on the *Mercado Municipal de Matosinhos*, students developed editorial systems translating the market's sensory and social atmosphere into visual narratives combining photography, typography, and spatial rhythm. The iterative process of peer critique and reflection mirrored an intelligent-systems learning model based on observation, feedback, and synthesis. Beyond aesthetic production, the course positioned editorial design as a socio-technical interface connecting civic participation with cultural identity. The outcomes demonstrated that short, experimental modules can cultivate sustainable and inclusive values through community-oriented design, integrating hierarchy, modularity, and rhythm as communicative strategies.

Case 2: Interior Design for Nautical Environments

The *Interior Design for Boats* course addressed the convergence of human-centered creativity and technical precision in constrained environments. Through intensive project-based learning, students developed interior layouts for small vessels, integrating ergonomics, modularity, and space optimization. The course's diagnostic–formative–summative assessment fostered reflective iteration and peer learning. By simulating real-world conditions and emphasizing adaptive reasoning, the methodology aligned with human-centered intelligent systems. Students demonstrated an ability to reconcile comfort, efficiency, and sustainability within limited space, revealing how applied, short-term modules can strengthen interdisciplinary competencies and ecological awareness in higher design education.

Case 3: Food Design as a Tool for Sustainable and Inclusive Innovation

Led by Ricardo Bonacho, the *Food Design* course expanded design education into the multisensory and ecological domain. Structured around four modules - from taste physiology to food literacy - it linked sensory exploration with sustainability and social inclusion. Exercises such as *If I Were a Food* reframed food as a design material, connecting embodied cognition with ecological systems. In the final stage, students designed products, services, or experiences addressing real-world issues such as waste reduction and accessibility. The course illustrated how food can serve as a communicative medium for ethical and environmental awareness, merging creativity and responsibility. This case highlights how design education can mobilize multisensory cognition to foster systemic thinking and sustainable innovation.

Case 4: Illustration and Digital Narratives for Environmental Awareness

The *Illustration and Digital Narratives* program brought together several short courses - *Digital Illustration (Bitmap and Vectorial)*, *Comics: Sustainable Visual Narratives*, *Screen Printing*, and *Risography* - forming a pedagogical ecosystem at the intersection of art, technology, and environmental

communication. Students developed hybrid workflows linking digital and manual processes, employing sustainable materials such as recycled papers and soy-based inks. Through projects focused on environmental storytelling - particularly water as a symbolic and ecological theme - participants used visual narratives to promote ecological literacy. The tactile experimentation of risography embodied the value of imperfection as an ecological aesthetic. The program demonstrated how illustration can act as a tool for social communication and cultural transformation, integrating creativity, ethics, and environmental consciousness within a cohesive pedagogical model.

Case Studies Synthesis

Across all four applied cases, the pedagogical model of the BDA revealed a coherent strategy: to use short-term, project-based design education as a platform for *experimentation, interdisciplinarity, and critical reflection*. Each course adopted a different thematic lens yet shared the same underlying logic of *human-centered augmented-intelligence learning*.

By fostering iterative, collaborative, and embodied learning processes, these courses cultivated design thinking as an *integrative cognitive system*, capable of synthesizing creativity, ethics, and technology. Students not only developed technical and conceptual mastery but also internalized design as a form of ecological and cultural literacy. This model illustrates how higher design education can transition from a skills-based paradigm to an intelligence-based, where knowledge emerges through interaction, reflection, and adaptive experimentation. The integration of sustainability and human values within this framework confirms that design education can function as a policy-aligned experimentation field - bridging creative autonomy and systemic awareness in the face of complex global realities.

DISCUSSION OF PEDAGOGICAL OUTCOMES: COMPARATIVE INSIGHTS AND CHALLENGES

The empirical results from ESAD's Blue Thinking implementation confirms that design education can act as a laboratory for responsible innovation, capable of integrating sustainability, digital literacy, and ethical reflection within a learning model. Students report enhanced motivation when their design work addresses real community issues - a hallmark of effective experiential learning. As Manna et al. (2022) and Echeverry et al. (2025) demonstrated, problem-based and design-thinking pedagogies enhance not only creative confidence but also moral reasoning - an observation fully aligned with the outcomes recorded at ESAD.

Students trained under the Blue Thinking framework developed systems thinking and ecological literacy as central cognitive abilities. Through iterative, project-based collaboration, they learned to understand design problems as complex systems rather than isolated tasks. Interviews show a shift from "how to make" toward "why and for whom to make," revealing a maturing ethical awareness that directly corresponds to Floridi's (2019) notion of *informational ethics* in design.

This evolution supports a broader transformation within design pedagogy: from teaching technical skills toward cultivating design intelligence, understood as the capacity to interrelate human, technological, and ecological systems. Within ESAD, this shift was operationalized through curricular restructuring, the inclusion of sustainability rubrics in project evaluation, and the institutionalization of interdisciplinary collaboration across departments. The integration of intelligent technologies - AI visualization, parametric modeling, and digital fabrication - was found to enhance understanding of complex systems. These tools allow students to simulate environmental impacts, evaluate life-cycle performance, and communicate design intentions effectively to non-expert stakeholders. Such technological mediation aligns with Kunrath & Beliatis (2022) evidence that digital co-creation environments foster ecological empathy and collaborative problem-solving.

In the context of HCI, the integration of intelligent systems has often been framed in terms of usability and efficiency. Blue Thinking extends this discussion by reframing intelligent tools - AI-assisted visualization, parametric modeling, and digital fabrication - as cognitive partners in decision-making for sustainability. As Kunrath & Beliatis (2022) observed in engineering education, digital co-creation environments enhance both collaboration and ecological empathy. At ESAD, similar patterns emerged: students used AI visualization to test the implications of design proposals, parametric modeling to optimize spatial configurations, and digital fabrication to prototype low-waste components. Rather than replacing human creativity, these systems amplified the designer's capacity for foresight, enabling learners to simulate the environmental and social consequences of their decisions before implementation.

This aligns with Floridi's (2019) concept of *augmented intelligence* and supports Forlizzi's (2018) critique of traditional user-centered design. The findings suggest that Blue Thinking provides a practical framework for embedding AI ethics into design education, positioning intelligent systems as mediators of ecological awareness rather than as autonomous agents.

Importantly, ESAD's model shows how responsible design education can generate measurable institutional impact: Strengthening partnerships with public and private stakeholders (e.g., CIIMAR, Fórum Oceano, municipalities); Expanding international visibility through BDA dissemination; Producing empirical evidence of learning outcomes aligned with the UN SDGs (12 and 14). Thus, Blue Thinking operates not only as a pedagogical framework but as a governance tool that unites curricular development, institutional strategy, and regional sustainability objectives. Cross-comparison with international studies (Murata & Kobayashi, 2025; Filho et al., 2024) suggests that blending digital education with sustainability outcomes requires institutional support and interdisciplinary governance. The BDA's success depends on administrative alignment among partners and sustained public funding - conditions echoed by global research on sustainability education (Cebrián & Junyent, 2015).

Nevertheless, challenges persist. First, the sample size ($n \approx 500$ students) reflects a single-institution context; cross-institutional comparisons would strengthen external validity. Second, while descriptive data reveal positive trends, longitudinal tracking of graduates' professional trajectories is needed

to assess long-term impact. Third, quantitative environmental metrics (e.g., CO_2 reduction, material savings) were not systematically measured, limiting the depth of sustainability assessment. ESAD tries to address these through inclusive pedagogy, open-source digital tools, and collaboration with municipalities to democratize design innovation. Future research should therefore combine design-based research (DBR) with life-cycle analytics and AI-driven data visualization to establish stronger evidence of environmental outcomes. Comparative studies across European Blue Economy initiatives could also test the replicability of the Blue Thinking framework and its scalability to other creative disciplines.

CONCLUSIONS AND FUTURE WORK

This paper (i) formalizes Blue Thinking through a set of design principles and assessment dimensions - pedagogical effectiveness, design quality and creativity, sustainability performance, community engagement, and scalability/transfer potential within the broader Blue Economy context; (ii) reports empirical evidence that students' systems thinking, ecological literacy, and technological self-efficacy improve across iterations; and (iii) demonstrates how intelligent systems augment - rather than replace - human judgment in decision-making for material choices, spatial strategies, and communication. The findings of this study confirm that Blue Thinking functions as both a conceptual framework and an operational model capable of advancing sustainability education through human-centered and intelligent design practices. By embedding co-design, digital intelligence, and ecological ethics into its curriculum, ESAD exemplifies how higher education can transition from teaching *about* sustainability to *practising* it as a measurable and transformative form of innovation.

This study addressed RQ1 by operationalizing the Blue Thinking framework as a metric-based model that integrates sustainability into design education through explicit indicators of pedagogical effectiveness, creativity, ecological performance, community engagement, and scalability. RQ2 was answered through empirical evidence showing that learners developed enhanced systems thinking, ecological literacy, and technological self-efficacy, demonstrated by their ability to articulate material and environmental impacts, integrate circular strategies, and critically apply intelligent tools in project ideation and evaluation. RQ3 was explored through case-based analysis revealing that intelligent systems amplify sustainable decision-making when embedded within participatory, reflective, and ethically framed pedagogical contexts. Rather than replacing human judgment, these systems act as cognitive partners that support foresight and sustainability reasoning, provided their use is guided by responsible innovation principles. Pedagogically, Blue Thinking redefines design education from a skill-based to an intelligence-based paradigm. It cultivates digital fluency, ecological empathy, and ethical foresight, competencies essential for addressing the intertwined crises of climate, culture, and technology. Institutionally, the framework aligns with national policy (PRR, 2024) and global frameworks such as the *New European Bauhaus* and *UN SDGs 12 and 14*, demonstrating how higher education can move from teaching *about* sustainability to practising it.

From a Human Intelligent Systems Integration perspective, this research shows that intelligent tools, when applied within ethically guided and collaborative learning environments, act as mediators of cognition and ecological reasoning. Design schools can thus function as catalysts for sustainability transitions, uniting pedagogy, research, and governance through measurable outcomes.

Future work should include longitudinal and comparative studies tracking graduates' professional trajectories and assessing the socio-ecological impact of Blue Design Alliance projects. Cross-institutional collaboration with other European design schools could consolidate best practices for integrating the blue economy into curricula. Ultimately, Blue Thinking reframes design as a mediator of living systems, connecting human creativity, technological intelligence, and ecological integrity toward regenerative futures.

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