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If we never do it, we will never know

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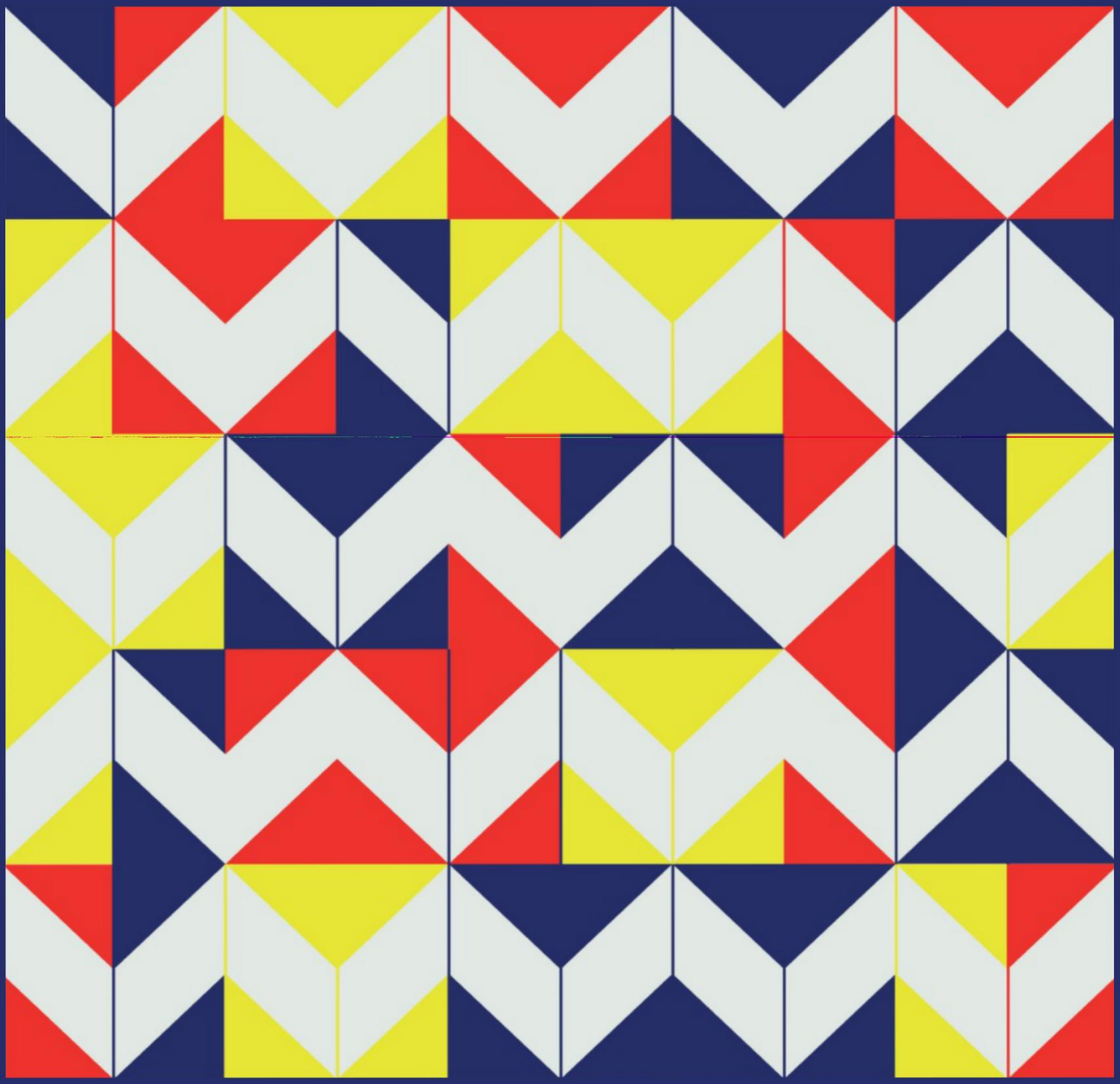

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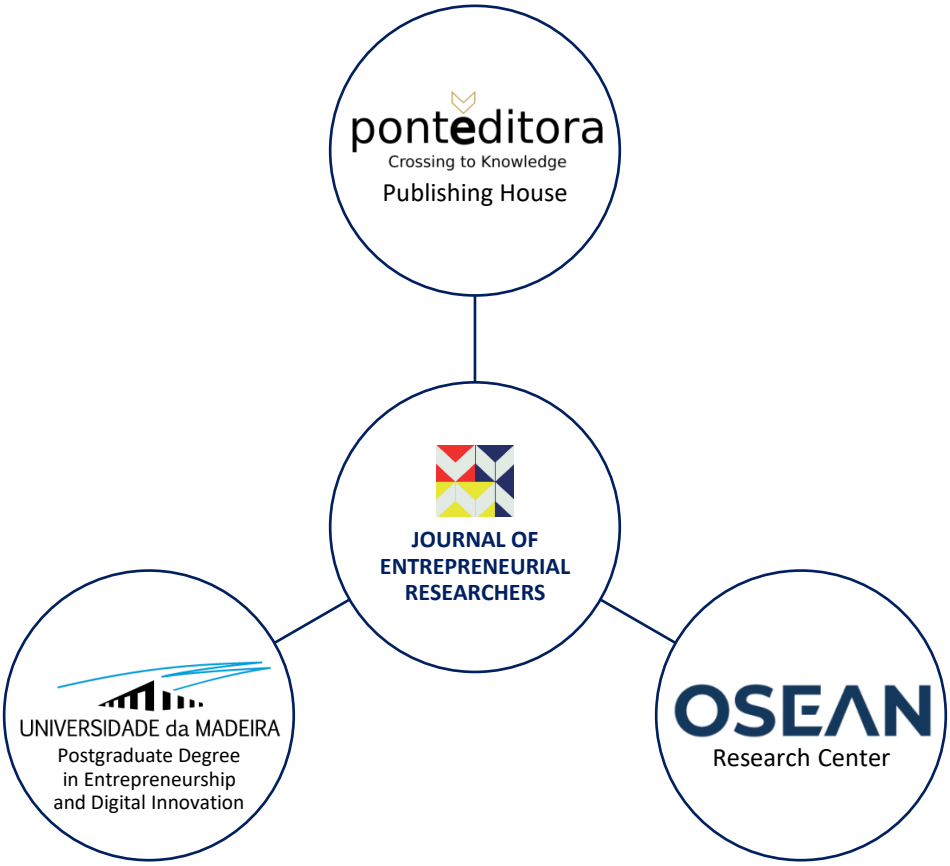

Editorial Team

Editorial Status

The *Journal of Entrepreneurial Researchers (JER)* is a peer-reviewed, semiannual scientific journal published in digital open-access format by Ponteditora, Sociedade Unipessoal, Lda. *JER* is committed to advancing research in entrepreneurship and related fields by providing an international platform for the publication and dissemination of high-quality, original scientific contributions.

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JER aims to foster academic inquiry and global dialogue on topics central to the entrepreneurial research domain. The journal welcomes interdisciplinary, multidisciplinary, transdisciplinary, and pluridisciplinary approaches in areas such as the green and blue economy, eco-entrepreneurship, green accounting, sustainable finance, digital innovation, sustainability, and social inclusion.

Our mission is to promote excellence in entrepreneurial research, stimulate original thinking, and facilitate the exchange of ideas, experiences, and collaborative projects among scholars, professionals, and institutions worldwide.

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Final Note

JER is a growing international platform committed to contributing meaningfully to the global conversation on entrepreneurship. Through rigorous peer review, ethical integrity, and a collaborative editorial culture, we aim to support the ongoing advancement of research and innovation.

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Editorial—Cultivating entrepreneurial ecosystems at the crossroads of education and systemic innovation

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Eduardo Leite, University of Madeira, OSEAN—Outermost Regions Sustainable Ecosystem for Entrepreneurship and Innovation, Portugal, eduardo.leite@staff.uma.pt.

This issue of the *Journal of Entrepreneurial Researchers* emerges at a pivotal moment, when entrepreneurship reconnects with its deepest mission: to serve as a catalyst for structural transformation amidst increasing social, economic, and technological complexity. Far from being confined to merely technical or instrumental approaches, this collection of articles challenges the ethical, ontological, and educational foundations of entrepreneurial practice, while proposing new avenues for action and inquiry. As Isenberg (2010) argues, entrepreneurial ecosystems thrive when education, policy, and culture converge—a vision embodied in the interdisciplinary dialogues of this volume.

Bringing together genuinely interdisciplinary perspectives, this volume articulates educational innovation, technological sustainability, digital transformation, and social responsibility. The contributions go beyond mere description: they offer interpretive and operational frameworks aimed at enhancing the responsiveness of individuals, institutions, and systems to contemporary challenges.

Highlights of this Issue

Below, we present the studies featured in this volume—each one contributing a vital piece to our understanding of how to build resilient and innovative entrepreneurial ecosystems:

1. Entrepreneurship Education in Higher Education: The Poliempreende Network as a Driver of Systemic Innovation

By Vieira, A. R., Mónico, L., Carvalho, C., & Parreira, P.

This study delves into the role of Higher Education Institutions (HEIs) as levers of innovation and economic development. Drawing on the Poliempreende network and applying both the Triple Helix model (Etzkowitz & Leydesdorff, 2000) and an adapted Framework Conditions Index, the authors identify progress in curricular integration and entrepreneurial support mechanisms. At the same time, they highlight persistent challenges—such as limited resources and the need for improved evaluation tools. The article offers a practical and reflective guide for the continued enhancement of entrepreneurship education, underlining the value of inter-institutional collaboration.

2. Artificial Intelligence in Healthcare: Ethical Challenges, Opportunities, and the Future of Humanity

By Carlos Costa Gomes

This article provokes a profound reflection on the boundaries of the human condition in the face of the rise of Artificial Intelligence (AI) in healthcare. Grounded in the fundamental question "What makes us human?", the text explores emerging ethical dilemmas such as informed consent, algorithmic transparency, and data privacy. Floridi (2018) reminds us that the governance of AI must balance innovation with human dignity—a principle central to Gomes' advocacy for autonomy, justice, and sustainability as pillars of ethical AI.

3. Navigating the Blue: Rhetoric, Poetics, and Storytelling in Oceanic Advertising

By Vanda de Sousa & Jorge Veríssimo

Combining semiotics, literary theory, and discourse analysis, this innovative study investigates the campaign *"It's not tourism. It's futurism."* and its impact on ecological awareness. As Salmon (2017) demonstrates, storytelling

is a transformative force for cultural change—a idea echoed here through classical rhetoric (ethos, pathos, logos) and maritime conservation ethics.

4. Crypto Assets and Sustainability: Can the Digital Economy Be Green?

By Joel Sepúlveda, Amanda Lemette & Karla Ohler-Martins

This study assesses the environmental impact of crypto assets (e.g., Ethereum, Cardano) through their consensus mechanisms (PoW vs. PoS). Mora et al. (2018) warn that unchecked blockchain energy use could exacerbate climate change—a challenge the authors address with a novel framework for sustainable digital finance, aligned with the EU's MiCA regulation.

5. Scenario Projection and Strategic Envisioning for SMEs and Startups

By Ana Leite, Luís Sardinha, Carlota Sardinha & Sancha Campanella

Leite et al.'s work on future-oriented planning techniques builds upon Schoemaker's (1995) foundational framework of scenario planning as an essential tool for navigating uncertainty in complex business environments. Their emphasis on integrating these methods into entrepreneurship education resonates with Mintzberg's (1994) paradigm-shifting view that effective strategic leadership requires balancing analytical rigor with creative visioning - particularly crucial for startups operating in volatile markets.

6. Strategic Profiles in Gamified Education: A Game Theory-Based Approach

By Élvio Camacho & Pedro Nunes

Camacho and Nunes taxonomy of gamification profiles (competitive, cooperative, adaptive, cautious) significantly expands Bartle's (1996) original player type model into educational contexts. Their findings empirically validate Deterding's et al. (2011) critical distinction between superficial "pointsification" and meaningful gamification design that adapts to learners' psychological profiles - a breakthrough for developing truly effective entrepreneurial training programs.

A Cross-Cutting Reflection

What unites these contributions is not merely technical insight, but a shared imperative to reframe entrepreneurship as a space of critical reflection and systemic interdependencies. This meta-level insight—rarely articulated yet powerfully present—may well be the most significant contribution of this volume.

Geographical Diversity

The breadth of this issue is also reflected in the geographical origin of its authors, who represent institutions from Portugal, Brazil, Germany, and Spain. This diversity not only enriches the theoretical and methodological contributions, but also attests to the journal's growing role as a platform for international dialogue on entrepreneurship, innovation, and education.

On the Editorial as Institutional Anchor

With this issue, the editorial is reaffirmed not merely as a prologue, but as a vital institutional anchor of the *Journal of Entrepreneurial Researchers*. It seeks to articulate the journal's intellectual compass, curate its dialogical coherence, and frame each volume as a milestone within an evolving scholarly ecosystem. As the journal grows in reach and ambition, the editorial must increasingly serve as both reflective synthesis and prospective orientation—bridging the immediacy of the present with the demands of a shared academic future.

To conclude, as Schell (2008) observed about game design frameworks, innovative approaches require both creativity and rigor to address complex challenges**.** This journal issue is a call to action: entrepreneurial ecosystems demand not just solutions, but a symbolic reconfiguration of education, innovation, and ethics.

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Reinforcing education for entrepreneurship in higher education institutions: Poliempreende—Polientrepreneurship Innovation Network

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Abstract

Theme: Strengthening entrepreneurship education in higher education is critical to preparing students for dynamic labor markets and fostering innovation ecosystems. In Portugal, the Polientrepreneurship Innovation Network (PIN), rooted in the Poliempreende program, exemplifies a national initiative to embed entrepreneurial practices across polytechnic institutions.

Objectives: This study aims to understand the institutional conditions that support the reinforcement of entrepreneurship education in Portuguese Higher Education Institutions and to identify opportunities for improving the implementation of the Polientrepreneurship Innovation Network (PIN). It is guided by the research question: *What institutional conditions and strategic factors influence the implementation and development of the PIN, particularly regarding strategic integration, program development, student outcomes, inter-institutional collaboration, and faculty engagement?*

Methods: Drawing on the Triple Helix model and adapting the Framework Conditions Index to the Portuguese context, a qualitative content analysis was conducted on 13 semi-structured interviews with top and middle managers from five polytechnic institutes and two non-integrated schools.

Findings: Four main categories emerged from the analysis: Entry Context, Implementation Conditions, Impact, and Evaluation. These include factors such as strategic embedding, teaching methodologies, institutional interaction, stakeholder engagement, and evaluation practices. Gaps were identified in areas such as promotion, funding, and systematic evaluation.

Implications: The study highlights key enablers and barriers to effective entrepreneurship education, offering strategic insights for strengthening institutional frameworks. Findings support the continued development and potential internationalization of the PIN, positioning it as a critical instrument for sustainable and inclusive entrepreneurial education.

Keywords: Entrepreneurship; Entrepreneurship Education; Higher Education; Polientrepreneurship Innovation Network, Innovation Ecosystem.

1. Introduction

Entrepreneurship within Higher Education Institutions (HEIs) has garnered significant attention as a catalyst for economic development and innovation. Beyond traditional models, interdisciplinary approaches integrating philosophy and psychology—such as the W.O.M.B. model (Well-being, Open-mindedness, Mindfulness, Brilliance) proposed by de Almeida Leite et al. (2024)—highlight the role of emotional well-being and open-mindedness in fostering creativity within entrepreneurial education ecosystems like PIN. Among the various

stakeholders in an entrepreneurial ecosystem, HEIs play a crucial role in cultivating an entrepreneurial society (Lv et al., 2021; Ranga & Etzkowitz, 2013). They are essential for preparing students to face the challenges of the job market, promoting an entrepreneurial mindset characterized by innovation, adaptability and resilience (Rodriguez & Lieber, 2020).

The integration of entrepreneurship education into HEIs curricula has been shown to positively influence students' entrepreneurial intentions. Exposure to entrepreneurial education enhances students' competencies and intentions to engage in entrepreneurial activities (Lv et al., 2021). This finding underscores the importance of structured entrepreneurial programs in shaping future entrepreneurs.

Rejecting the notion of a genetic basis for entrepreneurial competence—especially considering that, as Turkheimer et al. (2003) argue, competencies are acquired and gene expression is influenced by environmental conditions—several educational institutions, governments, and businesses are increasingly interested in developing synergies and strategies to foster entrepreneurship (Leydesdorff & Etzkowitz, 1996; Redford, 2013).

This study draws from the experiences of multiple stakeholders involved in the Polientrepreneurship Innovation Network to reflect on the critical conditions and strategies needed for entrepreneurship education. Using different models and conceptual frameworks such as the Global Entrepreneurship Monitor, the Triple Helix model, and the Framework Conditions Index, the necessary adaptations have been made to develop a conceptual model more suited to the Portuguese context.

Given the central role of higher education institutions in fostering entrepreneurial ecosystems and the strategic implementation of the Poliempreende Program, this study seeks to answer the following research question:

"What are the institutional conditions and strategic factors that influence the effective implementation and future development of the Polientrepreneurship Innovation Network in Portuguese Higher Education Institutions?".

This study aims to understand the institutional conditions that support the reinforcement of entrepreneurship education in Portuguese Higher Education Institutions and to identify opportunities for improving the implementation of the Polientrepreneurship Innovation Network (PIN). It is guided by a primary research question: *What institutional conditions and strategic factors influence the implementation and future development of the PIN, particularly in terms of its impact on students, faculty, institutional practices, and external stakeholder engagement?* Sub-questions explore how entrepreneurship is integrated into institutional strategies, how teaching methodologies and faculty practices support student development, how external stakeholders contribute to implementation, and how outcomes and challenges are perceived across institutions.

In this context, the main analytical focus lies in understanding how specific institutional dimensions—such as strategic integration, teaching methodologies, stakeholder engagement, and resource management—influence the implementation and development of entrepreneurship education. These thematic dimensions, which emerged from both the literature and the adapted Framework Conditions Index, serve as the core dependent elements analyzed in this study.

To guide this analysis, the study is structured around the following central research question: What institutional conditions and strategic factors influence the implementation and future development of the Polientrepreneurship Innovation Network (PIN) in Portuguese Higher Education Institutions, particularly in terms of:

1. *its strategic integration within institutional governance*.
2. *the development and operationalization of entrepreneurial education programs*.
3. *student learning outcomes and employability preparation*.
4. *inter-institutional knowledge transfer and collaboration*; and
5. *the enhancement of faculty competencies and engagement in entrepreneurship education?*

To frame this analysis, we draw not only on the Triple Helix model (Etzkowitz & Leydesdorff, 2000) but also on the broader concept of the entrepreneurial university. Clark (1998) identified five elements critical to entrepreneurial transformation in HEIs: a strengthened steering core, an expanded development periphery, a diversified funding base, a stimulated academic heartland, and an integrated entrepreneurial culture. Etzkowitz (2003) further developed this perspective by articulating how universities evolve through internal transformation and external engagement. Rothaermel et al. (2007) provided empirical grounding to these frameworks by examining how university structures and networks shape entrepreneurial outcomes. More recently, Iakovleva and Adkins (2023) emphasized the importance of institutional readiness and collaborative cultures for entrepreneurship education. These perspectives inform the analysis of the Polientrepreneurship Innovation Network and its role in transforming Portuguese polytechnic institutions.

1.1. Context & Background

1.1.1. Entrepreneurship as a Driver of Economic and Social Development

Entrepreneurship has been the subject of study across various fields of knowledge, allowing for a holistic understanding of the phenomenon today. A conceptual analysis reveals, beyond the dimension of time, diverse perspectives in areas such as psychology, sociology, education, civic engagement, environmental science, technology, and others. Entrepreneurship can be seen as a “kaleidoscope, as there are multiple possible views and combinations” (Portela et al., 2008). For instance, social entrepreneurship is recognized as a significant force in addressing complex social dilemmas and global issues. It moves beyond traditional business models to create innovative solutions that tackle social, racial, and environmental challenges (Antoniuk et al., 2023; Godwin & Crocker-Billingsley, 2024). Social entrepreneurship redefines the entrepreneurial landscape, combining entrepreneurial principles with a commitment to social good, aiming for a positive and equitable impact on society while also achieving financial success. Entrepreneurship is the engine of a nation’s economic, cultural, and social development (Ramalho et al., 2022).

To better understand entrepreneurship, one must begin by examining the individual who drives it—the entrepreneur. The concept originates from the French verb *entreprendre*, which means "to be positioned in the market between the supplier and the consumer" (Brouwer, 2015). From an economic and business standpoint, Schumpeter developed the Theory of Economic Development in 1911, where he referred to entrepreneurs as "wild spirits," responsible for fostering innovation and technological change. According to several authors (e.g., Cunha, 2014), Schumpeter viewed entrepreneurship as the introduction of innovation in a business context, which could manifest as a new product, a new production method, the opening of a new market, the acquisition of a new source of materials, or the establishment of a new firm. Schumpeter linked entrepreneurship closely with the concept of innovation, a perspective that was later reinforced by Drucker (1993). However, contemporary scholars like Leite et al. (2024) critique the “atomistic hero” narrative, proposing instead a “post-individualist” view where entrepreneurship thrives through networks and ‘affects’ (emotions that shape collaboration). This resonates with Portugal’s PIN, where inter-institutional ties and student motivation are central. For Drucker, not all businesses can be deemed entrepreneurial, as some neither create a need nor bring forth new consumers, nor do they undertake risks. In his view, innovation is a specific tool of entrepreneurship that enables entrepreneurs to discover new opportunities. Furthermore, according to Drucker, opportunities can be found in available resources, evolving lifestyles, changes in the organization of time, and socio-economic activities (Drucker, 1993, 2007).

Entrepreneurship is a complex process and dependent on different contingencies and family (e.g., family business), social (e.g., networking), political, and economic contexts. Furthermore, this phenomenon can be understood as the ability to design something innovative with creativity and motivation. In recent years, creating an entrepreneurial activity has become a necessity, on the one hand, especially considering the competitiveness of markets and high unemployment rates. On the other hand, this socio-economic phenomenon generates new jobs and boosts economic growth. Moreover, the entrepreneur is a game-changer and transforms, applies the acquired knowledge and experience, creates value, and, in addition, disseminates this innovative product, often

achieving financial rewards and personal satisfaction. However, the reverse side of the coin brings the confrontation of psychological, financial, and social risks (Mónico et al., 2024).

Within the realm of Social Sciences, there is a particular focus on the individual and contextual components of entrepreneurship. Regarding the individual component, several scholars argue that entrepreneurs are not born but made (Antoniuk et al., 2023; Cunha, 2014; Drucker, 1985; Ferreira, Santos, & Serra, 2010), highlighting the importance of personality traits for understanding entrepreneurial success (Rauch & Frese, 2007). In turn, entrepreneurs are motivated by their environment and the broader business world, striving for the creation, growth, and survival of their enterprises. According to Hisrich, Peters, and Shepherd (2008) and Redford (2013), entrepreneurial ideas are closely linked to goals that the entrepreneur aims to achieve. In a contextual perspective, Ferreira, Santos, and Serra (2010) noted that in less developed countries, entrepreneurial opportunities are often tied to meeting basic unmet needs, such as shelter and food. In contrast, in more developed nations, needs are associated with education, satisfaction, personal fulfillment, entertainment, and social interaction. This highlights a growing societal interest in understanding the concept of entrepreneurship.

According to Baptista et al. (2024), more recently, entrepreneurship is known as a source of expansion, rising and competitive power. It can be described as the recognition and exploitation of opportunities in the business world within the individual and the opportunity nexus, leading to the creation of new business models or just to the consolidation of the ones that already exist (Duman, 2018; Fitz-Koch et al., 2017; Klofsten, 2000; Testas & Moreira, 2014; Wennekers & Thurik, 1999).

For Baptista et al. (2024), the term *business model* has been used to describe an organization business mainly from the supplier's perspective, outlining what the organization is offering and the associated activities with its customers (Priem et al., 2018). In a simpler way, this concept represents the story that aims to explain how an organization works, being interpreted as a design of thoughts on how it generates revenue (Magretta, 2002). Business models can have two main purposes: (1) being a tool to analyze the value creation of an organization; and (2) being a mediator of the transfer of a technology or of an idea to the market, attending to the value created for the potential customers (Carvalho et al., 2019).

The Global Entrepreneurship Monitor (GEM) defines entrepreneurship as "any attempt to create a new business or new venture, such as self-employment, a new business organization, or the expansion of an existing business, by an individual, a team of individuals, or established businesses" (GEM Portugal, 2013, p. 3). GEM is an independent global entrepreneurship study aimed at analyzing the relationship between the level of entrepreneurship and economic growth, as well as identifying the factors that promote or hinder entrepreneurial dynamics in each participating country (GEM, n.d.).

To comprehend entrepreneurship as a driver of economic and social development, it is essential to consider its variability across different countries. To facilitate the analysis and understanding of cross-country differences, GEM categorized economies into three types based on their economic development characteristics: factor-driven economies, efficiency-driven economies, and innovation-driven economies (Bosma et al., 2009; Bosma & Levie, 2010).

1.1.2. Entrepreneurship in Portugal

Portugal joined the Global Entrepreneurship Monitor (GEM) initiative in 2001 and contributed data until 2015, participating in international comparisons during that period. These earlier reports classified Portugal as an innovation-driven economy, characterized by a strong industrial base, an expanding service sector, and a growing capacity to respond to market demands through entrepreneurship (Bosma et al., 2009; Bosma & Levie, 2010). In such economies, entrepreneurs are seen as "agents of creative destruction," generating innovation and driving structural transformation.

Kelley, Singer, and Herrington (2016) highlighted Portugal's strong performance in entrepreneurial education, particularly at the school and academic levels. At the time, Portugal ranked first in this domain, which may explain

the high levels of entrepreneurial activity among individuals aged 25 to 34, followed by the 35–44 and 45–54 age groups. The country also scored highly in knowledge transfer from R&D (third place) and governmental policy support (second place), reinforcing its position as an emerging entrepreneurial ecosystem.

However, Portugal has not published country-specific GEM reports since 2015. To capture more recent developments, this study draws on updated international sources. The GEM Global Report 2022/2023 identifies key trends in innovation-driven economies, including a growing emphasis on digital transformation, sustainability-driven ventures, and institutional readiness for entrepreneurship (GEM, 2023). In parallel, the European Innovation Scoreboard 2024 classifies Portugal as a "strong innovator", with notable progress in areas such as human capital, business-academia collaboration, and digital infrastructure (European Commission, 2024).

Together, these updated indicators demonstrate Portugal's continued investment in entrepreneurship and innovation, reinforcing the importance of initiatives such as the Polientrepreneurship Innovation Network (PIN) in aligning higher education with national and global innovation agendas.

1.1.3. Catalysts for Change: The Role of Higher Education Institutions

Drucker (1985) argues that entrepreneurship is not a genetic trait but a discipline. Kurato and Hodgetts (2004) further assert that entrepreneurship encompasses models, processes, and case studies that contribute to a comprehensive understanding of the field. Baptista (2016) posits that higher education correlates with increased skills and knowledge, enhancing individuals' likelihood of engaging in entrepreneurial activities (Baptista, 2016; Ferreira, Santos, & Serra, 2010). Education is crucial for fostering entrepreneurship, a key driver of competitiveness and development (Ávila, 2015). To establish entrepreneurship as a socially accepted process, early formative models must be introduced (Parreira, Pereira, & Brito, 2011). Ávila (2015) emphasizes the need for a consolidated entrepreneurial culture within educational institutions. However, initiatives are often sporadic rather than part of a comprehensive strategy, undermining the effectiveness of entrepreneurial academies.

A supportive environment, alongside appropriate incentives, is vital for enabling individuals to learn and develop entrepreneurial behaviors. Education thus serves to transform ideas into reality, equipping youth with the knowledge and skills necessary for active societal integration. Through its various Eurydice reports, the European Commission highlights that the objectives of entrepreneurship education extend beyond business practices, significantly contributing to personal development and life paths (European Commission/EACEA/Eurydice, 2012, 2016). At the higher education level, entrepreneurship education is particularly relevant due to its strong linkage to employability. Sousa (2014) indicates that in Portugal, the transition from graduation to the labor market is complex and unstable, primarily due to misalignment between educational systems and labor market needs.

Higher Education Institutions (HEIs) are pivotal in shaping the entrepreneurial landscape, serving as hubs of knowledge and innovation that can cultivate an entrepreneurial culture and stimulate economic growth. Incorporating entrepreneurship into both curricula and extracurricular activities enhances students' readiness for the workforce.

1.1.4. Poliempreende—Polientrepreneurship Innovation Network

The Poliempreende Program exemplifies the potential of structured entrepreneurship education across Portuguese Higher Education Institutions (HEIs). Its primary goal is to integrate entrepreneurial thinking and practices into various academic disciplines, thus broadening the scope of traditional education.

The Poliempreende Program encompasses almost the entire national polytechnic network and some non-integrated schools, serving as a prime example of cooperation among HEIs. It is built on a rotating coordination system among partner institutions, following a well-defined methodological structure and a specific operational regulation. Within the Polytechnics and Schools, Poliempreende engages at all stages of the entrepreneurial journey, starting with fostering creativity and innovation, supporting the development of business plans, and culminating in company creation through financial awards. The Poliempreende program aims not only to

stimulate entrepreneurship but also to transfer technology, thereby contributing to regional and national development (Parreira, Pereira, & Brito, 2011).

PoliEntrepreneurship Innovation Network (PIN) project was established, serving as a continuation of the Poliempreende initiative. The PIN project aims to assess and analyze the program's potential improvements, ensuring it remains responsive to the evolving economic landscape.

1.1.5. The Helix Model in Higher Education

The Triple Helix Model originated as a framework to understand the dynamic and recursive interactions among universities, industry, and government in fostering innovation. This model asserts that collaboration among these stakeholders enhances innovation and fosters a robust educational ecosystem.

Leydesdorff and Etzkowitz (1996) conceptualized the Triple Helix to address the diverse relationships among these entities. They identified three configurations: (a) the "statist configuration," where government leads but limits innovation; (b) the "laissez-faire configuration," characterized by minimal state intervention, with industry as the primary driver; and (c) the "balanced configuration," which facilitates collaboration among universities, industry, and government, leading to innovative initiatives.

This system includes components (universities, industry, and government), their relationships (collaboration, conflict resolution, networking), and functions occurring within a space of consensus and innovation, known as the "Triple Helix space" (Etzkowitz & Leydesdorff, 2000; Ranga & Etzkowitz, 2013).

In the 2000s, the Triple Helix model evolved into the Quadruple Helix, incorporating civil society as a fourth key actor. This development acknowledged the significance of integrating social and cultural perspectives into the innovation process (Carayannis & Campbell, 2009). For higher education institutions, this shift involved expanding their roles beyond economic demands to address societal challenges and fostering co-creation of solutions in collaboration with citizens and local communities. Initiatives such as living labs and an emphasis on social responsibility and interdisciplinarity exemplify this transformation.

Subsequently, the model further progressed into the Quintuple Helix, which introduced the environmental dimension, emphasizing the alignment of innovation with sustainability goals (Carayannis et al., 2012). Within this framework, universities have increasingly incorporated sustainability and environmental governance into their curricula and research agendas, tackling critical issues such as climate change and the circular economy. Moreover, partnerships with global organizations to achieve the Sustainable Development Goals (SDGs) have reinforced the role of higher education institutions as leaders in green innovation.

In the context of the Poliempreende Program, the Helix model serves as a guiding principle for analyzing how these relationships can be leveraged to improve entrepreneurship education within Portuguese HEIs.

1.1.6. The Framework Conditions Index: Structure and Theoretical Support

In October 2008, at the request of the European Commission, NIRAS Consultants, FORA, and ECON Pöyry jointly published the *Survey of Entrepreneurship Education in Higher Education in Europe*. The study aimed to assess the state of entrepreneurship education in European HEIs, identify best practices, and analyze the barriers and incentives associated with its implementation. Based on interviews with institutional actors from 46 case studies (including two from Portugal), the researchers developed the Framework Conditions Index (FCI**)**—a conceptual model to evaluate the inputs (conditions) and outputs (impact/results) of entrepreneurship education.

The FCI comprises six core dimensions that offer a systemic view of the structural conditions enabling entrepreneurship education within HEIs:

- **Strategy**—how entrepreneurship is embedded in institutional mission, policies, and strategic planning (Clark, 1998; Etzkowitz, 2003).

- **Resources**—how institutions ensure scalability and sustainability, including budget allocation and funding diversification (Guerrero & Urbano, 2012; Rothaermel et al., 2007).
- **Institutional Infrastructure**—presence of support structures such as entrepreneurship offices, research centers, incubators, and interdisciplinary teams (Philpott et al., 2011; Iakovleva & Adkins, 2023).
- **Teaching and Learning**—curricular and extracurricular entrepreneurship education, teaching methodologies, and student-centered learning (Fayolle & Redford, 2014; Nabi et al., 2017).
- **Outreach**—engagement with alumni, businesses, and external stakeholders, and participation in regional innovation ecosystems (Audretsch, 2014; Guerrero et al., 2015).
- **Development**—continuous improvement mechanisms, such as goal evaluation, feedback systems, and staff development (HEInnovate, 2023; Markuerkiaga et al., 2016).

Although the FCI is a useful analytical tool, it has limitations. It tends to prioritize structural and institutional dimensions, while underrepresenting cultural, disciplinary, and relational factors that are central to the Triple Helix and Entrepreneurial University models. Moreover, it does not explicitly account for non-formal learning, inter-institutional dynamics, or context-specific challenges such as academic autonomy or regional disparities in innovation ecosystems.

To address these limitations, the present study adapts the FCI to the Portuguese context and complements it with literature on innovation systems and entrepreneurial universities. The FCI served both as the basis for the interview script and as an analytical framework for coding and interpreting the data, ensuring consistency between theory and empirical analysis.

Table 1: Framework Conditions Index**.**

Framework Conditions	Strategy	Entrepreneurship goals
		Entrepreneurship policies
		Strategic embeddedness
	Resources	Budget allocation
		Income generation
		Type of funding
	Inst. Infrastructure	Approaches
		Entrepreneurship appointments
		Entrepreneurship research
		Cross-discipline structures
	Teaching & Learning	Courses
		Degrees
		Teaching methods
		Curriculum
		Extra-curricular activities
	Outreach	Alumni
		Links with stakeholders
		Community engagement
	Development	Evaluation
		User-driven improvement
		HR management & development

Source: (European Commission, 2008).

These dimensions represent structural inputs that HEIs can leverage to become more entrepreneurial. While the framework focuses on fostering entrepreneurship within institutions, it does not encompass broader perspectives, such as the Triple Helix conceptualization of HEIs' role in innovation ecosystems (European Commission, 2008).

1.1.7. Research Gaps and Contribution

Despite the increasing attention given to entrepreneurship education in higher education, significant research gaps remain—particularly regarding **system-level initiatives** that transcend institutional boundaries. Most of the literature focuses on individual case studies, course-level evaluations, or university-centric innovation models, often neglecting the **polytechnic sector** and **inter-institutional cooperation frameworks**.

Moreover, while existing studies discuss entrepreneurial universities (Etzkowitz, 2003; Clark, 1998), few explore how national networks such as the Polientrepreneurship Innovation Network (PIN) operate in practice to foster systemic entrepreneurial capacity. There is limited understanding of how such networks are governed, how they align with institutional strategy, and how they influence faculty engagement, curricular innovation, and knowledge transfer in diverse institutional contexts.

This study addresses these gaps by:

- Analyzing PIN as a multi-institutional case using a theoretically grounded framework (FCI + Triple Helix).
- Focusing on polytechnic and non-university institutions, which remain underrepresented in the literature.
- Exploring the strategic, structural, and pedagogical conditions that facilitate or constrain entrepreneurship education in Portuguese HEIs.
- Proposing an adapted analytical model that can inform both academic research and policy design in similar innovation ecosystems.

1.1.8. Theoretical Framework and Conceptual Model

This study draws on two complementary theoretical perspectives to construct a conceptual model linking institutional conditions, networked collaboration, and entrepreneurship education outcomes:

- **The Framework Conditions Index (FCI)**, originally proposed by NIRAS et al. (2008), identifies six core dimensions—Strategy, Resources, Institutional Infrastructure, Teaching and Learning, Outreach, and Development—which reflect the structural conditions enabling entrepreneurship education within HEIs.
- **The Triple Helix Model** (Etzkowitz & Leydesdorff, 2000) situates universities as innovation actors embedded in dynamic relationships with industry and government, emphasizing interdependence, co-creation, and systemic innovation.

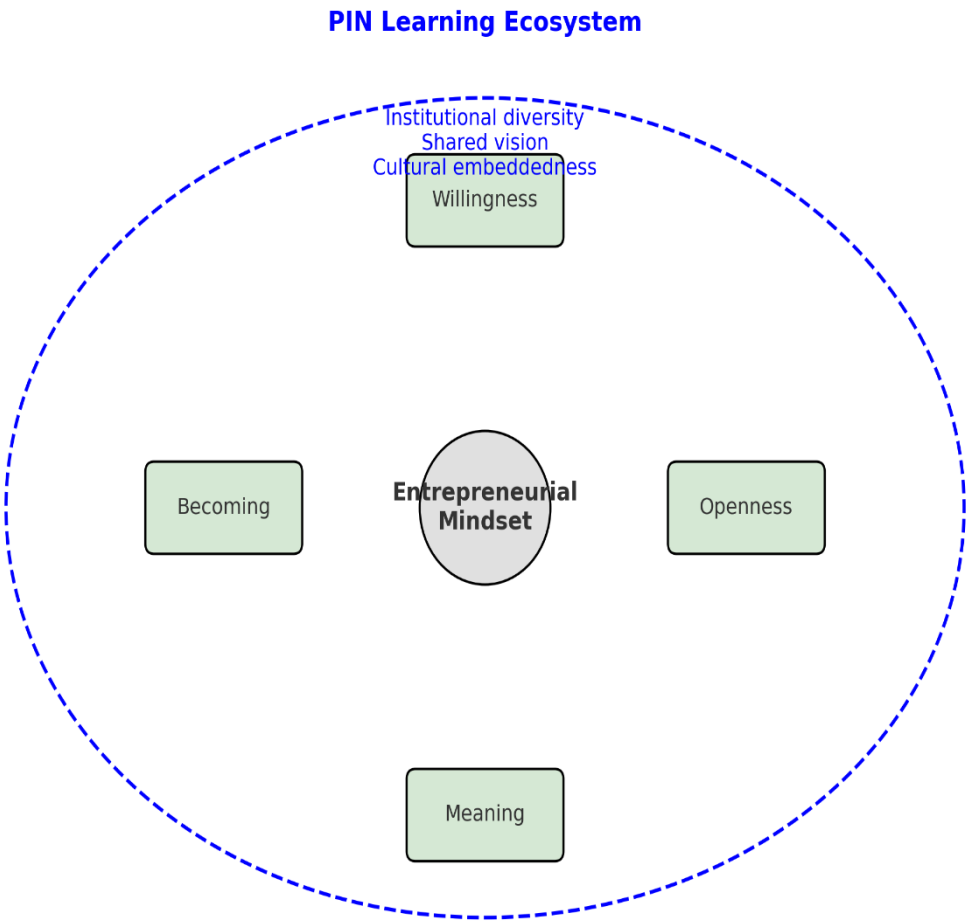
In this study, these frameworks are integrated into a conceptual model that views entrepreneurship education outcomes (e.g., curricular integration, student competencies, faculty engagement, and inter-institutional collaboration) as being shaped by:

1. **Institutional Conditions**—Strategic prioritization, available resources, and organizational infrastructure (FCI dimensions 1–3).
2. **Pedagogical and Outreach Practices**—Teaching strategies and external stakeholder involvement (FCI dimensions 4–5).
3. **Quality and Sustainability Mechanisms**—Evaluation systems, staff development, and continuous improvement processes (FCI dimension 6).
4. **Networked Governance**—The PIN is conceptualized as a mediating structure that enables knowledge sharing, benchmarking, and alignment between institutions.

This model posits that entrepreneurship education outcomes are not solely dependent on internal institutional characteristics but are co-shaped by participation in collaborative networks (like the PIN) and the alignment with national policy agendas.

The conceptual framework is represented in Figure 1, showing the interaction between FCI dimensions, network-level mediation, and targeted outcomes. This framework guided both the interview design and the interpretation of results, ensuring analytical consistency across cases.

Figure 1: Symbolic model of the entrepreneurial mindset within the PIN learning ecosystem.



Source: Developed by Authors

2. Method

2.1. Research Design

This study employs a qualitative research design, utilizing semi-structured interviews to explore institutional and strategic factors shaping the implementation of the Polientrepreneurship Innovation Network (PIN). The research was structured around five analytical dimensions that emerged from the literature and conceptual frameworks: (i) strategic integration of entrepreneurship within institutional governance, (ii) development and implementation of entrepreneurship education programs, (iii) student learning outcomes and employability preparation, (iv) inter-institutional knowledge transfer and collaboration, and (v) faculty competencies and engagement. These dimensions guided both the development of the interview protocol and the thematic coding.

2.2. Participant Selection

The sample was selected based on relevance and included five Portuguese Polytechnic Higher Education Institutions (Polytechnic Institute of Beja, Polytechnic Institute of Leiria, Polytechnic Institute of Lisbon, Polytechnic Institute of Santarém, Polytechnic Institute of Setúbal) and two non-integrated higher education schools (Higher School of Nursing of Coimbra and Estoril Higher Institute for Tourism and Hotel Studies). These

institutions were selected because they promote and integrate the Poliempreende Program within their structure. From each institution, one "top-level manager" and one "mid-level manager" were interviewed, except for the Polytechnic Institute of Lisbon, which participated only through its "mid-level leader". In total, 13 managers took part in the study.

2.3. Data Collection and Analysis

Data were gathered through semi-structured interviews, guided by a predefined script designed to explore various dimensions of the entrepreneurship project—including participation motivations, the evolution of institutional involvement, and perceived impacts at institutional and societal levels. With the consent of all participants, the interviews were audio-recorded, transcribed verbatim, and analyzed using NVivo software.

The interview script and subsequent coding process were structured around the six dimensions of the Framework Conditions Index (Strategy, Resources, Institutional Infrastructure, Teaching and Learning, Outreach, and Development), adapted to the Portuguese higher education context. These dimensions were theoretically grounded in the literature on entrepreneurial universities and innovation ecosystems, ensuring analytical consistency. The coding process also reflected five broader analytical domains outlined in the research design—namely, strategic integration, program development, student outcomes, inter-institutional collaboration, and faculty engagement—allowing for systematic cross-case comparison and thematic interpretation.

In line with qualitative content analysis practices, the frequency of thematic codes was recorded across the 13 interviews. This approach does not aim to produce statistically generalizable findings but rather to provide **indicative patterns** and **support the analytical transparency** of the coding process. Similar procedures are common in qualitative research to highlight the relative prominence of themes, particularly when multiple respondents engage with a structured set of analytical dimensions (e.g., Bengtsson, 2016; Schreier, 2012). Table 4, therefore, should be interpreted as a **descriptive summary of code occurrence** rather than as statistical evidence, consistent with accepted standards in qualitative methodology.

2.4. Ethical Considerations

Written informed consent was obtained from all participants, ensuring voluntary participation, confidentiality, and anonymity. All data were securely stored and used solely for academic purposes.

3. Results

The results are presented based on categories and subcategories emerging from the content analysis, organized into entry context, implementation conditions, impact, and evaluation.

Table 2: Emerging categories and subcategories

1. Entry Context	2. Implementation Conditions	3. Impact	4. Evaluation
1.1. Motivations	2.1. Interaction Between	3.1. Students	4.1 Difficulties and
1.2. Length of	Institutions	3.2. External	Opportunities
Participation	2.2. Strategy	3.3. Institution	4.2 Future
	2.3. Teaching Methodologies	3.4. Professors	
	2.4. Human Resources		
	2.5. External Engagement		
	2.6. Infrastructure		
	2.7. Resources		
	2.8. Promotion and Dissemination		
	2.9. Development		

Although primarily qualitative in nature, the data allowed for a basic comparative mapping across the seven participating institutions (see Table X). All institutions reported having implemented entrepreneurship-related curricular offerings, and most had established dedicated support structures, such as entrepreneurship offices or

working groups. While the majority joined the network around the 5th edition of the Poliempreende program (circa 2008), the extent of integration and institutional maturity varied. Some institutions emphasized project professionalization or curriculum integration, while others highlighted student motivation, external partnerships, or faculty development. The presence of incubators ranged from fully operational units to informal or developing structures. The interviews were coded according to Table 3.

Table 3: Coding of interviews.

Interviews	Layering	Code
A; B; C; D; E; F; G; H; I; J; L; M; N	mid-level manager	.M
	top-level manager	.T

3.1. Entry Context

3.1.1. Motivations

Interviewees identified motivation as a key factor in implementing entrepreneurship education strategies. They highlighted four main dimensions: (a) promoting the learning of competencies through formal methods and practical examples (e.g. '(...) they realize that just having ideas isn't enough, they need to consolidate them and they have to learn them and realize that in fact entrepreneurship is multidisciplinary and it's not enough just to have an idea, you have to be able to work on it so that it becomes something objective, the competition is a way of doing that.'(E.T); (b) integrating students into social and professional contexts e (e.g. '(...) there is no society without entrepreneurship, therefore, it is a concept that is installed, because it would necessarily have to be installed, we cannot think of any organization today without thinking of its functional content and its soul, it has to be an entrepreneurial soul (...)' (A.T); 'In terms of employability, even if they go to work for a company they get (...) completely different ideas.' (J.T); (c) addressing societal needs through knowledge transfer (e.g. '(...) overcoming the great problems, the enormous problems, with which the interior of the country is currently confronted (...)' (A.T); '(...) I call the social dimension of higher education intervention in the community, this has a lot to do with what the social role of higher education in the community actually is! One of the strongest aspects is the transfer of knowledge (...)' (A.T); and (d) raising awareness within the academic community about the significance of entrepreneurial education (e.g. '(...) trying to sensitize the academic population to the issue of entrepreneurship.' (M.T); '(...) I was at the beginning of the polyempreende programme and obviously the school immediately recognized the immense advantages of it to speed up its internal development process and formalize it further.' (C.T). According to the answers given, we can see that motivation to join Poliempreende can come from both professors and students (e.g. 'We've had the idea here at school for a long time, particularly a group of professors (...)' (C.T)'It started with a challenge from some students about 7 or 8 years ago, to find out if there was a possibility of (...) a final course work (...) through a business plan and if I could teach them how to build a business plan.' (F.M)).

3.1.2. Length of Participation

The duration of the institutes' participation varies according to the year in which they began their collaboration with Poliempreende. Having been integrated into the project progressively, the records point to an increase in participation in the 5th edition (e.g. '(...) I think it was the 5th or 6th polyempreende at national level.' (D.M), 'It wasn't the first one because we hadn't been challenged yet. but, if I'm not mistaken, it was in the second, when Castelo Branco was still coordinating.' (C.T), '(...) at the time we were invited (...) at most I think there were 6/7 polytechnics' (B.I), 'We joined in the 5th edition, which was in 2008 (...)' (H.M), 'I think we've been involved since the 5th edition (...)' (G.T), 'We started Poliempreende in 2008.' (N.I)).

3.2. Implementation Conditions

3.2.1. Interaction Between Institutions

The interviews revealed significant interaction among HEI, characterized by information sharing and experience exchange. This collaborative approach fosters the identification of best practices and promotes continuous improvement of methodologies (e.g. 'And we'll see, and our mates will say 'here it went better, there it went

worse'. And the very fact that we have access to this information makes it possible for us, we can then bring back or validate what we're doing or improve it. It's very much that way, in terms of a learning space in relation to what national coordination is, and the national coordination meetings themselves, I think they're essential. I think that without this Poliempreende wouldn't be what it is.' (N.M)). The interviewees regarded inter-institutional collaboration as a differentiating factor, enhancing institutional development and aligning with the strategic objectives of the Poliempreende Program (e.g. 'The learning was actually realizing that there are many ways to get to the same destination, so with the interaction we had with the other polytechnics, each one was implementing the project, complying with the regulations and finding very creative ways to put things into practice, and that's the learning that takes place in this kind of interaction.' (M.T)).

3.2.2. Strategy

In the context of the Framework Conditions Index, three subthemes were analyzed: Entrepreneurship Goals, Entrepreneurship Policies, and Degree of Strategic Embeddedness. While interviewees acknowledged entrepreneurship as a strategic priority, only the Polytechnic Institute of Leiria explicitly incorporates it into its institutional mission. Other institutions promote entrepreneurship through the Poliempreende mission and operational frameworks. Participants noted the existence of defined activity plans and objectives, indicating a transition from voluntary initiatives to a more structured approach to entrepreneurship education (e.g. 'I see the evolution as very positive. I would say that this project has become professionalized. And so, what was initially a collection of good wills started to have a sustained organization and of course today it runs more smoothly without the involvement of the managers because everything is coordinated. And so, likely, at the beginning I was more aware of everything that was happening as things needed to be pushed forward, but not today, today it's organized, it's a steamboat. It's perfectly integrated within the organization and within its development.' (C.T). In terms of strategic embeddedness, there is a recognized collaboration between top managers and mid-level management. Leadership values the competencies of management in executing entrepreneurial strategies, while management commits to fostering entrepreneurship within their respective institutions.

3.2.3. Teaching Methodologies

All institutions offer curricular units related to entrepreneurship, including adaptations to specific fields. The curriculum emphasizes the development of soft skills, creativity, marketing, and business planning, all geared towards enhancing employability (e.g. ''In all schools there is training in areas of entrepreneurship, some may not have specific teaching areas for entrepreneurship, but there is constant talk of entrepreneurship, I think this is extremely important.' (J.T)). Teaching methodologies prioritize experiential learning, involving entrepreneurs and business leaders to provide practical insights. These findings align with studies like de Almeida Leite et al. (2024), which show how mindfulness and open-mindedness (core components of W.O.M.B.) enhance experiential learning by helping students bridge ideation and practical solutions—a key goal of PIN. Interactive approaches such as brainstorming sessions, workshops, and company visits are also employed, often complemented by personalized mentoring, extracurricular activities, including entrepreneurship workshops and forums, further promote a culture of innovation and entrepreneurial thinking among students (e.g. 'So the general idea is to bring in some names that are more someone who is closer to the reality of our students, who are usually the majority of participants. The idea is to bring them here to share their experiences and be a source of willingness to do things.' (H.M); 'We have a consultant here who comes to mentoring us for 12 hours, from five until seven/eight, and we have planned one to two times a week. Towards the end of drawing up the business plan to help them in the financial area, which is the most difficult part for us, because we don't have specific training.' (D.M)

3.2.4. Human Resources

The analysis of the human resources involved in the Poliempreende project revealed a diverse group of participants, mainly made up of faculty members with multidisciplinary profiles (e.g. 'This is networking, a contact between professors, technicians, between all the staff, which supports the area of entrepreneurship (...)' (G.T)). Each polytechnic institution coordinates the project with teams of between two and six people. The

involvement of directors and middle management is crucial to the success of the project, as they bring valuable experience and insight. While no specific reward strategies were in place, interviewees emphasized the importance of creating incentives and allocating enough time to manage entrepreneurial activities (e.g. '(...) where, for example, professors have guaranteed time to dedicate to this area.' (D.M);'There are two; the first is the mobilization of teaching colleagues for the cause; on the one hand, it's appealing because it's an interesting and challenging project; on the other hand, whether we like it or not it's going to involve more work for colleagues, it's extra to the curricular units, extra to the work they already have at academic level.' (H.M); 'I think that before we can captivate the students, we always need to captivate the professors.' (N.M)). Faculty members with prior entrepreneurial experience contribute positively to the learning environment and foster an entrepreneurial culture within their institutions (e.g., 'We're lucky enough to have colleagues who are involved in entrepreneurship, they're entrepreneurs by nature and that's how they are in life. And I think that makes all the difference because it means we're teaching by example, living the projects you're involved in with passion helps and 'contaminates' the students in a positive way.' (C.T).

3.2.5. External Engagement

All polytechnic institutions reported substantial engagement with external entities, in line with the outreach component of the Framework Conditions Index. This engagement encompasses collaborations with regional, national, and international partners, including other educational institutions, municipal chambers, and both public and private organizations. Six out of the seven institutions noted the participation of external agents who support entrepreneurship education through sponsorships and direct contributions to the Poliempreende project. External stakeholders, including entrepreneurs and industry representatives, often participate in training events and serve as judges for student projects.

The commitment to community engagement is evident, with institutions providing consulting services through incubators and supporting entrepreneurial initiatives. The interviewees also acknowledged the importance of fostering entrepreneurship in pre-higher education levels, highlighting a comprehensive approach to nurturing entrepreneurial talent.

External engagement is evident in the various interviews: '(...) whenever possible, we collaborate with institutions in the region, both local councils and other non-higher education institutions for information, and we also support people and organizations who are interested in setting up companies, but who end up not applying to Poliempreende, because they are people from outside the institute.' (B.M); 'We have the privilege of having many small and medium-sized companies here in the region that still have a face. We know who the owners are. They are people who have often built their own companies and who have gone through all the difficulties of developing a business, so they have experienced first-hand what this reality is like.' (H.M).

3.2.6. Infrastructure

All participating HEI have dedicated infrastructures to support entrepreneurship education. Interviews and institutional website analysis confirmed the presence of incubators and complementary facilities (e.g. 'IPBeja entrepreneurship.' (B.M), '(...) I created IPBeja business and IPBBeja entrepreneurship here,' (A.T), '(...) the entrepreneurship office' (D.M), '(...) our entrepreneurship group, the entrepreneurship office, which is a formalized structure at the school, saw itself grow from there because I felt that the project would be a permanent challenge.' (C.T), 'This year we're also going to include the academic federation, which has the academic associations of all the IPL schools' (I.M), 'Orbis Innovation is currently within the entrepreneurship and employability support unit' (L.M), '(...) we're launching an incubator' (B.M), 'The incubator is already working informally' (N.M).). Although efforts were made to integrate entrepreneurship into curricula, many participants noted challenges in fostering interdisciplinary engagement among students.

3.2.7. Resources

According to the European Commission (2008), financial sustainability is fundamental for an entrepreneurial higher education institution (HEI). The allocation of funds to entrepreneurship activities was highlighted by

interviewees, indicating a commitment to developing this area. Some institutions generate income through external services provided by incubators. Interviewees emphasized the importance of diverse sources of funding, including external funding through sponsorship and prizes awarded to winning teams in the Poliempreende competition. However, many acknowledged that limited resources pose a significant challenge to the rapid expansion of the programme, highlighting the need for diversified funding strategies to ensure long-term sustainability (e.g. 'It's been sustained growth, maybe we'd like it to be faster but with the limited and scarce resources we have, as everyone has, it's been sustained growth.' (F.M), 'The only thing that I think we haven't yet successfully achieved is precisely in funding. I think there should be more funding for Poliempreende.' (J.M)).

3.2.8. Promotion and Dissemination

Interviewees discussed various communication strategies for promoting Poliempreende-related activities, such as distributing flyers, posting posters in strategic locations, publishing banners on institutional websites, sending emails, and leveraging social media platforms like Facebook and Twitter. Personal approaches, including classroom presentations by faculty and recommendations, were also noted as effective. Despite these efforts, interviewees perceived that Poliempreende still lacks visibility and national recognition. Some institutions mentioned targeted outreach to alumni as an effective strategy to enhance engagement. This category is based on statements such as: '(...) it's very much through the person-to-person way that they themselves bring to class, that they encourage the students to participate.' (H.M), 'We put up posters at visible points in the school, we publicize it on the website with banners, above all we talk about the prizes.' (E.T), 'It's through the flyers we make; we have a page in the school and then it's through presentations in class.' (D.M), '(...) for the first time we publicized our graduates and two or three ideas came to us' (N.M), 'In national terms I think Poliempreende lacks a lot of projection in terms of communication' (N.I).

3.2.9. Development

The development category includes two subcategories: Evaluation of Goals and Strategies for Entrepreneurship Education and Improvement from the User Perspective. Regarding the first category, only one relevant transcript was identified: '(...) we don't have, let's say, very objective data to understand that' (F.M). Interviewees reported a lack of objective data to assess the effectiveness of current strategies, noting that informal evaluations of entrepreneurship-related activities by students were generally positive.

3.3. Impact

3.3.1. Students

Middle and top management of the participating polytechnic institutions believe that students become better equipped to face job market challenges by developing diverse skills and competencies. These learnings enhance students' effectiveness in future entrepreneurial endeavors. Interviewees emphasized that with the acquired knowledge, students could participate in external competitions and potentially become successful entrepreneurs or intrapreneurs (e.g. 'Here they gain the so-called soft skills, in practice, they are confronted with these challenges.' (G.T), 'They get completely different notions of the market and marketing, so it will always be an asset' (J.T), 'For the students, I think it also opens them up a lot more; some continue to develop their projects. Even in the research unit, the group I have with me has already developed their prototype and applied for funding. So, I think they somehow get the bug.' (D.M), '(...) I think it adds value to their CVs. It gives them this vision; one day if they need to draw up a business plan, they'll know what to do, how to do it and who to turn to.' (D.M).

Additionally, students can select topics for their master's thesis, which can lead to funded or incubated projects. Throughout their academic journeys, students also learn about real entrepreneurial experiences and have opportunities to visit companies, further bridging the gap between education and practice.

3.3.2. External

The results of the interviews conducted in this study indicate that regional public institutions and private companies significantly benefit from the support provided by Polytechnic Institutes (IPs) and Schools, particularly

through knowledge transfer. There is also a growing interest from companies and institutions in recruiting qualified human resources trained by the IPs/Schools, who are seen as potential future collaborators. Moreover, the community has access to consulting services through incubators and other entrepreneurial structures affiliated with the institutions. Interviewees highlighted the positive impact of these initiatives on regional development, contributing to the enhancement of the local economic landscape by fostering the creation of new businesses and innovations (e.g. 'We are enriching the economic fabric of the region.' (H.M), '(...) it also gives us the possibility of being able to transfer knowledge to the community, to companies,' (J.T), '(...) or a group of people from the region who ask us for support, we usually help.' (B.M), '(...) because many of these companies also, at the end of the day, when they come to the incubator, ask us for some CVs so that they can then recruit our students.' (B.M)).

3.3.3. Institution

For the various Polytechnic Institutes (IPs) and Schools participating in our study, the Poliempreende-PIN has accelerated the enhancement of entrepreneurship education, as well as the restructuring of curricular plans that are increasingly aligned with market needs (e.g. '(...) at ESTG we're now integrated, I'd say all the courses except solicitors, have the subject of entrepreneurship.' (B.M), 'Initially, there wasn't as much development as we're doing with Poliempreende.' (J.T); '(...) at least, even students who are finishing recently have asked us to show them the incubator,' (B.M), '(...) we've actually had companies that have been created, probably the type of support we've given our students over the editions has been more effective, more directed towards what they need and we've also managed to make them more effective in terms of the company and the project.' (H.M)). The interviewees believe that students are more interested in becoming entrepreneurs and that there is "probably" greater effectiveness in entrepreneurship education. According to the interviewees, both the quality of projects from each IP/School and the number of companies, job positions, and patents created are becoming increasingly significant. It was also concluded that IPs/Schools gain greater influence in the surrounding community, have a greater impact on the lives of students and faculty, and are witnessing the development of new work networks (e.g. '(...) which is a greater sensitization of the whole community to the importance of the issue,' (E.T) 'On balance I think it's clearly positive, given the number of young people involved, the number of companies that have already been set up, the whole dynamic. Clearly our students and our institution have become richer because of this event.' (G.T)).

3.3.4. Professors

The data analysis revealed that professors benefit from integrating entrepreneurship education into their institutions. They could develop new skills and adopt innovative approaches. As entrepreneurship education becomes more widespread, professors recognize its importance and thus develop professionally and personally (e.g. 'I think that for us professors, and for me, it's been a learning experience. Every day we learn, and every year, I think this has been a continuous learning and development of skills in this area.' (D.M), 'Even the professors involved in the project have felt encouraged to embrace other ways of thinking.' (C.T), 'I'd say it's a permanent challenge that we must somehow turn this practice, whether it's formal teaching or non-formal teaching, into something that is effectively very creative, very stimulating, I think this is a permanent challenge that institutions must do. I think this is an ongoing challenge that all of institutions must fulfil.' (G.T), 'we are very committed to preparing students to achieve these good results, the professors also dedicate themselves to giving specific guidance. specific guidance and, as I said, it's an extremely important area in our institute.' (J.T)).

3.4. Evaluation

3.4.1. Difficulties and Opportunities:

The interviewees reported various challenges in entrepreneurship education, including student dropouts due to the overlap of projects with evaluation periods, lack of initiative, risk aversion, and a shortage of technical skills. Students also face difficulties in generating market-applicable ideas, requiring support for project development (e.g. '(...) there are always people interested, but then they give up, and maybe we have to start earlier because then the projects are due on top of the exams.' (B.M), '(...) When we asked for an idea for a business, everyone

wanted to make a roulette to sell puppies. I said, "Hey, you must use your skills, you went to school for three years to sell puppies? Use your intellectual abilities, which you have. You have a hobby; you practice yoga and karate. Go and do a job, but within what you know'. And I come up with everything from a van/bus. to take the drunks home from Lisbon at night, the ideas even come up but they're not ideas for them, I ask 'and what are you going to do? Drive the roulette, fry the steaks?' and they say, "oh no, I don't know how to do any of that, I'll take care of communication", a quarter of an hour a day. So, this notion of doing things is very complicated.' (I.M)). Regarding the faculty, high workload and a lack of human resources were identified as challenges, while faculty training was seen as an opportunity for improvement. Furthermore, the importance of strengthening relationships between the Polytechnic Institutes (IPs) and companies, as well as enhancing the promotion of Poliempreende, was emphasized.

Suggestions included rewarding first-year students and creating a Poliempreende manual to guide participating institutions (e.g. '(...) a kind of manual, a kind of script that each institution had to follow, a kind of pre-content (...) A Poliempreende script that had the structure, the duration, the number of workshops, the evaluation dates... I think that's what was appropriate, it doesn't mean that people follow it afterwards, but there was a script...' (E.T)).

3.4.2. Future

The future is seen by the interviewees as a continuation of the Poliempreende project. Despite the desire to reformulate curricula, invest in areas of community interest and develop students in this regard, there is a belief that the project needs to evolve, grow and become more formalized. The need to foster greater engagement with the business community and develop more partnerships was also identified. Interviewees expressed a strong desire for the project to be internationalized, for example by developing contacts with young people from other countries. Some evidence on this topic has been: 'And who knows, for example an area that is now being developed is social entrepreneurship, which is a very important area, and we have three colleagues who are developing this area, I think it will be around there, because volunteering is very important and developing this area and these skills in students.' (D.M), '(...) I think it's time for the competition to go international, maybe to the PALOP'S, Brazil, Macau...' (F.M), 'The future of entrepreneurship... I think it should develop increasingly. The subject is fundamental to all areas of education. Polyempreende has been a very successful competition and programme, so I think it's worth continuing and even boosting it further' (J.T).

3.5. Correlations Between Categories

Table 4: Pearson correlation analysis between categories.

Node A	Node B	Pearson correlation coefficient
\4 Evaluation\Difficulties & Opportunities	\2 Implement.\Teaching Methodologies	.90008
\3 Impact\Students	\2 Implement.\Teaching Methodologies	.882289
6D\5 Outreach\Links w stakeholders	\2 Implement.\Teaching Methodologies	.878276
6D\1 Strategy\Entrepreneurship policies	\2 Implement.\Teaching Methodologies	.874604
\4 Evaluation\Difficulties & Opportunities	\2 Implement.\Promotion & Dissemination	.872571
\4 Evaluation\Difficulties & Opportunities	\3 Impact\Students	.865543
\4 Evaluation\Future	\4 Evaluation\Difficulties & Opportunities	.86193
6D\6 Development\HR	\4 Evaluation\Difficulties & Opportunities	.856507
\4 Evaluation\Future	\2 Implement.\Teaching Methodologies	.852267
\4 Evaluation\Future	\2 Implement.\Interaction between institutions	.851126
6D\1 Strategy\Entrepreneurship policies	\4 Evaluation\Difficulties & Opportunities	.84949
\3 Impact\Students	\2 Implement.\External Engagement	.844986
6D\5 Outreach\Links w stakeholders	\4 Evaluation\Difficulties & Opportunities	.843968
\4 Evaluation\Difficulties & Opportunities	\3 Impact\Professors	.843506
6D\5 Outreach\Links w stakeholders	\4 Evaluation\Future	.84085
\3 Impact\Students	\1 Entry Context/Motivations	.839745

Through NVivo, a Pearson correlation analysis based on word similarity was conducted. From this analysis, we can observe that the categories Impact on Students, Links with Stakeholders, and Entrepreneurship Policies are correlated with the category Methodologies and Teaching, with Pearson correlations of .882289, .878276, and .874604, respectively. The categories most strongly related to Difficulties and Opportunities are Methodologies and Teaching (.90008), Promotion and Dissemination (.872571), Future (.86193), Human Resources (.856507), Entrepreneurship Policies (.84949), Links with Stakeholders (.843968) and Impact on Professors (.843506). Correlated with the category Future, we find the categories Methodologies and Teaching (.852267), Interaction between institutions (.851126), and Links with Stakeholders (.84085). Furthermore, we can see that Impact on Students is correlated with External Engagement (.844986) and Motivations (.839745).

4. Discussion

4.1. Alignment with Research Questions

This study focuses specifically on public Portuguese Higher Education Institutions participating in the Polientrepreneurship Innovation Network (PIN). As a qualitative study based on semi-structured interviews with a limited number of institutional representatives, it does not aim for statistical generalization but rather for a conceptual and exploratory understanding of systemic dynamics. The scope is limited to institutional conditions and strategies within PIN, and does not include private institutions, international networks, or policy actors external to HEIs.

The findings provide structured and comprehensive answers to the central research question and its five sub-dimensions. They show that the implementation of the Polientrepreneurship Innovation Network (PIN) has been shaped by distinct levels of strategic integration, program development, faculty engagement, inter-institutional collaboration, and student outcomes across Portuguese Higher Education Institutions (HEIs). Crucially, the results reaffirm the role of HEIs as key agents in fostering entrepreneurial mindsets and employability, particularly when supported by committed leadership and institutional networks that facilitate rapid learning.

The research highlights the essential role of leadership in accelerating institutional transformation and the importance of embedding entrepreneurship as a transversal mission. Despite national policy support, only one institution explicitly integrated entrepreneurship into its formal strategic documents, suggesting that cultural and institutional inertia remain significant obstacles.

4.2. Convergences and Divergences with the Literature

The results show strong alignment with the literature on entrepreneurial universities and innovation ecosystems (Etzkowitz, 2003; Clark, 1998), especially in how institutional missions and governance influence entrepreneurship education. Institutions more advanced in entrepreneurial education echoed the strategy-structure-environment fit proposed by Guerrero and Urbano (2012).

However, the findings diverge from idealized representations of inter-institutional collaboration often presented in Triple Helix models. While participation in PIN fostered some collaborative initiatives, cooperation remained informal, lacking systemic coordination and common governance tools. Leite et al. (2024) caution that overly rigid networks (‘strong ties’) may stifle innovation by limiting exposure to new ideas. The PIN could thus balance formal governance with Granovetter’s ‘weak ties’ to maintain diversity and adaptability. This echoes Iakovleva and Adkins' (2023) observation that symbolic participation in networks does not guarantee substantive collaboration or innovation diffusion.

Moreover, barriers such as curriculum overload, fragmented communication, and inconsistent teaching methodologies were consistent with critiques of entrepreneurship education in traditional academic environments (Fayolle & Redford, 2014; Nabi et al., 2017).

4.3. Emergent Patterns and Critical Interpretation

Three cross-cutting patterns emerged from the data:

1. The centrality of motivated individuals (“champions”) in initiating and sustaining entrepreneurial initiatives, often without formal institutional support.
2. The uneven integration of entrepreneurship into curricula, which ranged from elective courses to mandatory, cross-disciplinary modules.
3. A shared perception that entrepreneurship education enhances students’ employability, particularly through soft skills, adaptability, and project-based learning. Nevertheless, challenges remain. Institutions struggled with inconsistent implementation, a lack of formalized human resource strategies, and the voluntary nature of many initiatives. Teaching staff reported fatigue and conflicting priorities, especially when entrepreneurship activities lacked recognition in career advancement structures. These

patterns suggest that, without a comprehensive institutional strategy, entrepreneurial initiatives risk becoming peripheral or unsustainable.

4.4. Strategic and Systemic Implications

The study reinforces the idea that entrepreneurship education must be embedded within strategic governance, supported by adequate resourcing, and articulated through coherent institutional structures. The PIN has served as a catalyst for innovation, but its impact is limited by the absence of formal governance mechanisms, shared digital tools, and monitoring instruments.

From a Triple Helix perspective, the collaboration between academia, government, and industry remains more aspirational than operational. The potential for external stakeholder engagement is high but unevenly realized. Several institutions lacked structured outreach programs or consistent alumni engagement strategies, which are essential for sustained entrepreneurial ecosystems (Audretsch, 2014; Guerrero et al., 2015).

Additionally, the study reveals a critical gap in evaluation and sustainability planning. Financial constraints, limited staff development programs, and the absence of monitoring frameworks were frequently cited as limitations, highlighting the need for institutional and systemic reforms.

4.5. Unexpected Findings and Tensions

Despite a shared commitment to entrepreneurship education, several tensions emerged. Notably, there was a clear disconnect between national policy aspirations and local institutional autonomy. HEIs expressed difficulties in aligning external expectations with internal capacity, often citing the lack of resources or rigid bureaucratic structures.

Student engagement was often hindered by overlapping curricular demands and the perception that entrepreneurship was extracurricular rather than integrated. Furthermore, while faculty generally viewed entrepreneurship positively, many expressed concerns over insufficient pedagogical training, lack of recognition, and workload implications.

These tensions underscore a broader issue: without robust governance and sustainable funding models, networks like PIN risk being perceived as externally imposed, rather than organically embedded within institutional strategy.

4.6. Hypotheses for Future Testing

The qualitative data and comparative analysis allow for the formulation of hypotheses that could guide future research:

- The existence of dedicated entrepreneurship units or offices is positively correlated with deeper curricular integration and sustained institutional engagement. Inter-institutional collaboration is more likely when supported by joint funding mechanisms and shared governance structures.
- Faculty involvement in entrepreneurship education increases when linked to formal recognition, pedagogical support, and career incentives.
- Student participation grows when entrepreneurship is embedded in the core curriculum and linked to real-world employability outcomes.

Future studies should consider using mixed methods approach to test these hypotheses. Quantitative metrics such as the number of students enrolled in entrepreneurship courses, startup formation rates, incubator outputs, or faculty development programs could offer robust indicators to complement qualitative insights. The establishment of such metrics could form the basis for national or institutional benchmarking frameworks.

5. Conclusion

This study provides a critical and multi-institutional analysis of entrepreneurship education within Portuguese Higher Education Institutions (HEIs) participating in the Polientrepreneurship Innovation Network (PIN). The

findings reveal that while substantial progress has been made—including the integration of entrepreneurship into curricular structures, the development of incubation programmes, and the establishment of partnerships with external stakeholders—several structural and strategic challenges remain. These include inconsistencies in human resource management, insufficient funding models, and the lack of formal evaluation mechanisms to monitor the effectiveness and long-term impact of entrepreneurial initiatives.

The research underscores the need to institutionalize entrepreneurship education through coherent strategies that prioritize faculty development, financial sustainability, and systematic quality assurance. Moreover, the study highlights the importance of leadership, cross-institutional collaboration, and policy alignment in fostering an entrepreneurial culture capable of responding to the evolving demands of the labor market and innovation systems.

By structuring the analysis around a revised version of the Framework Conditions Index (FCI) and embedding it within the theoretical lenses of entrepreneurial universities and Triple Helix models, the study contributes a conceptual model that may inform both institutional practices and policy development in this domain. It also enriches the academic debate by proposing a multi-dimensional framework linking strategy, infrastructure, pedagogy, outreach, and evaluation to measurable educational outcomes.

Nevertheless, the scope of the study is bounded by its qualitative nature and its focus on a specific network of public HEIs in Portugal. These boundaries limit the generalizability of the findings, although they offer valuable exploratory insights into system-level dynamics. Future research should expand the analytical scope by including private institutions and applying longitudinal or mixed methods approach. To amplify PIN's impact, integrating holistic models like W.O.M.B. (de Almeida Leite et al., 2024)—which ties innovation to psychological well-being and sustainability—could align the network with Industry 5.0 and digital economy demands. Additionally, the use of quantitative indicators—such as entrepreneurship course enrolments, incubation outcomes, and faculty engagement metrics—would strengthen the empirical foundation for comparative studies.

Finally, integrating recent literature on digital transformation, sustainability, and post-pandemic innovation ecosystems will be critical for contextualizing entrepreneurship education within contemporary global challenges. As HEIs evolve into more agile and socially engaged institutions, entrepreneurship education must be strategically positioned at the intersection of academic excellence, societal relevance, and systemic innovation.

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Reconfiguring informed consent in the age of artificial intelligence: Bioethical and normative challenges in digital health

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Abstract

Man knows that his time to live is limited. Anxiety and the desire to eliminate limited time from your life has been a constant throughout human history. Current advances in biotechnology, namely and especially Artificial Intelligence, "seem to lead" man towards his desire for immortality. This article starts from an anthropological narrative in confrontation with a technological narrative, having as a question for reflection: "What makes us human?" Given the exponential development of Artificial Intelligence with an impact on human life and people's health, we reflect on the challenges of Artificial Intelligence and the opportunities or threats, as well as the associated ethical issues, informed consent, not in relation to values humans, but in relation to new rights and new duties.

Keywords: Anthropology; Artificial Intelligence; Duties; Ethics; Informed Consent; Rights.

"I am a man, so nothing that is human can be considered as alien to me."
(cf. Terence).

1. Introduction

Heidegger (2023), in his *Letter on Humanism*, states that Humanism can be summarized as follows: "to reflect so that man may be human and not inhuman, barbaric outside of his essence" (Martin, 1998).

In short, humanists are those who dedicate themselves to the study and action of this astonishing complexity that is a human being in its essence, traveling from its ontology to its ethical structuring.

Our conception of man, from the perspective of biological ontology, typically stages nine months, sheltered in the mother's body, and then emerges into the world, beginning a developmental process that manifests in the time he is given to live, until death. This development, in the human being, grants him a special ontological category.

From his biological constitution, the human brain has a certain area, with a few million neurons, that make all the difference: the executive brain (Goldberg, 2015), which is almost like the conductor of a large brain orchestra, regulating the activation of groups of neurons and their multiple synaptic networks so that human decisions are a coherent symphony rich in meaning, both rational and emotional. It is through this that the human being elaborates and models his decisions. As Daniel Serrão states, man is essentially a being of desires and decisions, who imagines and plans the future, knowing that his time as a human being is limited.

Conscious of this reality, the man who knows his time to live is limited, the anxiety and desire to eliminate the limited time of his life have been constants throughout human history.

Current advancements in biotechnology, particularly Artificial Intelligence (AI) and Human Genome Editing, "seem to lead" man toward his yearning for immortality and a world dominated by technology applied to digital health. The application of AI in the context of health calls into question, on one hand, the fundamental rights of the individual subjected to digital intervention, and, on the other hand, raises the assumption of new duties for

healthcare professionals who use AI as a tool in their professional activity, namely in teleconsultation, telemedicine, and telesurgery.

To understand what makes us human, we begin with an anthropological reflection and the ethical issues associated with it, particularly about the principles and values that should guide AI—in both its threats and opportunities. Finally, informed consent, as a fundamental right, involves not so much a reflection on ethical values, but rather on new rights and new duties.

In recent years, scholarly discourse has increasingly addressed the ethical and legal implications of Artificial Intelligence (AI) in healthcare, focusing on informed consent, patient autonomy, and algorithmic transparency. Floridi et al. (2018) proposed an ethical governance framework that highlights the need for explainability in AI-driven clinical decision-making. In parallel, Vayena et al. (2018) argued for the reinterpretation of informed consent in the context of predictive and personalized medicine. Mittelstadt et al. (2016) emphasized the risks of bias, opacity, and limited accountability inherent in algorithmic systems, calling for enhanced ethical safeguards and the reinforcement of patient rights. As Floridi and Cowls (2019) further contend, AI's opaque and autonomous decision-making capabilities fundamentally challenge traditional bioethical paradigms, necessitating a recalibration of normative frameworks to accommodate these emergent complexities.

2. Methodological Approach

This study adopts a normative-theoretical methodology, grounded in a critical analysis of selected scholarly literature, international legal frameworks, and emblematic case studies involving the use of AI in healthcare. The analytical process comprises three steps:

(i) identifying key bioethical principles (autonomy, beneficence, non-maleficence, justice); (ii) examining how these principles are challenged or reconfigured in contemporary digital health practices; and (iii) applying these principles to real-world cases through ethical reasoning.

The method is deductive and interpretative, drawing on doctrinal and legal sources to offer a conceptual and normative contribution to the debate on informed consent in AI-mediated contexts.

To support the ethical reasoning process, the following analytical matrix contrasts traditional medical ethics with emerging tensions in AI-driven healthcare:

Table 1: Ethical tensions in classical vs. AI-mediated informed consent.

Principle	Classical Medicine	AI-Mediated Healthcare
Autonomy	Patient chooses based on human explanation	Patient relies on algorithmic output, often opaque
Beneficence	Physician judges best interest	Algorithm optimizes outcomes statistically
Accountability	Physician is liable	Shared liability between human and technological agents
Transparency	Human reasoning is explicit	AI decision-making may be non-interpretable or black-boxed

This typology illustrates the layered complexity introduced by algorithmic systems and reinforces the need to reconceptualize ethical duties and legal safeguards in the age of digital healthcare.

While this study does not adopt an empirical design, its normative-theoretical approach adheres to established protocols in applied ethics. Normative analysis is widely recognized as a valid scientific method in bioethics, as

it allows for the conceptual refinement of principles and the interpretive assessment of moral dilemmas within specific technological contexts (DeGrazia & Beauchamp, 2019; Gracia & Júdez, 2004). Through a structured engagement with primary ethical principles—namely autonomy, beneficence, non-maleficence, and justice—the study advances critical reflection on their applicability in AI-mediated healthcare. This method does not aim to produce statistical generalizations but to offer conceptual clarity and ethical guidance for policy-making and clinical practice.

3. Brief Anthropological Narrative

3.1. The Narrative of the Beginning:

In the narrative of the beginning, from Genesis (Couto, 2013), "sexual polarity is a created reality, not divine" (Von Rad, 1972). In truth, the Bible does not know "man" except as man and woman. The biblical narrative recognizes humanity only as it has always perceived itself: two complementary and reciprocal beings, whose attraction, needs, and possibilities of union are inscribed in their own conformation (Couto, 2013).

In the biblical account, when God pronounces that emphatic "it is not good for man to be alone" (Gn 2:18), He alerts us to the grave problem of solitude, which consists of man potentially being left alone amid objects. This alert leads us to think that when man surrounds himself with objects, he aims to become the owner of everything and everyone. Surrounded by objects, man tends to lose his humanity.

Still, in this biblical context, as Adolphe Gesché rightly asks: "Does the mysterious plural—let us make—no longer contain our presence?" (Gesché, 1991). Yes, in fact, this "let us make" means that God does not speak only to Himself but also to man, inviting him to join in the work of creation (Wénin, 1998), in the sense of the duty to dominate the earth and subdue the earth and its creatures (Gn 1:26b-28b). Clearly, this is not about a domineering rule of man but about becoming a collaborator, a co-creator, and being in the world as God is in Heaven, receiving the world and the earth as a gift, knowing how to give it back to God, freely.

It is also, as Paul Beauchamp points out, about governing with sweetness, a sweetness that does not limit man's power, for it is Power itself (Beauchamp, n.d.). This means that the biblical verb "to dominate" and "to subdue" imply leading, commanding, either to protect and defend the house of life, or to resist injustice and the animality that might subjugate man.

That majestic plural "let us make" spoken by God does not exist in biblical anthropology (in Hebrew), rather, it is a deliberative or declarative plural given the importance of the work of creation. However, man did not, and often still does not, know how to interpret this "let us make." Man wanted, and still wants, to dominate instead of caring, and thus he does not know how to dominate the animal within him. Dominated by his animality, he was soon expelled from the garden where God had placed him.

Man quickly concluded that he wanted to dominate other men, and thus was expelled from the "garden of delights..."; this desire for domination leads him to kill his neighbor. It has been this way since his origins: in man lies the yearning and desire for possession and power. Yet, never before has man, in his quest to dominate a world that welcomed him freely, been so close to being expelled from his humanity.

Man, created by love and given to himself by love; the world created by love, given to man by love—this is the meaning, reason, and intentionality of the work of creation. To read man and to read the world without respecting the creator's intentionality, who gave it to us, selfishly interrupts the sense of humanity's creation, and by not respecting this sense of God, man lives according to his own interests and whims.

Man is not the owner but the gift. Man, as a gift and not as an owner, does not take the world or others as possession. Man, as a gift, kills the animality within him and exalts, as Aristotle says, his rationality and intelligence (Di Sante, 1999). By choosing this path as the source of all law and meaning, man lives without killing, because he has killed his animality, and follows a different path, not starting from himself, but from the other (Levinas, 1974). The source of this path is the grace of the creative voice that has never been heard, but from a

silence that has never been silenced (Beauchamp, n.d.). Man, as a gift, accepts this founding grace and gives thanks.

In stark contrast to the animal, which also lives by grace, but knows nothing of this grace. It is clear that the human being is no longer in the garden created by the Creator. That territory is now a lost paradise. The human being finds himself already in a man-machine dialogue, dependent on the economic system that creates him. This man, who freely received the world and his neighbor, is rapidly traveling toward a world without humanity and without work; a world where problems will be solved by technology: by artificial intelligence and human genome editing; and where man will enjoy universal abundance. Man desires and yearns to be the master of the world, not a gift in the world. With this utilitarian totalitarian vision, man seeks to control and dominate humanity and his own future. If that is the case, who needs to dream of another future?

3.2. The Anthropocentric Narrative

In the Greek world, man lives in harmony with nature, cooperating with the rational order of nature, as a "universal symphony" that expresses the diversity of elements in an articulation of unity and obedience to the same principle.

In the Middle Ages, with no significant changes, a new element and a new meaning are introduced: "God, the absolute creator." Man is created in the image and likeness of God, and nature is the work of divine creation. The new element is that there is a coincidence between the law of nature and the divine law; and the new meaning presents God as a moral criterion that calls man to freely follow his unique path toward the Creator—God. Therefore, man acquires a different status from other beings, as a spiritual being that grants him a superior quality in the world he inhabits, but for which he was not destined. In Christianity, the icon of this relationship with nature and God was Francis of Assisi (1181–1226).

Regarding the Renaissance period, we can affirm that the two perspectives on man's relationship with nature are found: man is a microcosm in a macrocosm, living in a "universal sympathy" of harmonic proportionality between all beings. Man appears as a superior being in relation to the world but also distances himself from it to better understand it objectively.

In the Modern Age, particularly with Descartes, man is increasingly affirmed as the starting point of all true knowledge; nature is no longer understood through final causes and is instead explained by efficient causes. This period also marks the development of experimental sciences and the production of instruments and techniques for more diversified and effective intervention in nature. Science evolves and, in turn, allows for scientific progress that leads to an exponential increase (in contemporaneity) in man's power to shape nature according to his needs and interests. The anthropocentric perspective elevates to anthropocentrism by considering man as the center of the universe in relation to nature, reducing nature to a mere utility. Nature becomes an object in the hands of man.

It is in this deification of technology and science that Hans Jonas will denounce the "unregulated evolution" of technology. In this context, he proposes a new ethics and a new principle that can respond to technological civilization—the principle of responsibility—which is capable of predicting the effects of actions caused by emerging technologies. An ethics of prediction that acknowledges that the effect of each action always carries ethical significance for the future, formulating an ethics of responsibility as follows: A new imperative: act in such a way that the effects of your action are compatible with the permanence of authentically human life on earth; or act in such a way that the effects of your action do not destroy the future possibility of such life.

From Jonas' (2006) perspective, the promise of modern technology has become a threat. Technology, which was previously devoid of morality, now, because of its intervention in the subjective ends of human action, acquires ethical significance. Its constant demand for human inventiveness, both in what has yet to be done and in the maintenance of its artifacts, responds to human ambition in that it achieves success and crowns man with triumph.

4. From Technological Innovation to Artificial Intelligence

History teaches us that technology is inherent to human activity. We are always inventing and improving tools to serve humanity. Now, the technologies—Artificial Intelligence (AI)—that we create are shaping and inventing us (Kuskis, 2013). None of the technology, such as AI, invented so far, can change man entirely.

4.1. But What Makes Us Human?

What makes us human is not the mathematical, nor even the chemical or biological, but what surrounds us as individuals. That is, what goes unnoticed, the unspeakable, consciousness, the capacity for reflective intelligence in evaluating the good and the evil of actions through the consideration of moral values. The subject, the person, is not a thing; it is neither reifiable, instrumentalizable, nor objectifiable. The person, as an end in itself, is neither comparable nor equivalent. Its nature, being human, intrinsically acquires autonomy, freedom, and dignity.

It is due to the capacity for reflective intelligence that a person knows they have the freedom and autonomy to question the goodness, or lack thereof, of technology. Modern humans, if they want to dominate the confrontation between AI and Humanity, will have to apply basic ethical standards: be demanding in evaluating AI while understanding that their mission is not to stop progress but to humanize it.

Understanding the exponentiality of technology and its implications for the future of humanity is crucial. We must learn to imagine and then live with the changes. In the immediate future, which is ours, waiting to see is as bad as doing without thinking. We must look to the horizon, for the future is a constant definition and not something that simply happens. This means we must examine technology and question its necessity and appropriate use. The current time is no longer about the capacity to use a technology, but above all, how to apply ethics to technique; or, in other words, that technology meets the ethical demands of humanity.

The present time forces us to see, to be awake and attentive, to emerge in future scenarios, to discover how it would be to live in that future, because technology can be either paradise or hell, so we must be cautious and ask what is at stake: the how, when, how much, and for whom. The future is not a yes or no answer, but rather, it depends. If the questions of why and for what are heard, technology will be more balanced, but for this to happen, it is necessary to ask.

The answer lies in becoming better stewards of humanity. Each of us—a worker, a business leader, or any politician in their public representative role—must accept this task and act with responsibility, honesty, and truth. We must generate trust in the present and future of humanity because without an ethics of trust, technology, and AI without ethics will condemn the society dreamed of by Aristotle, whose goal is to achieve the just mean; the just mean, or measurement, is only possible when we research and invest in technologies that offer more effective ways to reduce or limit undesirable consequences.

Thus, organizations and institutions have the ethical duty to evaluate and judge whether this technology will diminish humanity. Evaluate and judge whether this technology will promote human happiness. Evaluate and judge the involuntary and potentially disastrous side effects and verify whether this technology will assume too much power. Finally, it is an ethical imperative of precaution to understand whether this technology will serve man or will serve itself. In other words, if technology (AI) should serve humanity and not man serve technology.

A technological future without humanity is a future without the human being. Humanity without an anthropology could become a technological orchestra supervised by superintelligent computers—machines and algorithms, cyborgs, and robots—or by those who dominate them!? The technological future, from this perspective, may even tolerate humans as pets or, at best, as a necessary evil; at worst, enslaved by the goddess of technology. It would be a desensitized, disembodied, and dehumanized society.

The curve of technological advancements continues to grow exponentially. This represents a cognitive challenge for us. Technological advances are increasingly combined and integrated. Radical advances, such as machine intelligence and deep learning, the Internet of Things, and human genome editing, are beginning to intersect

and complement each other. Technology seems to have no understanding of ethics, norms, or beliefs. These are matrices or values of human society. However, AI may, in the future, learn to read or understand our social or moral considerations, and even our moral dilemmas. But the question is: will it experience empathy, compassion, and exist as a "self" (Leonhard, 2017)? We live largely according to our values and beliefs, not according to data and algorithms. AI will never cease to be a computerized machine, and even with its immense capacity to analyze and simulate how humans act, it will be far from existing as a "self."

That is, despite simulating the most diverse and imaginative human interactions increasingly close to perfection, technology does not know, nor does it want to know, about happiness, personal satisfaction, personal fulfillment, emotion, or values and beliefs. It only understands logic, rational action, incompleteness, efficiency, effectiveness, and a simple yes or no response. The intelligent machine, to understand what happiness is, would first have to be happy. And to be happy, it needs to be incarnate and not nihilistic. Simulation is not duplication; mediated reality is not the experience of embodied reality (Leonhard, 2017).

For example, as Daniel Serrão says, if one day ectogenesis becomes possible, i.e., the generation of children outside of any woman's womb, without pregnancy or childbirth, it will be socially accepted, welcomed, and practiced as a great triumph of biological science, although for the author, this triumph reduces humanity itself. The human being, instead of being conceived, will be produced. Daniel Serrão also talks about quantum teleportation of a human body, the manufacture of cyborgs equipped with brain implants that will allow them to communicate telepathically with each other and with poor humans, who will become a subspecies with primitive and very limited forms of communication.

But is all this technology neutral and devoid of ethics until the moment we apply it? Is it only when applied by humans that it has ethical consequences? Or can we think that a technology with the potential to cause harm is not neutral, but already responsible for the act it causes?

5. Challenges of Artificial Intelligence: Opportunities or Threats

In medicine, for example, advanced technologies such as human genome editing, like CRISPR-Cas9, may soon help combat cancer and increase longevity. Another example of science's continuous surprises is what's already happening with reproductive techniques. After artificial insemination and surrogacy, the latest advancement allows a couple to have a child with DNA from a third person to prevent a genetic disease.

This technique is now legally practiced in the United Kingdom. For some, these scientific advances are remarkable; for others, they raise considerable ethical issues. At stake is a procedure, technically known as Mitochondrial Donation Treatment, used to prevent the child from inheriting mitochondrial diseases from the mother—rare, debilitating, and serious conditions present in maternal mitochondrial DNA. This triple genetic parentage raises an "ethical issue": the manipulation of human life during the generational phase and the destruction of embryos, which violates ethical principles such as "human dignity" and "genetic identity protection" (Neves, 2023).

Other examples can be discussed: robotics will increasingly invade operating rooms, and surgeons may no longer need to be physically present for procedures such as gallbladder removal or coronary bypass surgery—situations that are already real today. Recent scientific developments have revolutionized surgical procedures with the inclusion of robotics. The global market for surgical robots, which perform procedures both in-person and remotely (tele-surgery), has also been growing rapidly in recent years. Six million robot-assisted surgeries have already been performed worldwide, and these procedures can take place in locations that lack specialists, thanks to tele-surgery. Robotic technology is now used in minimally invasive surgeries, especially in urology, gynecology, general surgery, thoracic and abdominal surgery, and neurosurgery—especially due to the need for millimetric precision in surgical interventions.

AI, with its deep learning algorithms, can already read tomography scans faster than humans; natural language processing (NLP) can search for unstructured data in electronic health records (EHRs), and AI applications have become omnipresent in healthcare, with seemingly endless technical applications.

AI has the potential to reveal new data inputs and simplify interaction with health data, but the threat is the violation of privacy and the reservation of people's private lives, which is ethically reprehensible. Additionally, within the doctor-patient relationship, AI raises concerns about medical errors.

AI and its employment in healthcare will raise new challenges to the state of the labor market in healthcare as the sector adapts to new technologies. The first changes will affect the doctor-patient-professional relationship. Another aspect is that AI will replace workers in healthcare.

The replacement of workers in healthcare is already a concern. A 2018 Gallup Institute survey found that 71% of Americans believe AI will eliminate more jobs in healthcare than it will create. Just under a quarter of respondents believed healthcare would be one of the first sectors to lay off healthcare professionals due to the exponential rise of AI applications (learning tools). The most vulnerable are radiologists and pathologists, as many of the most impressive advances in AI are occurring in image analysis and diagnostics. “In recent years, AI-based imaging technologies have shifted from academic activity to commercial projects. There are tools to identify a variety of ocular and skin disorders, detect carcinomas, and support the necessary measurements for clinical diagnosis” (Stanford University, 2024). According to the report, some of these systems rival the diagnostic abilities of specialized pathologists and radiologists and can help alleviate specific tasks, such as counting the number of dividing cells in cancerous tissue.

Another issue is that AI presents a new set of challenges related to data privacy and security—challenges exacerbated by the fact that most algorithms require access to large data sets for training and validation. The exchange of vast amounts of data between different systems is an unknown territory for most healthcare institutions. The financial and reputational risks of a high-profile data breach, due to an inability to protect the data, is a relevant ethical, legal, and technical issue. Most institutions are advised to keep their data assets well-protected in highly secure systems that comply with HIPAA (Health Insurance Portability and Accountability Act), a set of standards healthcare institutions must follow to protect information.

Ensuring the privacy of all data will require updating data privacy laws and regulations to include data used in AI and machine learning systems, stated the Cloud Security Alliance (CSA). Privacy laws need to be consistent and flexible to account for innovations in AI and machine learning. Current regulations have not kept up with technological changes. HIPAA requires data de-identification; however, technology today can link de-identified data, resulting in identification.

This places AI in a regulatory gray area, making it difficult to ensure that each entity is required to protect patient privacy and will face consequences if they fail to do so.

Cyberattacks and concerns about patient privacy. Researchers at the University of Pittsburgh (TI Inside Online, 2024) found that cyberattacks using falsified medical images can deceive AI models. The study sheds light on the concept of “adversarial attacks,” in which perpetrators aim to alter images or other data points to cause AI models to draw incorrect conclusions. Researchers trained a deep learning algorithm to identify cancerous and benign cases with over 80% accuracy. They then developed a “Generative Adversarial Network” (GAN), a computer program that generates fake images by shifting cancerous regions into negative or positive images to confuse the model. The AI model was deceived by 69.1% of the falsified images. Of the 44 positive images made to appear negative, the model identified 42 as negative. Of the 319 negative images altered to appear positive, the AI model classified 209 as positive. As stated by Shandong Wu, Ph.D., The purpose of this study is to show that this type of attack is possible and can lead AI models to make incorrect diagnoses—which is a major patient safety concern. Understanding how AI models behave under attacks in medical contexts, we can begin to think about ways to make these models more secure and robust.

On the other hand, AI can also help alleviate the stress and burnout of doctors and nurses, reducing clinical absenteeism. The COVID-19 pandemic affected doctors, nurses, and other caregivers, who may reduce their working hours in advance. Automating some routine tasks that occupy a doctor's time, such as documentation (electronic health records), administrative reports, or even triage of CT scans, can be beneficial for doctors to focus on the complicated challenges of patients with rare or severe conditions.

In healthcare, it is believed (and AI experts also believe) that the balance point for AI in healthcare will be the combination of human experience and digital enhancement. Each type of intelligence should be adjusted to the needs, and together, human experience and AI will improve care delivery. For example, AI is ideally equipped to handle challenges that humans naturally cannot face, such as synthesizing gigabytes of raw data from various sources in real-time for a hospitalized patient. But no one expects a robot to converse with the family of the patient about treatment options or to provide compassionate and supportive care if the disease leads to death.

While it is true that AI brings benefits and the total, online machine body knowledge, expanded for technological performances we cannot yet imagine, will make medical activity almost exclusively preventive, total knowledge of the pathways leading to illness will create a rigorous science of disease prevention. The consequences, according to Daniel Serrão, “are both good and bad; some will be very bad and dangerous.”

5.1. From Telemedicine to Telesurgery

Telemedicine consists of the provision of healthcare services through information and communication technologies, where the healthcare professional and the patient are not physically present in the same location. This involves “the transmission of health data and information through text, sound, images, or other necessary means for the prevention, diagnosis, treatment, and monitoring of patients,” and is present in various medical specialties, “from teleradiology to telesurgery, including teleconsultations” (Pereira, 2020).

In fact, telemedicine is not a recent reality, but it has gained significant momentum in recent years—largely due to the digitization of health data, AI, and microcomputers linked to health information—enabling the adoption of new resources such as the provision of remote healthcare services with greater efficiency. A recent example of this potential was experienced during the COVID-19 pandemic, where various health systems published exceptional guidelines for remote medical care during the public health emergency.

In our view, and in the view of many experts, the pandemic caused by COVID-19 represents an important milestone in the history of telemedicine and access to healthcare (Eduardo & Rafaella, 2020). The benefits that can be highlighted are: “increased efficiency in medical care, consultations for populations located in remote areas from health centers and hospitals, effective support for the lack of specialized professionals, or where medical practice conditions are limited,” as is the case in Portugal, which faces a shortage of doctors, particularly in rural areas (a problem affecting developing countries worldwide). Therefore, the use of AI tools may not be a bad idea for doctors struggling to meet the needs of numerous complex cases and patients requiring significant care investments.

Regarding telesurgery, the use of robots makes surgery safer and more precise by eliminating the natural tremor of human hands; a micro camera amplifies the surgeon's view and decision-making during surgery. Specialists argue that this makes the surgery faster and more accurate. The robot precisely replicates the movements of the doctor's hands, and it is certain that AI technology is already working toward enabling the robot to one day perform an intervention without the human factor involved (Eduardo & Rafaella, 2020). These technologies could change the entire logic of healthcare, social security, and employment.

The technology of Artificial Intelligence, computing, and deep learning will produce recursive improvement—self-amplification (autonomous robots that reprogram themselves). According to some experts, this “explosion of intelligence” could lead to the emergence of superintelligence. AI will learn and think faster than humans (Leonhard, 2017), with the escalation of monitoring our digital lives: surveillance, reduced privacy, loss of anonymity, digital identity theft, security, and more. All these technologies use sensitive health data from the

patient, raising questions about the reflection on the values and ethical principles that should govern this data handling, especially regarding the patient's consent.

6. Ethical Values and Principles Applied to Artificial Intelligence

The values and ethical principles applied to AI remain the same as those principles and values applied to human life and intelligence. Norms and regulations should align with domestic law and international law, including the United Nations Charter, as well as being in harmony with international objectives regarding social, political, environmental, educational, healthcare, scientific, and economic sustainability.

6.1. What Ethical Values Should We Promote and Safeguard?

First and foremost, the inviolable, inherent, and intrinsic value of Human Dignity. Every human being forms the foundation for the system of human rights and fundamental freedoms. Each person enjoys this value, which is universal, ineffable, inalienable, intrinsic, and interdependent.

Therefore, the value of dignity demands the safeguarding of the principles of respect and protection of human rights, which are the guarantee of human dignity enshrined in the Human Rights Charter and democratic constitutions. It is from this indelible value that justice and equity are ensured, regardless of a person's condition: race, color, ancestry, gender, age, language, religion, ideology or political opinion, nationality, ethnic origin, or social and economic background.

Under no circumstances can an individual or community be harmed or subordinated, whether physically, economically, mentally, politically, or culturally, in relation to the development of Artificial Intelligence. AI systems must enhance, not diminish, the quality of life for every human being, and this definition of quality of life should be open to individuals or groups, as long as no human rights violations or abuses occur.

The value of human dignity calls for the principle of vulnerability. Interaction with AI systems should promote assistance and care for the most vulnerable, as well as for those in vulnerable situations—children, the elderly, and individuals with disabilities or illnesses. In such situations, AI must never objectify or commodify the human person, as doing so would ethically violate their dignity and infringe on fundamental rights. Human rights, as a human value, must be protected and respected by AI systems. Governments, institutions, and universities must respect human rights as a limiting framework for AI when they cause harm.

The environment and ecosystem are values of humanity and existential necessities. Environmental prosperity invokes the ethical principle of social responsibility toward future generations. AI must not serve interests that hinder humanity from enjoying the benefits of nature. AI can and should foster peace and environmental cohesion. All those involved in AI development should adhere to the ethical principle of precaution and comply with applicable standards to ensure that the planet's sustainability becomes a reality and to prevent the unsustainable exploitation, use, and transformation of natural resources.

Diversity and inclusion are valued principles that must be guaranteed in society. AI should provide tools that ensure the respect, protection, and promotion of these values—of inclusion and diversity. Lifestyle choices and beliefs cannot be excluded from these systems. The value of inclusion refers to the ethical principle of cooperation to transform disadvantages into advantages; to reduce the gap separating technological infrastructural weaknesses, education, and skill and competence. From the ethical principle of cooperation, the principle of solidarity is derived to bridge differences and promote diversity.

AI should also support all technological systems based on the value of Justice, in order to ensure peaceful societies and fair distribution of benefits. AI systems must contribute to the interconnection of society as a whole. Interconnection is based on the understanding that each person is part of a whole and that the whole thrives when all parts also thrive.

Our values and ethical principles are what guide and compel us. Therefore, in the face of the digital world, if we do not want to create a digital atomic bomb (as was the case with the analog atomic bomb), a reality we would

regret the consequences of, we must commit to the human team that can define which intelligent machines are most likely to promote the flourishing of humanity, rather than just the growth and development of technology (Leonhard, 2017). To ensure this, the European Union's recommendations are important and relevant, pointing to some fundamental requirements: 1) human oversight in decision-making; 2) technical and security standards—AI systems must be safe, robust, resilient, and trustworthy, in order to ensure that any accidental or intentional harm can be minimized and prevented; 3) data privacy—ensuring that data fully respects privacy, protection, and personal integrity.

6.2. What Ethical Principles Should Guide AI?

In 2021, the World Health Organization (WHO) released its first global report on the ethics and governance of AI in healthcare. The WHO emphasized the potential health disparities that may arise as a result of AI, primarily because many AI systems are trained with data collected from patients in high-level care settings.

The WHO suggested that ethical considerations should be taken into account during the design, development, and deployment of AI technology. Specifically, it recommended that individuals working with AI operate according to the following ethical principles: protect human autonomy; promote human well-being, safety, and the public interest; ensure transparency, explainability, and intelligibility; promote accountability; ensure inclusion and equity; promote responsive and sustainable AI.

- Protection of Autonomy: This means that humans should retain full control over AI systems. These systems must not, and should not, diminish human control over healthcare systems.
- Safety, Well-being, and Protection: AI must be able to eliminate unintended harm and vulnerabilities during the system's lifecycle, ensuring the protection and safety of human beings. It should also take into account mechanisms that safeguard privacy and the confidentiality of personal life.
- Ensuring Transparency, Explainability, and Intelligibility: Information and documentation should be truthful. Technologies must be explained in accordance with their audience; the rigor of information and the accuracy of explanations are critical ethical factors in understanding the use of AI in healthcare.
- Proportionality and Do No Harm: AI technologies do not, on their own, guarantee the social cohesion of humanity. All AI systems should be appropriate for the context and needs. They must also ensure risk assessment procedures and adopt measures to prevent harm. The ethical principle of proportionality helps to build: a) methods proportionate to their purpose; b) not infringing fundamental values or violating human rights; c) being appropriate for the context and based on robust and rigorous scientific foundations. This implies that if technical possibilities could impact life decisions or result in death, the final human determination must be applied. AI systems should not and cannot be used for social grading, mass surveillance, or individual surveillance.
- Equity and Non-Discrimination: AI should promote social justice and safeguard equity and non-discrimination. It implies ensuring that the benefits AI can offer are available to all. Inclusive access to AI systems with relevant services and content, respecting diversity, should be ensured to avoid digital exclusion.
- Guaranteeing Inclusion and Equity: AI in healthcare and for individuals should include everyone in healthcare needs to ensure equity, regardless of any social, cultural, economic conditions, or other vulnerabilities.
- Promotion of Responsive and Sustainable AI: AI technologies should only be applied if they serve humanity and meet the needs of each human being. Their sustainability requires an ethical perspective that favors the environment and a healthy, non-fundamentalist ecology.

7. Regulatory Instruments

What can and should we do to ethically regulate and minimize the risks or threats associated with AI?

The Portuguese government, in its “Portuguese Charter of Human Rights in the Digital Era,” states in Article 9 that “the use of artificial intelligence should be guided by fundamental rights, ensuring a fair balance between

the principles of explainability, safety, transparency, and accountability; it should take into account the circumstances of each specific case and establish moral criteria to avoid forms of discrimination" (Article 9, Law No. 27/2021, May 17, amended by Law No. 15/2022) (World Health Organization, 2021).

It also emphasizes that regarding the creation of robots, the principles of beneficence, non-maleficence, respect for human autonomy, and justice are applicable, as well as the principles and values enshrined in Article 2 of the Treaty of the European Union, including non-discrimination, tolerance, and the inviolability of human dignity, which must be respected and protected. Human dignity constitutes not only a fundamental right in itself but also the very foundation of fundamental rights (Article 3).

At the European level, on April 8, 2019, the European Union published the "Ethical Guidelines for Trustworthy AI," based on the premise that AI should be lawful, ethical, and robust, establishing seven requirements that AI must necessarily meet. These are: 1) AI supervision must be human-led; 2) Technical robustness and safety—systems must be resilient and secure; 3) Data privacy and protection; 4) Transparency and explainability of AI systems; 5) Diversity, non-discrimination, and equity—biases lead to negative implications, such as marginalization of vulnerable groups; 6) Social and environmental well-being and concern for present and future generations; 7) Accountability and responsibility for AI systems.

8. Informed Consent and AI—Applicability

It is imperative that informed consent be protected in the domain of AI tools and their various applications. The collection and storage of sensitive data raises concerns among individuals. The recent fundamental right to digital "forgetfulness" of personal data, except under specific circumstances (Correia et al., 2021), necessitates a reconsideration of the informed consent doctrine to better suit the digital age. Respect for privacy rights and the duty of transparency may create some difficulties. While transparency is essential for building trust, it can also pose a risk to individual privacy and the protection of personal data. That is, while the explainability of closed AI systems is important, excessive transparency can undermine the privacy process (CNECV, 2024).

As the National Ethics Council for Life Sciences (CNECV) states, the processes of anonymization and pseudonymization have shown flaws, suggesting that this risk be minimized by resorting to synthetic data (CNECV, 2024).

8.1. Consent in Robotic Surgery and Telemedicine Surgery

It is estimated that the Da Vinci robotic surgeon (manufactured by Intuitive Surgical) has already performed minimally invasive surgeries on about six million people worldwide. In areas without specialists, these interventions can be performed through telemedicine surgery.

As noted, there are numerous benefits of robotics in surgery—elimination of natural hand tremors, greater flexibility of robotic arms that can rotate 360º, increased precision in cutting and suturing tissues, leading to reduced blood loss and smaller scars. However, the complexity of the human body and the inevitable influence of external factors lead to uncertainty, an inseparable attribute of medical practice, and robotics in surgery does not eliminate unpredictability in medical treatment. Some examples of such unpredictability are already the subject of legal cases.

In the U.S. context, legal disputes over robotic surgery with Da Vinci robots have centered on violations of the duty to inform and product liability. While most cases have been settled out of court, the *Taylor v. Intuitive Surgical, Inc.* case (2017) offers a landmark example of judicial scrutiny regarding informed consent in robotic-assisted surgery. In this decision, the Supreme Court of Washington evaluated not only the clinical risks associated with robotic procedures but also systemic communication failures and the extent of the manufacturer's duty to inform hospitals, not just individual physicians. The ruling challenged conventional frameworks of medical liability and reinforced the necessity to reconceptualize informed consent in contexts of algorithmic mediation and robotic delegation.

In robotic surgery, as with any medical intervention, the duty to inform and clarify is an ethical duty, a good clinical practice, and an essential component of the doctor-patient trust relationship. This duty is embodied in the ethical and legal principle of informed consent. Its neglect signifies a breach of the relationship between the healthcare professional and the patient in terms of autonomy and self-determination.

In the case of an intervention using AI tools such as telemedicine surgery (robotic surgery), the doctor must clarify, in addition to clinical explanations, the methodology that will be used to perform the surgery. The patient has the right to know the risks and advantages of robotic surgery. In the event of damage, whether physical or moral—physical damage refers to harm to physical integrity, and moral damage refers to harm to personal integrity—if the lack of informed consent is proven, compensation is due for the deprivation suffered, as stated in the Portuguese Constitution, which affirms that no one can be harmed in their physical or moral integrity. This is also referenced in the Civil and Penal Codes, in the respective legal articles on informed consent. It is the victim's responsibility to demonstrate that the damage was caused by a risk they should have been informed about to make an informed decision on whether to accept the treatment, in order to establish and verify the causal link between the omission of information and the damage.

Currently, examples of conflicts between patients and doctors using robotic surgery are numerous. In 2009, a surgery involving the "Da Vinci" robot, the Pennsylvania District Court in the United States resolved the case *Mracek v. Bryn Mawr Hospital and Intuitive Surgical* without analyzing the merits (summary judgment) on the grounds that the patient did not provide sufficient direct or circumstantial evidence of a causal link between the device defect and the damage suffered. The case dates back to 2005, when, during a minimally invasive surgery, the robot began displaying error messages, and the team attempted to restart the robotic platform several times in an effort to continue the surgery. A technician from Intuitive Surgical had to intervene to try to fix the issues, including attempts to reposition the robot's arms, but was unsuccessful. Due to the inability to restart the robotic intervention, the medical team abandoned the robotic platform, and the surgeon completed the surgery using traditional laparoscopic equipment. The time between the suspension of robotic surgery and the initiation of conventional surgery was approximately 45 minutes.

This is an example of many situations where distance robotic surgery can be interrupted and replaced by conventional surgery, performed by a different doctor rather than the original surgeon. This issue is crucial because the initial premises are altered without the patient's consent. As a result, the change in procedures sometimes leads to larger scars on the patient's body, which were not anticipated in the consent and clarification process of undesirable effects. Moreover, the conversion of the procedure may result in "longer surgical time, more time under anesthesia, and/or the need for additional or larger incisions and/or increased complications." All of this information should be provided to the patient beforehand to allow them to make a more informed decision.

This case, along with others, demonstrates the possibility of complications during robot-assisted surgeries, leading to the need for conversion to an open surgery. Thus, the risks associated with robotic surgery become evident.

In this sense, Deborah Dubeck, in the article "Robotic-Assisted Surgery: Focus on Training and Credentialing," outlines specific aspects of informed consent in robotic surgery: 1) the patient needs to be informed and clarified on more than just the general risks; 2) the benefits and alternatives associated with the procedure; 3) the risk of robotic failure and the implementation of a contingency plan; 4) the possibility of converting to an open procedure. All of these issues must be addressed in the informed consent process with the patient, which increases the need for the healthcare professional operating robotic AI systems to clearly explain and clarify the benefits and risks, pros and cons of robotic surgery, alongside other therapeutic alternatives.

In a hypothetical case where a doctor remotely performs coronary artery bypass surgery and, during the procedure, the robotic arm makes an unexpected movement, cutting a coronary artery and causing significant damage to the patient, the professional may face legal action for damages. However, it is crucial to understand

the causal link between the medical conduct and the damage suffered. One might conclude that the doctor acted prudently, diligently, and with the required knowledge, and that the damage was caused by the time delay between the surgeon's hand movements and the robot's response.

8.2. Information Required for Free and Informed Consent in Robotic Surgeries

The following information is suggested for inclusion in the informed, free, and clarified consent process for robotic surgeries:

1. The possibility of interruption of telemedicine surgery due to internet connection issues or equipment failure.
2. The existence of a time delay between the surgeon's movements and the robot's response, which may lead to an adverse event.
3. The technical risks arising from software failure or technological limitations.
4. The potential for illicit third-party access to the patient's health data stored on a network.
5. Clear explanation to the patient of the differences between robotic surgery and conventional surgery for the specific case.
6. Demonstration of the surgeon's professional and technical skills to perform robotic interventions, clarifying their adequacy and technical expertise with robots.

Numerous cases of errors and accidents in telemedicine surgeries have occurred. One such case involved a patient in 2015 who died after undergoing robotic surgery at Freeman Hospital in Newcastle, England. The robot made a sudden movement, tearing part of the heart during the surgery. The doctor admitted to insufficient capacity and technical training to operate with the technology. This ethical and legal responsibility does not solely fall on the unprepared professional but also on the hospital for failing to adopt appropriate policies for robotic surgery training.

Thus, the doctor also has the duty to inform and clarify to the patient undergoing such interventions about their technical capacity:

1. The level of technical training and experience in robot-assisted surgeries.
2. The hospital's robotic surgery training and education policy.
3. Whether the specific robotic surgery has been performed by anyone else at the same hospital or another hospital within the country.
4. The benefits and risks of robot-assisted surgery in comparison to conventional surgery.

Patients who undergo telemedicine surgery, as per medical recommendation, must be informed about the surgeon's experience with the recommended robotic procedure. The doctor should discuss their surgical experience and explain all associated risks (Massachusetts Board of Registration in Medicine Guidelines).

In this sense, informed consent for robotic surgery, whether performed in person or via telemedicine (tele-surgery), should include at least 12 essential items (Eduardo & Rafaella, 2020), as follows:

1. A description of how robot-assisted surgery is performed and its main advantages.
2. Differences between robotic surgery and conventional surgery for the specific case.
3. General information on the expected benefits and potential risks associated with using the technology.
4. Clarification of the surgeon's aptitude, skill, and experience with robot-assisted surgeries.
5. Information about the robotic surgery training and education policy of the hospital where the procedure will take place.
6. Whether the robotic surgery has been performed by others at the same hospital or any other healthcare institution in the country.
7. A note on the possibility of interruption in telesurgery due to internet connection issues or equipment failure.

8. Information about the possibility of complications during surgery due to system or robotic equipment failure, leading to a conversion from robotic surgery to conventional (open) surgery, potentially with a different doctor performing the surgery than originally planned with the patient.
9. Information that the conversion from robotic to conventional surgery (open) involves larger incisions and more time under anesthesia, increasing risks for the patient.
10. Explanation that in telemedicine surgery, there is a time delay between the surgeon's hand movements and the robot's response, which could cause an adverse event.
11. Exposure to other technical risks from software failure or technological limitations.
12. Transparent explanation of how the patient's data is stored on a network and the possibility of illicit third-party access.

9. Patient, Digital Assistants (AI), and Informed Consent: From the Right to Information to the Right to Explanation

Informed consent from patients regarding artificial intelligence (AI), particularly health assistance robots and diagnostic analysis through intelligent software, cannot exclude the patient's right to information, explanation, and justification regarding the utility and use of these technologies. As previously mentioned, telemedicine, teleconsultations, and telesurgeries have benefits and risks. Logically, the technology we now discuss also carries its own advantages and disadvantages.

The various possibilities that AI offers in healthcare, such as the smart surgical robot developed by the U.S. Department of Defense in 2018 or the STAR (Smart Tissue Autonomous Robot) capable of analyzing case circumstances and choosing the most appropriate technique for the specific situation, are already realities.

A brief note about AI applied to medical practice serves to highlight some of the many benefits. However, as we know, these potential benefits are accompanied by risks, raising important ethical and legal questions, particularly concerning informed consent.

Given the possibility of AI causing unpredictable harm due to machine learning advancements, along with the necessity to ensure algorithm reliability, the same importance should be given to research guided by bioethical principles: beneficence, non-maleficence, autonomy, justice, and informed consent. However, given the sensitive nature of the ethical issues surrounding AI, these bioethical principles should be complemented by additional ethical and legal principles to ensure fairness and equity in addressing the complexity of AI and robotics, aiming to avoid harm to physical and moral integrity, which is a pillar of informed consent.

Respect for human autonomy is the primary ethical imperative that professionals in the field of AI must always uphold, ensuring that technology is developed, implemented, and used reliably. Intelligent systems should be designed to enhance, complement, and empower human cognitive, social, and cultural abilities, with human supervision and control always guaranteed.

Respecting the autonomy and self-determination of a patient undergoing AI-supported diagnostic analysis, such as through Watson for Oncology, means informing the patient that the technology has a degree of fallibility, and that, ultimately, the decision lies with the doctor. As remarkable as Watson for Oncology is in data processing, we cannot ignore that it makes errors. AI should serve as a support for medical decision-making, without intending to replace it.

The principle of explainability is equally crucial to maintaining trustworthy AI, following the guidance from the European Parliament mentioned earlier. The decision-making processes of intelligent systems need to be transparent, allowing, whenever possible, an explanation of a particular result or decision, along with identification of the entity responsible for it. Human autonomy and explainability demand a new ethical standard for informed consent when a person is receiving healthcare supported by AI. This includes:

- Clarification of information is critical, but it must also include the right to explanation and justification for the procedures performed by AI, promoting transparency throughout the artificial intervention, including traceability of the process.
- The explainability of decisions made by the intelligent system.
- Communication in a way that allows the patient to accept or refuse interaction with AI.

10. Final Note

The narrative from the beginning (Couto, 2013), in the Book of Genesis, teaches that by not embracing the nature of the world and merely possessing and using it as an object, man disrespects the free hospitality that humanity/universe offers him. Nature cannot be used at will, as an object to discard (Thayse, 1998). A man who treats humanity as an object is not a man humanized by the tenderness of fragile nature (cf. Heschel, 2001; Couto, 2013). A nature enslaved and objectified by man is a nature in which everything is reduced to mere numbers. Indeed, when man reduces and instrumentalizes nature as objects and numbers, it is man himself who is reduced to an instrument, i.e., to an object.

History teaches us that technology is inherent to human activity. We are constantly inventing and improving tools to serve humanity. Now, the technologies we create are shaping us and inventing us (Kuskis, 2013). None of the technology invented so far can change man entirely. What makes us human is not the mathematical, chemical, or biological. But what surrounds us. That is, what goes unnoticed, the unspeakable, consciousness, the ephemeral, and the un-objectifiable. Robotics and AI are not inevitabilities or fatalities but have a purpose. Technologization is not and cannot be a fatality but a tool whose purpose is to serve humanity.

Thus, while we have an ethical responsibility to not impede progress, we also have the ethical duty to ask about its purpose: for what, for whom, when, and how. We must be companions, not spectators, of this digital era and transformation, engaging in a "You to You" dialogue—man and technology—where the first "You" can care for the second and extract the best for the humanization of the individual. This "You to You" dialogue is one of open hands, between the humanities and the sciences, for building a more just and equitable humanity.

If we fail in this, we fail as humans.

It is important to underscore that this contribution is normative and conceptual in nature. Rather than producing empirical generalizations, it provides ethical reasoning and interpretative clarity to guide professional practices and policy frameworks in AI-driven healthcare. Future research should explore empirical data from healthcare practitioners, patients, and AI developers, as well as undertake comparative legal studies across different jurisdictions. Additionally, further inquiry into the operationalization of ethical-by-design principles—embedding ethics directly into AI system architecture—could provide pathways to make informed consent in digital healthcare more transparent, traceable, and enforceable.

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Navigating the blue: Storytelling, poetics, and rhetoric in oceanic advertising

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Abstract

This paper explores the application of poetic rhetoric in sustainable tourism advertising and its profound impact on shaping perceptions and behaviors towards sustainability. By integrating classical rhetorical techniques with modern storytelling methods, advertisements can effectively promote ethical and sustainable practices. The advertisement "It's not tourism. It's futourism." employs poetic and rhetorical elements to create a narrative that is visually striking and emotionally resonant. Ethos is established through connections with cultural traditions and images, pathos appeals to feelings of hope and responsibility, and logos presents rational arguments for adopting futurism as a new sustainable approach.

The discussion includes references to Jacques Cousteau's visual narratives and Henry David Thoreau's philosophical perspectives, enriching the approach to environmental communication. Cousteau's films, such as "The Silent World" (1956) and "The Undersea World of Jacques Cousteau" (1968-1976), use storytelling to evoke a sense of wonder and responsibility towards marine life. Thoreau's "Walden" (1854) emphasizes introspection and a deep connection with nature, advocating for a more conscious and sustainable way of life.

Furthermore, the analysis of digital narrative in advertisements, particularly in the context of the Atlantic Ocean, underscores the importance of protecting marine resources for local and global economies. The narrative approach in advertising not only attracts tourists but also educates them about the significance of ocean conservation, ensuring a sustainable future for all.

The interdisciplinary approach combining literary theory, rhetoric, and advertising provides a comprehensive perspective on crafting effective narratives for environmental communication. As digital platforms continue to evolve, the integration of storytelling techniques in advertising will play a crucial role in advancing environmental communication and promoting a sustainable future.

Keywords: Environmental Communication; Ethical Alterity; Ocean Conservation; Poetic and Rhetoric; Storytelling.

"Ó mar salgado, quanto do teu sal/ São lágrimas de Portugal"

("O salty sea, how much of your salt / Are tears of Portugal")

Álvaro de Campos/Fernando Pessoa, in Ode Marítima (1997, p. 34)

1. Introduction

Language and narrative play fundamental roles in our understanding of the world and in shaping our identity. They are more than mere means of communication; they are essential components in the construction of meaning and in forming our perceptions of complex issues such as climate change and ocean sustainability. In the contemporary environmental context, narratives help elucidate and respond to ecological uncertainties, offering new perspectives on the impact of human actions on the environment and suggesting strategies to address these challenges. Adopting a a qualitative, interpretative approach, this research, grounded in the articulation between critical discourse analysis, semiotic analysis, and narrative studies in advertising aims to

understand how the advertisement *"It's not tourism. It's futourism,"* promoted by Turismo de Portugal, constructs meaning and mobilizes affect around sustainable practices and ethical-environmental narratives.

Discourse analysis is approached from a Foucauldian perspective (Foucault, 1971), focusing on the relationship between knowledge, power, and the production of truths. It is complemented by insights from critical discourse analysis (Fairclough, 1995; van Dijk, 2008), which enables the examination of how advertising discourses operate ideologically by establishing normative representations of the "good tourist" and the "sustainable future."
Semiotic analysis is structured around the theories of Roland Barthes (1964, 1977) and Umberto Eco (1976), allowing for the interpretation of visual and textual signs involved in the symbolic construction of the campaign. Key concepts such as denotation, connotation, myth, and open reading are explored in conjunction with the theory of visual signs (Floch, 1990) and the view of advertising imagery as a vector of ideology (Williamson, 1978). The study also incorporates tools from narrative studies (Todorov, 1971; Ricœur, 1983; Escalas, 2004) to examine the dramatic structure of the piece, its discursive archetypes, and the way it articulates ecological time (future and responsibility) with aesthetic emotion. This approach highlights how advertising functions as a site for the production of meaning and ethical engagement with the natural world (Lazar, 2005; Kress & van Leeuwen, 2006).

A model of methodological triangulation was chosen, in which each approach (discourse, semiotics, narrative) contributes to a dense reading of the campaign. The analysis also considers the specificity of the digital medium and the role of the viewer as a co-author in the construction of meaning (Jenkins, 2006; Ryan, 2007).

So being, this article explores how engaging with narratives and their interpretation can train the public to accept and embrace ecological uncertainty as a central dimension of the current experience. The importance of narrative is discussed here with a focus on the construction of personal and collective identity, as well a social and cultural values, particularly in how digital narratives employ rhetoric and poetics to enhance advertising storytelling. The aim is to illustrate how advertising can foster greater empathy and collective awareness. This approach incorporates the concepts of Alexander von Humboldt, advocating a holistic view of the universe and emphasizing the interconnection of all elements—a perspective particularly relevant for sustainable tourism in the outermost regions of the European Union. These regions, notably vulnerable to the dynamics of tourism exploitation, require an approach that promotes sustainability and environmental awareness. In this context, we will draw on narrative texts (Ode Marítima (1915) by Álvaro de Campos/F. Pessoa, Walden (1854) by H. Thoreau, Journey to the Equinoctial Regions of the New Continent (1814) by A. Humboldt) and two audiovisual texts, one a documentary film (The Silent World by Jacques Cousteau (1956)) and the other an advertisement (It's not tourism. It's futourism. (2023)), from which we will conduct a detailed analysis, evaluating their effectiveness in promoting ocean sustainability through the creation of an authentic narrative. This analysis is guided by Aristotle's rhetorical principles and the concepts of greenwashing and colorwashing discussed by John Elkington. The article aims to demonstrate how digital narrative can avoid deceptive practices and foster greater environmental awareness and responsibility, particularly oceanic, considered from the perspective of Portuguese maritime identity.

2. Language and Identity

2.1. I versus Thou, Becoming We

How can I conjure images in the mind of another? How can I evoke the past or project the future? Or, how can I compel others to do so? Is it sufficient merely to emit sounds? Chomsky posits that human language relies on a specific cerebral module that serves as the locus of generative grammar[1] (2002, p. 14). Accordingly, language would be inconceivable without the cognitive faculties localized in Broca's and Wernicke's areas[2]. Conversely, Pinker (2008) contends that language is an instinct genetically encoded and activated through learning, akin to

[1] Universal generative grammar constitutes an underlying structure common to all human languages, signifying an innate, pre-programmed knowledge of fundamental linguistic structures." (Chomsky, 2002, p. 27)
[2] Regions situated within the left hemisphere of the brain" (Chomsky, 2002, p. 27).

other human cognitive and motor functions. While language is inherently genetic, individual languages are cultural artifacts that express and are expressed through symbols of identity and recognition.

Language articulates and constructs subjectivity through the use of the pronoun "I," which delineates the distinction between the individual (the subject) and "thou" (not-I), thus generating a sense of identity (Benveniste, 1958, p. 253). Lacan asserts that entry into the symbolic order of language is crucial for the formation of the subject (and subjectivity), shaping perception and comprehension of the world (Lacan, 2002, p. 13). Thus, language is defined by the capacity to name. As an intrinsic element of human nature, language is not merely an instrument in the broad sense but is integral to human nature itself—we cannot conceive of humanity preceding language any more than we can envisage humanity inventing language at a discrete moment in time (Benveniste, 1958, p. 254).

Language is indispensable in the constitution of both personal and social identity, perpetually shaping personal and collective narratives. That is, personal narratives, embedded within broader cultural frameworks, illustrate how language forges the connection between the individual and the collective, establishing itself as essential for understanding identity and constructing social cohesion.

2.2. Language and Narrative

Derived from the Latin *narrare* (to know), the term "narrative" invokes the concept of sharing (Meadows, 2003, p. 190). We share narratives to transmit culture, values, information, and knowledge across generations. In this manner, language emerges as a social and cultural construct; thus, we engage in the exchange of narratives as a means of seeking and ascribing meaning to our existence (Eco, 1974). Narratives act as conduits for meaning and emotion, enabling the profound and nuanced articulation and comprehension of human emotions, thereby intertwining individual experience with the collective and cultural (Nussbaum, 2001, p. 5). Aristotle characterized narrative as a sequence of actions conveyed through various mediums such as literature or theatre (Aristotle, 1997, 1450a) and, in contemporary times, through digital media. Michael Polanyi introduced the concept of tacit knowledge, frequently conveyed through narratives, which encapsulates experiences and practices not easily rendered through technical or scientific descriptions (Polanyi, 1966, p. 4).

3. Oceanic Identity: We in the Midst of the Atlantic

In Ode Marítima, Fernando Pessoa exalts the grandeur and adventurous spirit of the Portuguese navigators, encapsulating Portugal's profound connection to the sea—a bond that not only reflects the nation's identity but now also calls for the integration of environmental responsibility. Portugal's history is inextricably linked to the oceans, from the early explorers to contemporary sustainability initiatives. While Prince Henry the Navigator was instrumental in initiating the Age of Discovery, promoting expansion into the Atlantic alongside the exploration of the African coast, thereby establishing Portugal as a global maritime power (Marques, 1976, p. 112), this was achieved from a strategically significant geographical position, with Cape Roca, the westernmost point of Europe, playing a crucial role in maritime explorations, allowing Portuguese navigators to open new sea routes and expand global trade (Rosas, 2010, p. 45). The maritime adventure was not merely territorial expansion but also cultural expansion, introducing new influences and a global perspective that continues to define Portugal today (Cidade, 1983, p. 78). This paradigm-shifting philosophy must now center on fostering a culture of ocean sustainability driven by environmental consciousness.

Portugal possesses a natural vocation to lead in the defense of the oceans, particularly in the Atlantic. Just as it was once our mission to explore and safeguard the seas, it is now our responsibility to ensure that the vast resources of our Exclusive Economic Zone (EEZ) are utilized sustainably and ethically, thereby honoring the legacy of our navigators and ensuring the preservation of marine ecosystems for future generations, with a particular emphasis on recognizing the importance of the outermost regions[3].

[3] Outermost Regions and Sustainability

4. Advertising in Environmental Communication: The Role of Narrative in Promoting Oceanic Sustainability

4.1. Narrative and Climate Change

Narrative aids us in confronting the unknowable; thus, climate change may find equilibrium through narrative, as it presents us with the radical challenge of our existence, affecting all human societies and non-human species. Engagement with digital narratives facilitates the acceptance and embrace of ecological uncertainty as a fundamental dimension of our present experience (Herman & Vervaeck, 2017, p. 47), given that narrative involves an ongoing process of circulating and negotiating meanings, reflecting new understandings and perspectives (Herman & Vervaeck, 2017, p. 34). Climate change represents a multifaceted challenge encompassing phenomena such a polar ice melt, ocean acidification, and biodiversity loss. Its narrative formulation can influence public understanding and response. In this context, the so-called second ecocriticism examines the relationship between literature and the environment, exploring the interaction between nature and human culture, thereby elucidating how literature addresses environmental issues and reflects cultural perceptions of nature (Buell, 2005, p. 30). This approach demonstrates how narratives can shape our perception of ecological issues. The ecological crisis reveals the interdependence of all ecosystem elements, forming a network that should be reflected in the narratives representing it (Morton, 2010, p. 28). In other words, within the contemporary environmental context, narratives elucidate and respond to ecological uncertainties, offering new perspectives on the impact of human actions on the environment and suggesting strategies to address these challenges. Stories that illustrate local impacts of climate change and depict how communities confront these challenges can raise public awareness of the urgency to act and foster greater engagement with environmental issues, as storytelling involves a continuous process of circulating and negotiating meanings, reflecting new understandings and perspectives (Herman & Vervaeck, 2005, p. 34).

4.2. The Role of Advertising Narrative in Promoting Sustainability: The Atlantic at Our Feet

Advertising plays a crucial role in advocating for environmental practices and values. Through strategic narratives, color schemes, and rhetoric, advertising campaigns shape perceptions and behaviors regarding environmental issues. Narrative emotionally engages the audience, making the message more memorable and inspiring (Aristotle, 1997, p. 1450a). Ethical appeals build brand credibility, demonstrating a genuine commitment to environmental issues. Narratives that establish emotional connections and utilize evocative imagery and video are thus effective. Incorporating characters and poetic metaphors can help illustrate complex concepts in an accessible manner. From the perspective of classical rhetoric, narrative employs message, conflict, characters, and plot. The combination of rhetoric and poetics encourages the exploration of new narrative methods, aligning with creative capacities. Poetics refers to the creation of meaning through artistic narrative forms, used to emotionally engage viewers. Presenting data and statistics that validate brands' environmental claims and demonstrating a genuine commitment to sustainability through concrete actions are crucial logical and ethical approaches. Such narratives help forge an emotional bond with the audience, making environmental issues more tangible and urgent. From a classical rhetorical perspective, storytelling utilizes four key narrative concepts:

The term "outermost regions" was introduced by the European Union (EU) to designate specific areas that, although part of EU Member States, face unique challenges due to their geographically isolated locations and distinctive characteristics. These regions include, for instance, the Canary Islands (Spain), Madeira and the Azores (Portugal), and the French overseas departments such as French Guiana, Guadeloupe, Martinique, Réunion, and Mayotte (European Union, 2023). Situated at considerable distances from the European mainland, these regions encounter significant economic and social difficulties stemming from their insularity, climate, topography, and other natural limitations. To mitigate these challenges, the European Union provides additional support through cohesion policies, structural funds, and other initiatives aimed at promoting socio-economic development and reducing disparities relative to the European continent. Article 349 of the Treaty on the Functioning of the European Union (TFEU) is particularly pertinent in this context, emphasizing the need for tailored approaches that account for these regions' specificities. By fostering sustainable policies and practices, these regions can serve as inspiring models for addressing environmental challenges in diverse contexts. Promoting sustainable practices in these areas not only benefits the outermost regions themselves but also contributes to environmental resilience and social cohesion across the European Union. available https://eur-lex.europa.eu/.

message, conflict, characters, and plot. Rhetorical and poetic techniques are not merely theoretical; they have clear practical applications in developing effective and engaging advertising campaigns. Advertising narrative aims to integrate these techniques, promoting a sustainability-focused approach that creatively, effectively, and ethically addresses market challenges while maintaining a holistic perspective. Rhetoric provides tools for structuring compelling and engaging arguments, while poetics allows for the incorporation of elements such as ethos (credibility), pathos (emotion), and logos (reason), thus enhancing the persuasive power of a campaign. The combination of rhetoric and poetics encourages the exploration of new storytelling methods. In essence, narrative is the art of telling stories with engaging, immersive, and memorable messages. By employing elements of rhetoric (the art of persuasion) and poetics (emotional meaning-making), narrative aims to convey persuasive and memorable messages. Incorporating poetic elements (creative use of language and symbolic imagery) and rhetoric (argumentative persuasion and narrative construction), advertising achieves ethical and sustainability goals, particularly in messages aimed at social and environmental awareness.The concept of "greenwashing" refers to the practice of exaggerating or falsely promoting environmental initiatives to attract sustainability-conscious consumers.

Environmental advertising has emerged as an interdisciplinary field that brings together communication, ecology, and marketing to promote sustainable behaviours and values. According to Peattie and Crane (2005), environmental communication faces the challenge of avoiding *greenwashing*—superficial practices that simulate environmental responsibility without genuine commitment. It is therefore essential to develop campaigns that combine authenticity with impact, reinforcing public trust in the conveyed message. Digital storytelling, in turn, constitutes a powerful tool for constructing compelling and emotionally resonant narratives capable of influencing perceptions and behaviours (Pulizzi, 2012; Lambert, 2013). The literature highlights that the use of narrative elements such as *ethos*, *pathos*, and *logos* is central to establishing an empathetic connection between audiences and environmental issues (Fisher, 1987; Escalas, 2004). Moreover, the integration of digital media allows for interactivity and immersion, thereby amplifying both the reach and the effectiveness of the message (Jenkins, 2006). With regard to sustainable communication practices, scholars such as Del Rio-González (2018) and Muralidharan et al. (2011) underscore the importance of transparency, ethics, and community engagement in ensuring that advertising campaigns do more than inform—that they also inspire concrete and lasting action. Sustainable communication must move beyond mere dissemination, fostering relationships of ecological co-responsibility with audiences (Peña & Medina, 2018). On the other hand, the literature also warns of the risks of instrumentalising environmental communication, particularly when driven by commercial interests that compromise the authenticity of the message (TerraChoice, 2007; Lyon & Montgomery, 2015). This scenario underscores the imperative to develop critical and reflective approaches that assess not only the content but also the context and reception of sustainable narratives. In sum, the study of environmental communication practices reveals a dynamic field in which effectiveness depends on the interplay between conceptual rigour, narrative creativity, and ethical commitment. This review underpins the analysis presented in the current work, which aims to demonstrate how advertising can function as an agent of cultural and environmental transformation—especially through the strategic use of poetics and rhetoric in the context of sustainable tourism.

Narratives that expose greenwashing and highlight the need for transparency can help combat this practice and foster greater environmental responsibility. Similarly, "colorwashing" involves using colors associated with environmental issues without a genuine commitment to sustainable practices (Elkington, 1997, p. 155). Critical narratives can help inform the public about the difference between superficial marketing and concrete actions, encouraging more genuine engagement with sustainability. In contrast to the campaign *"It's not tourism. It's futourism."*, a notorious example of greenwashing in the tourism sector occurred with the airline British Airways, which launched campaigns promoting its "green" initiatives to reduce carbon emissions. However, research revealed that, despite its advertising claims, the company continued to expand routes and increase flight frequency, thereby significantly contributing to environmental pollution (Gössling et al., 2019). Also we can mention a classic example of greenwashing in the tourism sector as the campaign by luxury resorts that promote

their properties as "eco-friendly" or "sustainable" without implementing concrete practices to support such claims. For instance, some resorts claim to protect local ecosystems and minimize environmental impacts, yet continue to overuse resources, generate significant amounts of waste, and exploit local communities without providing real benefits (Fifield, 2020). These campaigns create an illusory image of environmental responsibility, misleading consumers and weakening the credibility of sustainable communication. In contrast to such superficial practices, the *"It's not tourism. It's futourism."* campaign stands out by employing a narrative that fosters empathy and ethical responsibility toward the ocean, portraying tourism as a conscious and sustainable activity capable of transforming the relationship between humans and nature. This dissonance between communication and actual practices illustrates how greenwashing can create a false perception of sustainability, undermining public trust and diminishing the real impact of environmental actions. Conversely, the *"It's not tourism. It's futourism."* campaign adopts an integrated approach in which poetic and ethical narrative contributes to environmental awareness, promoting a form of tourism that respects and preserves the ocean as a collective heritage.

4.3. The Anthropocentric Narrative: The Ocean at Our Feet

The "Ode Marítima" evokes the necessity for a response imposed by the call of the seas, interpreted in the allegorical resurrection of past ghosts, with a poetic self alone at the quay, facing the seas, contemplating the arrival of a small black and white packet, and establishing an intricate web of circular identifications culminating in the evocation of the same packet, now clear and bright as if the oceanic crossing had liberated it through a catharsis. In this text, the sea emerges without anthropocentric mediation; it appears as landscape and place to be navigated, including no more than geographic coordinates. The sea brings and the sea takes away, emerging as a cathartic mediator. Conversely, in the documentary text "The Silent World" by Jacques Cousteau, based on "Le Monde du Silence" (1956), directed by Jacques-Yves Cousteau and Louis Malle, the sea is portrayed as a realm of underwater life. The film presents documentary images of marine fauna and flora, revealing a world previously unknown to the general public. The film uses naturalistic colors, highlighting the deep blues of the ocean and the vibrant hues of marine life. The underwater camera was a crucial tool for creating visual immersion in the aquatic environment. Cousteau's figure, as an explorer, represents the human spirit of seeking the unknown, evoking themes of conquest, mastery of nature, and technological advancement, symbolizing the modern man who, with the aid of science, penetrates previously impenetrable realms. On one hand, there is evident respect and admiration for the beauty and complexity of marine life, but on the other hand, there are scenes that today may be interpreted as problematic, such as shark hunting, suggesting a relationship of domination over nature. Nevertheless, the film suggests an anthropocentric view of the world, where nature is seen primarily as an object of study and exploitation for human benefit.

4.4. It's Not Tourism. It's Futourism. An Analysis of the Audiovisual Text

The "It's not tourism. It's futourism." campaign, promoted by Turismo de Portugal and launched on December 31, 2023, is inscribed within the strategic framework of the Tourism Strategy 2027, positioning itself as a discursive and symbolic intervention aimed at the reconfiguration of contemporary tourism practices in light of ethical and environmental imperatives. Structured around twelve New Year's resolutions, the campaign invokes the imaginary of the future as a shared horizon of responsibility, mobilizing a poetic and axiological narrative that addresses the tourist as an ethical subject and agent of transformation.

By employing rhetorical and aesthetic resources and drawing on semiotic anchors in the values of sustainability, territorial belonging, and ecological care, the initiative seeks to foster a paradigmatic shift in the ways tourism is experienced and represented, promoting more immersive, conscious, and respectful practices toward the natural and cultural diversity of destinations.

Although empirical data on the campaign's direct behavioural impact is not yet available, its innovative narrative configuration, combined with broad dissemination across digital ecosystems, suggests a strong potential to influence audience attitudes and dispositions. In this sense, the campaign asserts itself as a performative

discursive device, capable of articulating symbolic, ethical, and affective dimensions, contributing to the emergence of a more responsible, situated, and ecologically committed mode of tourism.

The advertising narrative opens with the phrase "A new year has just begun," followed by "A movement has already started." Soon after, the phrase "Let me introduce" appears, followed by the word "FUTURISM" in uppercase letters, which is subsequently divided into "fu-turismo" and "fu-tourism." These words are presented against a landscape of the Earth with an impressionistic touch, enveloped in green and blue tones that stand out among grey patches, possibly representing devastation. The voice-over and subtitles urge viewers not to confuse this movement with the Futurist aesthetic movement. The image transitions to a close-up of a dew drop sliding down a plant stem, while the voice-over explains that it is not an artistic movement, though it encompasses movement and art, specifically the art of going. The image shifts to a close-up of human skin, with text informing us that it contains the art of walking and also the art of change. This image is replaced by a wide aerial view of a landscape in light brown tones, showing sand and water in the same hue. The voice-over clarifies that we are witnessing the emergence of a movement advocating for correcting past mistakes, urging us to leave things as they are, but emphasizing that this is different from mere passivity. This information appears over a detailed image of a water droplet falling on sand, creating concentric waves. The image shifts to an interior view of the dome of a rotating monument, revealing that many will say it is just a journey. The voice-over asserts that futurism is a movement that breaks conventions while respecting traditions. The image returns to the slow-motion close-up of the droplet falling on the sand, now filling the screen with sand scattered by the droplet's impact. The image merges into a close-up of sardines being grilled, evoking strong Portuguese iconography and traditions. The screen fills with a three-dimensional yellow pattern, allowing us to perceive the effect of a sunflower composed of an infinite number of sunflowers opening in motion, creating an iconographic allusion to the sun. The voice-over asserts that the movement will open so many horizons that we will realize it is not just a journey. The image transitions to the Marquês de Pombal roundabout in Lisbon, revealing nighttime traffic crossing the road. Subsequently, it shows a detailed shot of a child's hand navigating a small fishing boat, with fingers intertwined in the water. The voice-over informs us that from now on, everything will be as it should. This final phrase is emphasized by a detailed image of water hitting the shore, intersecting with the shadow of a young person riding a bicycle. The voice-over states that it is an evolution to do things as they should be done and to be aware of our actions. It transitions to an underwater scene, now filmed from below, asserting that we now know how it is done and when to stop. It changes to a close-up of the human iris, asserting that it is a change of perspective, transitioning to a dirt path, informing us that we now understand the differences between roads and trails, between lamps and stars, while showing a starry night sky. Over the image of a lot of fish, it informs us that we now understand "the flock to the unexplored path," as it is a movement with very simple rules: "if you are here, leave no trace; observe calmly with your heart and body." This message is reinforced by a lighthouse illuminated at night, asserting that it is time to be alert and vigilant, thinking about the future of all of us. This message is further reinforced by the image of a dense forest highlighting the multiplicity of vegetation, emphasizing that we must save what can be saved. The image of small barefoot footprints in the sand, erased by an approaching wave, underscores the message that we are the only ones who can save what must be saved. The screen turns black, and the caption appears: "It's not tourism. It's futourism. Don't be a tourist, be a futourist."

4.5. Poetic and Rhetoric in Advertising and Promoting Oceanic Sustainability

Poetic and rhetoric are fundamental techniques in advertising, allowing environmental messages to be communicated in an impactful and memorable manner. Jacques Cousteau's underwater world utilized narrative techniques to capture the public's imagination, presenting oceans as places of unexplored beauty and critical vulnerability. Integrating poetic rhetoric into ocean preservation, the advertisement "It's not tourism. It's futourism." is aligned with Humboldt's holistic thinking and Portugal's maritime heritage, offering a powerful strategy for promoting environmental preservation and responsible tourism practices; furthermore, it highlights Jacques Cousteau's impactful visual narratives and Thoreau's thoughts on connecting with nature contributing to a richer and more engaging approach to environmental communication. Portugal's Exclusive Economic Zone

(EEZ), by redefining the country's geostrategic position and asserting its responsibility over vast marine ecosystems, provides an ideal context for applying these poetic narratives and strengthening the conservation message. This focus is particularly relevant in the context of the Atlantic Ocean, where protecting marine resources becomes a priority to ensure the sustainability of economic activities and biodiversity preservation. Analyzing narrative in environmental advertising demonstrates its effectiveness in promoting sustainability and shaping perceptions and behaviors. Through narrative and rhetorical techniques, advertising campaigns can create powerful messages that inspire action and increase awareness about the importance of sustainability. In the context of the Atlantic Ocean, advertising can play a crucial role in promoting sustainable tourism, highlighting innovative practices, and addressing the complexities of cultural and environmental identity. The interdisciplinary approach combining literary theory, rhetoric, and advertising offers a comprehensive and rich perspective on crafting effective narratives for environmental communication. The examined advertising narrative uses visual, auditory, and narrative elements that support a Weberian reading, emphasizing the importance of interpretative analysis in understanding social phenomena (Weber, 1978, p. 20–25). The advertising text employs various rhetorical figures such as metaphors, personification, anaphora, oxymoron, symbolism, and parallelism, reinforcing the ad's message while observing the logical progression from presenting current issues to introducing "futourism" as a solution and concluding with a call to action, in line with narrative structures focusing on understanding the logical progression of the narrative (Propp, 1968, p. 25–30) in accordance with the concept of the monomyth (Campbell, 2008, p. 45-50). The text considers cultural, social, and environmental context, aligning the analysis with Humboldt's holistic perspective on nature and human activities, providing a relevant and consolidated ethical perspective, viewing the planet as the Other, through the lens of ethical alterity (Lévinas, 1961, p. 20-25). The analysis reveals the use of classical rhetorical theories and modern narrative methods, demonstrating how combining these approaches can promote sustainable practices. The text discusses how well-executed environmental advertising can influence perceptions and behaviors, promoting a sustainable future (Dewey, 1979, p. 40–45). Thoreau's reflections on nature in "Walden" emphasize the importance of living in harmony with the natural world. Thoreau's belief in the value of a simple and thoughtful existence supports the promotion of sustainable tourism practices that minimize environmental impact (Thoreau, 1854, p. 121).

5. Conclusion: The Holistic Narrative: Becoming One with the Oceans

Cousteau's vision, thus, reflects an anthropocentric perspective on nature, which diverges from the current paradigm necessitated by climatic changes and resonates with Humboldt's philosophy articulated in his work Personal Narrative of Travels to the Equinoctial Regions of the New Continent (1814). Humboldt's work advocates for the interconnectedness of natural elements and emphasizes the importance of a holistic view of the environment. In essence, understanding natural systems requires an integrated approach that acknowledges the interdependence of various environmental components (Humboldt, 1805, p. 29). Additionally, Thoreau offers a supplementary perspective on the relationship between humans and nature, advocating for introspection and a direct connection with the environment as a means to foster a more conscious and sustainable way of life. This perspective complements the poetic narrative in advertising aimed at fostering a more sustainable oceanic consciousness, reinforcing the necessity for a deeper and more respectful engagement with the environment (Thoreau, 1854, p. 121). It supports the notion that protecting the oceans is crucial for the overall health of the planet and can be effectively communicated through poetic narratives in advertising.

To achieve this, we invoke Emmanuel Lévinas's concept of ethical alterity, which adds a moral dimension to the necessity of ocean sustainability, underscoring the responsibility to care for the environment. Lévinas argues that ethics begins with the responsibility for the Other, extending this responsibility to our relationship with the natural environment. This ethical approach encourages a relationship of respect and consideration for the impacts of our activities on the oceans, reinforcing the importance of adopting practices that are not only environmentally sustainable but also ethically responsible (Lévinas, 1985, p. 75). The concept of ethical alterity emphasizes ethical responsibility towards the Other, seen not merely as an individual but as a presence demanding an ethical response. For Lévinas, true ethics emerge in the relation with the Other, where the self is

continually called to respond to the alterity of the Other in a responsible and sensitive manner (Lévinas, 1969, p. 43). Integrating ethical alterity into messages about the urgency of ocean preservation involves recognizing the responsibility to care for the environment. By adopting ethical alterity, our actions are perceived not merely as an environmental obligation but as a moral imperative that requires a genuine response to the needs and dignity of the Others.

Persuasive, culturally relevant, and socially responsible advertising messages promote sustainable environmental attitudes. Companies committed to ethical advertising provide clear and detailed information about their sustainable practices. We draw upon Perelman and Olbrechts-Tyteca's (1958) concept of the audience to propose a new vector that also redirects focus on the audience. Thus, the intertwining of rhetoric and poetics in advertising narratives acquires a new dimension by considering argumentative theory with a persuasive point of escape—implying both practical rationality and social context, recognizing the values and beliefs of both the audience and the narrative producers (Durand, 1987). Storytelling is committed to consent (or suspension of disbelief) and the presumption of rationality (Olbrechts-Tyteca, 1958). It is crucial not to confuse argumentation with manipulation; individuals have the right to be persuaded through reasonable and legitimate arguments, consenting to a holistic understanding of argumentation and its application across various social and cultural contexts.

Advertising not only sells products but also ethical and sustainable values, contributing to the creation of a more just and equitable society. By combining elements of rhetoric and poetics, it is possible to craft narratives that not only persuade but also educate and raise awareness about sustainability issues. Storytelling revitalizes the Aristotelian classical tradition of catharsis, allowing for social and cultural purification of emotions. The information society, characterized by digital proliferation and ubiquitous access to information, has introduced new forms of storytelling through diverse and interconnected platforms, shaping not only the economy but also social and cultural structures (Castells, 1996).

We have used the advertisement "It's not tourism. It's futourism." as a starting point, evaluating its effectiveness in promoting sustainability in tourism through an authentic narrative guided by Aristotle's rhetorical principles. Additionally, we examined how digital narratives can avoid deceptive practices and foster greater awareness of greenwashing and colorwashing concepts discussed by John Elkington. We also considered Humboldt's concepts and his advocacy for a holistic view of the universe, emphasizing the connection between all environmental elements in order to propose a new point of view which considers nature and seas as an Other under the ethical alterity of Lévinas philosophy compassing with Thoreau's thought. This perspective is deemed particularly relevant for advocating sustainable tourism in the seas, and specifically in the Atlantic Ocean, which defines the environment of Portugal's outermost regions.

As digital platforms continue to evolve, the integration of narrative techniques in advertising will play a crucial role in advancing environmental communication and promoting a sustainable future.

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Can crypto be green? Evaluating the environmental and financial impact of the digital assets economy

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Abstract

The rise of cryptocurrencies and decentralised finance (DeFi) has fuelled a fast-growing digital assets economy with major environmental and financial implications. Proof-of-work (PoW) systems like Bitcoin demand high energy and emit large volumes of CO_2, while proof-of-stake (PoS) alternatives such as Ethereum and Cardano significantly reduce environmental costs. This paper analyses seven major crypto projects: Ethereum, Uniswap, Aave, Maker, Cardano, XRP, and Stellar. It focuses on their energy consumption, financial performance, and sustainability. The study proposes a novel sustainability scoring framework to support ESG-aligned investment and regulatory design. While PoW offers unmatched security, its environmental toll is unsustainable. PoS models show promise but face governance and scalability concerns. The study highlights the urgent need for sustainable innovation and regulatory differentiation to align crypto markets with climate goals, investor expectations, and long-term economic viability.

Keywords: Carbon Emissions; Cryptocurrencies; Decentralized Finance (DeFi); Proof-of-Stake (PoS); Sustainability.

1. Introduction

The advent of cryptocurrencies has ushered in a transformative era for the global economy, redefining financial systems through decentralization and tokenization. Bitcoin, introduced by Nakamoto (2008), pioneered this shift, leveraging PoW to secure its network, a process now criticized for its environmental toll, with annual energy consumption exceeding 150 TWh (Digiconomist, 2025). As the market evolved, PoS emerged as a sustainable alternative, exemplified by Ethereum's 2022 transition and Cardano's Ouroboros protocol, slashing energy use dramatically (Buterin, 2021; Cardano Foundation, 2025). Concurrently, the rise of DeFi has amplified the financial stakes, with platforms like Uniswap and Aave facilitating billions in decentralized transactions, while projects like XRP and Stellar bridge traditional and digital finance (DeFi Pulse, 2025).

This paper examines the environmental and financial ramifications of the cryptocoins, and tokens market spread, focusing on seven pivotal projects: Ethereum, Uniswap, Aave, Maker, Cardano, XRP, and Stellar. These span smart contract platforms, DeFi protocols, and payment systems, offering a comprehensive lens on the digital assets economy. The environmental analysis centres on energy consumption and sustainability, while the financial perspective explores market growth, adoption, and economic viability. By synthesizing these dimensions as of April 2025, this study aims to illuminate the trade-offs and opportunities shaping the future of digital assets, addressing a critical question: Can this economy thrive sustainably?

2. State of the Art

This section outlines the current landscape of cryptocurrencies, focusing on PoW and PoS mechanisms. PoW consumes 204 TWh globally (2024), with Bitcoin at 150 TWh and 90 million tons of CO_2 emissions. PoS reduces

energy use by over 99%, with Ethereum dropping from 112 TWh to 0.03 GWh (baseline) and Cardano at 6 GWh. DeFi thrives on Ethereum, with over $150 billion in total value locked, while Cardano, XRP, and Stellar expand their roles (Gomez and Medrano, 2025; Krause, 2025).

The cryptocurrency landscape is defined by two dominant consensus mechanisms, PoW and PoS, each with distinct environmental and financial profiles. Proof of Stake (PoS) is significantly more energy-efficient and sustainable than Proof of Work (PoW) because it eliminates the need for intensive computational mining. While PoW requires vast amounts of electricity to solve complex cryptographic puzzles, a process known as computational mining, PoS secures the network through token ownership, drastically reducing energy consumption. Computational mining in PoW involves miners competing with specialized hardware (like ASICs) to be the first to validate transactions and create new blocks, consuming as much energy annually as some small countries (e.g., Bitcoin's estimated 2024 consumption is around 85 TWh, comparable to Finland). In contrast, PoS networks like Ethereum 2.0 have reduced their energy use by over 99.9% after transitioning, making PoS a far greener alternative for blockchain technology.

PoW, underpinning Bitcoin and Litecoin, relies on miners solving computational puzzles, a process that consumed 204 TWh globally in 2024, equivalent to Argentina's annual energy use (CCRI, 2024; de Vries, 2018). Bitcoin alone accounts for 150 TWh, emitting over 90 million tons of CO_2 annually and generating approximately 0,000 tons of e-waste from obsolete ASIC hardware, as miners upgrade to maintain profitability (Digiconomist, 2025; Krause & Tolaymat, 2018). Its security and decentralization, however, remain unmatched, cementing its $1.5 trillion market cap as of 2025, a testament to its enduring financial relevance (CoinMarketCap, 2025; Swan, 2020).

PoS validates transactions through staked assets, reducing energy demands significantly. Ethereum's Merge in 2022 dropped its consumption from 112 TWh to a baseline of 0.03 GWh, a shift driven by environmental pressures and scalability needs (Buterin, 2021; Sedlmeir et al., 2020). Cardano's Ouroboros PoS consumes approximately 6 GWh annually, supporting a growing DeFi ecosystem with projects like SundaeSwap, leveraging its layered architecture for efficiency (Cardano Foundation, 2025; Kiayias et al., 2017). Solana, another PoS leader, processes 65,000 transactions per second at minimal energy cost (approximately 0.5 GWh/year), though its reliance on a smaller validator set has sparked centralization debates (Solana Labs, 2025; Yakovenko, 2018). These advancements reflect a broader push toward sustainability, yet PoS faces criticism for potential security risks, such as stake concentration, and its untested resilience at scale compared to PoW's decade-long track record (Wood, 2021; Saleh, 2021). Table 1 presents the energy consumption of the major cryptocurrencies in the year of 2025.

Table 1: Energy Consumption of Major Cryptocurrencies (2025 Estimates).

Cryptocurrency	Consensus	Energy (GWh/year)	CO2 Emissions (Mt)	Notes
Bitcoin	PoW	150,000	90	High mining energy
Ethereum (pre-merge)	PoW	112	60	Pre-2022 data
Ethereum (port-merge)	PoS	25	0.015	Includes DeFi load
Cardano	PoS	6	0.003	Scalable PoS design
Solana	PoS	0.5	0.003	High throughput

Source: Developed by authors.

One of the most relevant factor in the calculation procedure is the Total Value Locked (TVL). This indicator represents the total value of cryptocurrencies deposited in a specific DeFi protocol, effectively showing the amount of assets "locked" within the platform. In DeFi, Ethereum remains the cornerstone, hosting Uniswap

($5B+ TVL), Aave ($3B+ TVL), and Maker (Dai's $10B circulation), driving a global TVL more than 150Billion dollars as of 2025 (DeFi Pulse, 2025; Schär, 2021). Cardano's Alonzo upgrade in 2021 enabled smart contracts, fostering DeFi growth with platforms like SundaeSwap, though its TVL remains modest at $1B (Cardano Foundation, 2025; Hoskinson, 2020). XRP Ledger's liquidity pools and Stellar's built-in DEX expand their utility beyond payments, with XRP facilitating cross-border transactions and Stellar targeting financial inclusion (Ripple, 2025; Stellar Development Foundation, 2025; Schwartz et al., 2014). These developments underscore a dynamic state of the art, balancing technological innovation with environmental and financial challenges (Tapscott & Tapscott, 2016).

Finally, it is essenctial to mention the MICA regulation framework in green digital assets. The Markets in Crypto-Assets (MiCA) framework marks a critical milestone in the harmonization of crypto-asset regulation within the European Union, yet its implementation raises several regulatory and structural considerations that merit deeper analysis. While MiCA introduces legal certainty and consumer protection, it may impose significant compliance burdens, particularly for small and decentralized entities, potentially disincentivizing innovation within the rapidly evolving decentralized finance (DeFi) sector. Cross-border enforcement also presents unresolved challenges, as the extraterritorial scope of MiCA may clash with divergent national regulations, complicating the supervisory landscape. Compared to the United States' fragmented regulatory environment—characterized by overlapping mandates from the SEC, CFTC, and FinCEN—or Asia's prohibition-driven models, MiCA's unified approach provides a novel regulatory architecture that could influence global regulatory discourse. However, this uniformity might not necessarily translate into global adoption, as jurisdictional fragmentation and geopolitical divergence persist.

Despite being a landmark regulation for the crypto-assets sector, the MiCA framework exhibits a significant regulatory gap in addressing environmental impacts. It largely omits explicit provisions on the energy consumption and carbon footprint associated with consensus mechanisms like Proof of Work (PoW). This omission is particularly concerning given the EU's broader commitments under the European Green Deal and Fit for 55 package. The regulation lacks enforceable sustainability standards or reporting obligations for crypto-asset issuers and service providers. Furthermore, it fails to integrate environmental risk as a core component of crypto-asset supervision. As a result, MiCA risks misalignment with EU environmental objectives is an issue to address high-energy consensus mechanisms undermines the EU's ambitious climate neutrality goals by 2050. By not mandating environmental impact assessments, MiCA creates a regulatory blind spot that could exacerbate the carbon-intensive practices of certain crypto activities. This disconnect risks positioning MiCA as a siloed framework, out of step with the EU's holistic push for sustainable economic systems.

3. Methodology

This study investigates the intersection of sustainability, climate change, and the blockchain economy, focusing on decentralized finance (DeFi) systems. A dual approach of bibliographic and bibliometric data analysis was employed to systematically review and quantify the current scientific literature. We utilized databases such as Web of Science and Scopus to ensure a comprehensive selection of relevant literature from 2015 to 2025. The methodology aimed to identify key themes, research gaps, and publication trends related to the sustainability implications and climate change impacts of blockchain economies, particularly DeFi systems.

In the qualitative synthesis, thematic analysis was used to explore emerging patterns and narratives in the literature. Quantitative metrics were derived from citation analysis and publication trends to map scholarly discourse on this evolving topic.

Additionally, case studies of specific DeFi projects were incorporated to provide concrete examples of sustainability challenges and innovations within the blockchain space. This integration enhances the depth of analysis by linking theoretical insights with practical applications.

Potential limitations, such as publication bias and the evolving nature of the field, were acknowledged and mitigated by cross-verifying findings across multiple data sources and focusing on peer-reviewed articles.

This comprehensive approach offers a robust overview of the topic's development and its environmental dimensions, addressing the research question: "How does the scientific literature from 2015 to 2025 characterize the sustainability implications and climate change impacts of blockchain economies, particularly DeFi systems?

3.1. Research Design

The research design combines bibliographic analysis for a qualitative review of content with bibliometric analysis for a quantitative assessment of publication patterns. Bibliographic analysis synthesizes concepts, case studies, and findings related to blockchain's energy use, DeFi's ecological footprint, and sustainability solutions, offering a narrative perspective. Bibliometric analysis measures publication output, citation networks, and keyword relationships, revealing the field's structure and influence. The study covers 2015 to 2025, a period capturing blockchain's rise and DeFi's expansion, ensuring relevance to contemporary sustainability and climate change debates. The key stages of the research process, along with the corresponding approaches, tools, and anticipated outcomes, are summarised in Table 2.

Table 2: Summary of Research Design and Methodological Stages.

Stage	Approach	Tool(s)	Expected Outcome
Literature Search	Systematic search	Scopus, Web of Science, Google Scholar	Identification of relevant peer-reviewed publications
Article Screening	Inclusion/exclusion criteria	Manual screening	Refined dataset focused on blockchain and sustainability themes
Bibliographic Analysis	Qualitative synthesis	Zotero	Extraction of key concepts, themes, and illustrative case studies
Bibliometric Analysis	Quantitative mapping	VOSviewer, Excel	Visualisation of citation networks, keyword clusters, and trends
Triangulation & Validation	Mixed-methods integration	Cross-database verification	Enhanced reliability through convergence of qualitative and quantitative insights

Source: Developed by authors.

3.2. Data Collection

Data were sourced from peer-reviewed scientific articles retrieved from Scopus, Web of Science, and Google Scholar, chosen for their extensive coverage of technology and sustainability research. The search, conducted in April 2025, used keywords including "blockchain economy," "DeFi systems," "sustainability," "climate change," "energy consumption," and "environmental impact," refined with Boolean operators (AND, OR). An initial pool of 50 articles was identified. Inclusion criteria were: (1) publication between 2015 and 2025, (2) focus on blockchain and/or DeFi with relevance to sustainability or climate change, (3) peer-reviewed status, and (4) English-language availability. After screening titles and abstracts, 298 articles were selected for full-text review, yielding a final dataset of 25 articles. Bibliographic metadata (e.g., author, year, journal) and full texts were exported to Zotero for management and analysis. The process has been as follows:

1. Relevance to the Research Question

- Include only papers directly addressing the specific topic (e.g., environmental impact of PoW vs PoS).
- Exclude general blockchain studies unless they have a dedicated section on sustainability/energy use.

2. Publication Quality and Peer-Review Status

- Prioritize articles published from **high-impact journals** or **peer-reviewed conference proceedings**.
- Exclude preprints unless they are highly cited or from reputable institutions.

3. Recency (Publication Date)

- Focus on studies from the **last 5–7 years** (e.g., post-2017), since blockchain technology and consensus algorithms have rapidly evolved.

4. Methodological Rigor

- Select studies that use **quantitative energy consumption data**, **comparative lifecycle analyses**, or other robust methods.
- Exclude purely theoretical or opinion-based papers unless they are foundational.

5. Citations and Influence

- Prefer **well-cited** papers (e.g., over 20 citations) indicating academic impact.
- Include recent high-quality papers despite low citations due to novelty.

6. Diversity of Perspectives

- Ensure a balance between technical analyses, environmental assessments, and socio-economic impacts, especially for interdisciplinary research.

7. Language and Accessibility

- Include only papers available in a language you can evaluate (likely English).
- Ensure full-text access to verify methodology and conclusions.

Example of Application:

- Step 1: Remove all papers older than 7 years → Remaining approximately 150
- Step 2: Remove non-peer-reviewed papers → Remaining approximately 90
- Step 3: Screen abstracts for direct relevance → Remaining approximately 45
- Step 4: Assess methodological rigor and citations → Final 28 selected.

3.3. Data Analysis

Bibliographic analysis involved a qualitative review of the to extract key themes, such as blockchain energy efficiency, DeFi carbon footprints, and sustainable innovations (e.g., proof-of-stake vs. proof-of-work). A coding framework was developed iteratively, categorizing content into themes like “energy consumption,” “climate mitigation strategies,” and “DeFi scalability.” Annotations were tracked in Zotero for consistency. Bibliometric analysis was conducted using VOSviewer software, focusing on: (1) publication trends, showing a 50% increase in articles since 2020; (2) citation analysis, highlighting influential works (e.g., studies on Ethereum’s energy use); and (3) keyword co-occurrence, generating clusters (e.g., “blockchain sustainability” and “DeFi emissions”) visualized in network maps. Annual publication counts and citation frequencies were calculated in Excel to support VOSviewer findings.

3.4. Limitations and Validation

Limitations include the exclusion of non-English literature, potentially missing regional insights, and reliance on database indexing, which may omit nascent 2025 publications. Validity was ensured by cross-checking multiple databases and refining keywords through pilot searches. The combination of bibliographic and bibliometric methods provided a robust analysis, triangulating qualitative insights (e.g., sustainability solutions) with quantitative patterns (e.g., research growth). This methodology effectively charts the scientific discourse on sustainability and climate change in blockchain economies and DeFi systems, offering a foundation for future empirical studies.

The findings derived from this methodological framework are presented in the subsequent section, where the environmental and financial profiles of selected blockchain projects are analysed.

3.5. Sustainability Score Calculation

To assess the sustainability of blockchain-based projects, we developed a composite Sustainability Score ranging from 0 to 5, with 5 representing the highest level of sustainability. This score combines quantitative metrics, like energy consumption, with qualitative factors such as consensus mechanisms, utility, and environmental transparency. The methodology is detailed below.

1. Normalization of Energy Consumption

The first step is to translate raw energy usage (in GWh/year) into a normalized Energy Efficiency Score on a scale from 0 to 5. In this scale lower energy consumption results in a higher score, highlighting more efficient projects. This normalization is achieved using Equation 1.

$$Energy\ Score = 5 \cdot \left(1 - \frac{Energy_{project}}{Energy_{max}}\right) \quad (01)$$

Where $Energy_{project}$ is the annual energy consumption of the specific blockchain project; $Energy_{max}$ is the highest energy consumption observed among the evaluated projects (e.g., Ethereum with 25 GWh/year).

While the Energy Score captures relative energy efficiency, it does not fully account for the observed sustainability scores. For instance, although Ethereum's energy consumption post-Merge decreases to approximately 0.03 GWh/year, its total sustainability score remains lower than Stellar's. This indicates that energy efficiency alone is not enough to comprehensively assess a project's sustainability profile.

2. Incorporating Weighted Adjustments

To improve the accuracy of our sustainability assessment, we integrate weighted components that reflect various dimensions of sustainability:

- Energy Efficiency: 30%
- Consensus Mechanism (e.g., PoS vs. PoW): 30%
- Utility/Functional Role (e.g., DeFi, payments): 20%
- Transparency and Offsets (e.g., carbon neutrality): 20%

Each qualitative factor is scored based on expert interpretation and thorough analysis of existing project documentation. These scores are then linearly combined with the normalized energy score, as shown in Equation (02).

$$Sustainability\ Score = (E \cdot 0.3) + (C \cdot 0.3) + (U \cdot 0.2) + (T \cdot 0.2) \quad (02)$$

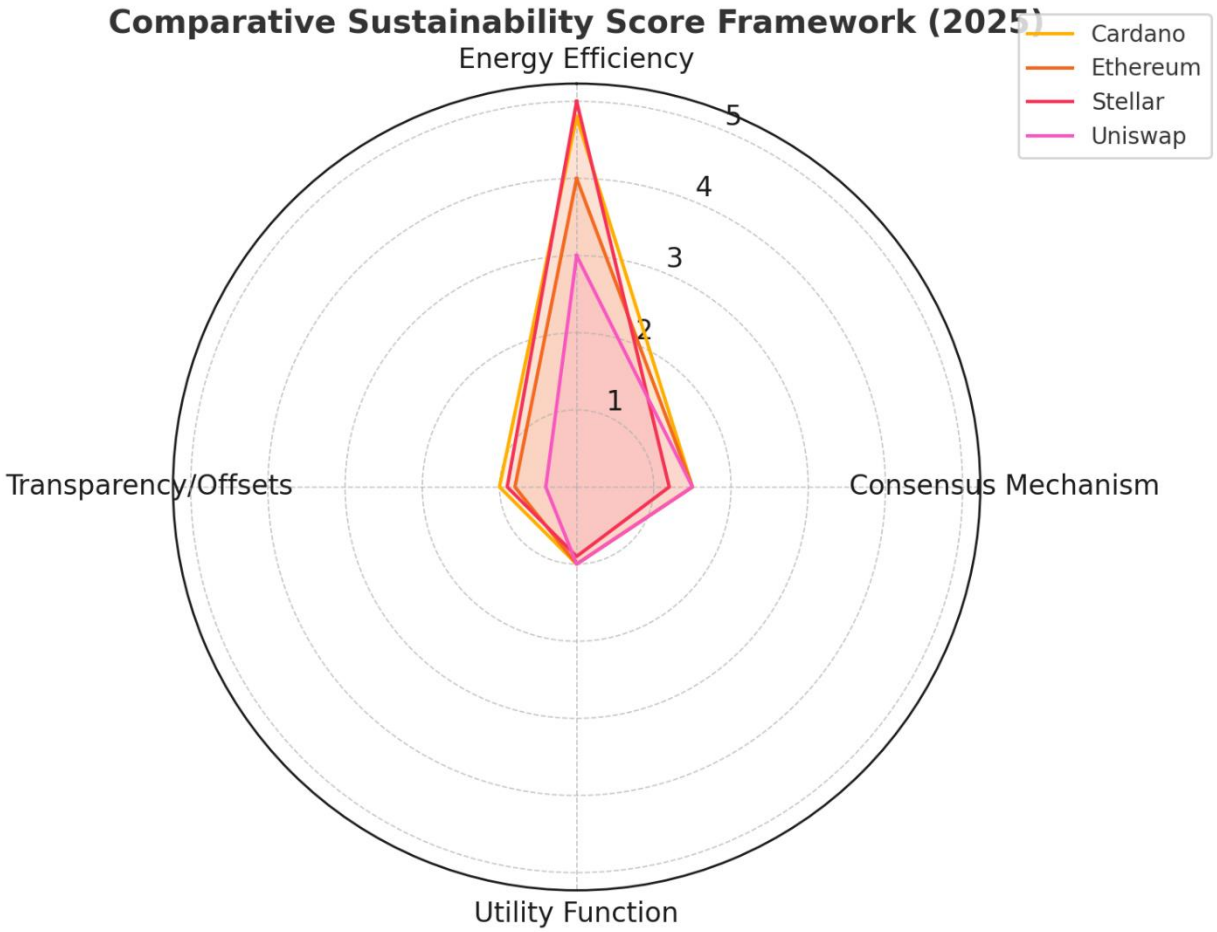
Where *E*: Normalized Energy Score (0–5); *C*: Consensus score (0–1.5), with PoS receiving the highest weighting; *U*: Utility score (0–1), based on application versatility and *T*: Transparency/offsets score (0–1), based on environmental claims and disclosures

This approach demonstrates that energy efficiency alone is insufficient for determining overall sustainability. For example, while Ethereum's energy consumption significantly decreased following its shift to Proof-of-Stake (PoS), its overall sustainability score remains heavily influenced by factors such as consensus design, scale of adoption, and environmental transparency.

Additionally, the relationship between energy use and sustainability scores may not be linear. Minor reductions in energy consumption do not necessarily lead to higher sustainability scores unless they are accompanied by broader operational or environmental improvements. This non-linearity justifies the importance of including qualitative modifiers and highlights the need for multi-dimensional frameworks in evaluating sustainability in blockchain systems.

Figure 1 illustrates the comparative sustainability profiles of four major blockchain projects—Cardano, Ethereum, Stellar, and Uniswap—based on our proposed composite scoring framework. The chart synthesizes four key dimensions: Energy Efficiency (30%), Consensus Mechanism (30%), Utility/Functional Role (20%), and Environmental Transparency/Offsets (20%). These dimensions were weighted and normalized on a 0–5 scale to construct a multi-dimensional ESG assessment, as derived from the values presented in Table 3.

Figure 1: Sustainability Score Framework for Blockchain Projects.



Source: Developed by authors.

The visual integrates normalized scores across four weighted dimensions—energy efficiency, consensus mechanism, utility/functionality, and environmental transparency—offering an intuitive comparison aligned with the ESG evaluation model developed in this study.

4. Analysis

This section analyses environmental and financial impacts of seven blockchain projects. Energy consumption varies widely, from Stellar's 0.1 GWh to Uniswap's 10-20 GWh. In terms of Sustainability scores, Cardano ranks highest at 4.8 out of 5, while Uniswap scores lowest at 3.9. Financially, Ethereum leads with $500B market cap and $100B TVL, followed by Cardano ($50B) and XRP ($2.45/token). These seven selected projects reflect both prominence in the literature (as identified in the bibliometric analysis) and diversity in technological and sustainability profiles. This selection is further supported by global overviews such as the World Economic Forum's (2020) mapping of cryptocurrency use cases, which highlights these platforms as foundational elements of the decentralised digital economy.

This section evaluates the environmental and financial impacts of Ethereum, Uniswap, Aave, Maker, Cardano, XRP, and Stellar, integrating provided data with market insights.

Environmental Impact

Energy Consumption: Stellar's SCP consumes approximately 0.1 GWh/year (approximately 0.00002 kWh/tx), XRP uses approximately 0.2 GWh (approximately 0.0079 kWh/tx), and Cardano's PoS consumes approximately 6 GWh (approximately 0.02 kWh/tx) (Stellar Development Foundation, 2025; Ripple, 2025; Cardano Foundation, 2025). Ethereum's PoS baseline is approximately 0.03 GWh, but DeFi activity drives it to 20-30 GWh (CCRI, 2025). Uniswap (approximately 10-20 GWh), Aave (approximately 8-15 GWh), and Maker (approximately 5-10 GWh) reflect their Ethereum-based loads.

E-Waste and CO_2: PoW-based systems such as Bitcoin generate significant e-waste due to the short lifespan of ASIC mining devices. De Vries and Stoll (2021) estimate that Bitcoin alone produces up to 30.7 kilotonnes of e-waste annually, with mining devices becoming obsolete in just over a year. This contrasts sharply with PoS systems, which eliminate e-waste concerns by operating on general-purpose hardware (Digiconomist, 2025). In the table number 3 we can see the energy consumption and sustainability scores.

Figure 2 illustrates the comparative sustainability profiles of four major blockchain projects based on our proposed scoring framework. The radar chart visually integrates energy efficiency, consensus mechanisms, utility functions, and environmental transparency, offering a multidimensional assessment of each project's ESG alignment. The input data for this chart is grounded in the sustainability scores and energy consumption values detailed in Table 3, which compares seven blockchain platforms across environmental impact and DeFi roles. Notably, Cardano leads with a score of 4.8, followed by Stellar (4.6) and Ethereum (4.3), while Uniswap scores lowest at 3.9 despite benefiting from Ethereum's post-Merge energy efficiency.

Table 3: Energy Consumption and Sustainability Scores (2025).

Cryptocurrency	Energy (GWh/year)	Sustainability score	DeFi Role
Stellar	0.1	4.6	Payments/DEX
XRP	0.2	4.5	Payments/DeFi Utility
Cardano	6	4.8	Smart contract platform
Ethereum	25	4.3	Smart contract platform
Maker	15	4.1	Stable coin protocol
Aave	13	4.0	Lending/Borrowing
Uniswap	15	3.9	Decentralized Exchange

Source: Developed by authors.

Table 3 provides a comparative overview of the environmental sustainability of seven different cryptocurrencies: Stellar, XRP, Cardano, Ethereum, Maker, Aave, and Uniswap. It focuses on two key metrics:

- **Energy (GWh/year):** Shows the estimated annual energy consumption of each cryptocurrency's network, measured in gigawatt-hours. Table 3 highlights significant differences in energy usage across diverse blockchain technologies.
- **Sustainability Score:** A numerical score, presumably on a scale from 1 to 5, representing the overall environmental sustainability of each cryptocurrency. A higher score indicates a more sustainable design and operation.
- **DeFi Role:** Describes the primary function or of each cryptocurrency within the decentralized finance (DeFi) ecosystem.

Figure 2: Energy and sustainability score.

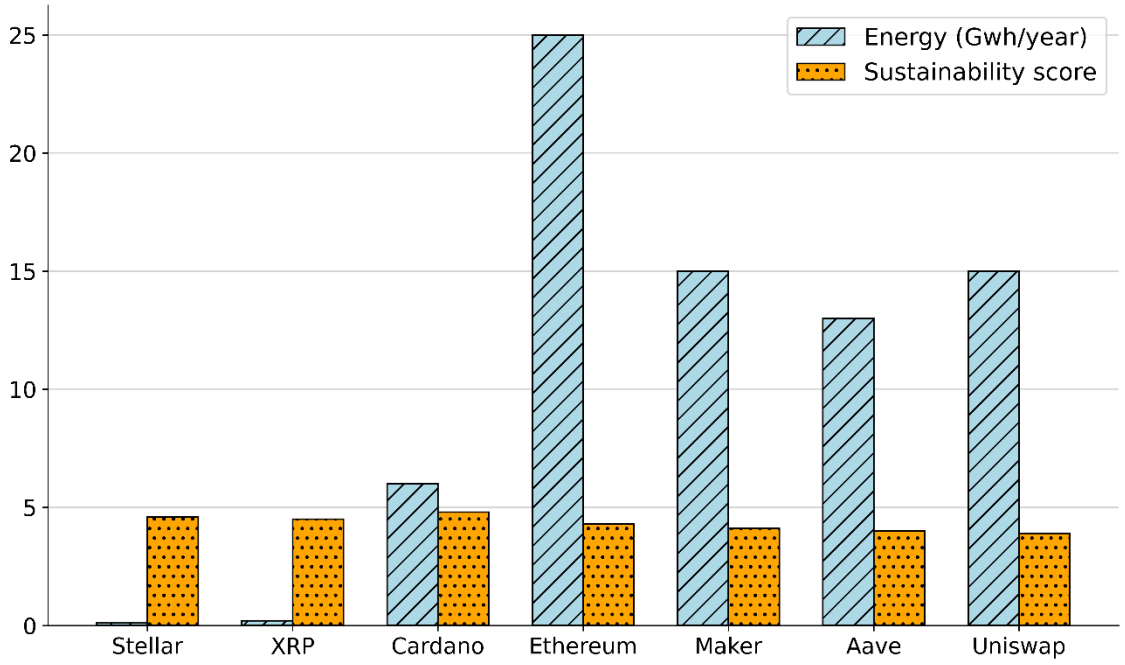


Table 4: DeFi Projects by Sustainability.

Project	Token	Primary DeFi Function	Sustainability Factors	Sustainability Score (1–5)
Cardano	ADA	Smart Contract Platform	**Environmental:** Proof-of-Stake (PoS), highly energy-efficient (approximately 6 GWh/year). **Economic:** Growing DeFi ecosystem, low fees, strong research focus. **Technological:** Scalable via Hydra, but DeFi adoption still maturing.	4.8
Stellar	XLM	Payments / DEX Infrastructure	**Environmental:** Stellar Consensus Protocol (SCP), very low energy use (approximately 0.1 GWh/year). **Economic:** Focus on payments and tokenization, steady partnerships, niche DeFi role. **Technological:** Fast and scalable, but limited smart contract capabilities.	4.6
XRP	XRP	Payments / Emerging DeFi	**Environmental:** XRP Ledger uses minimal energy (approximately 0.0079 kWh/tx, approximately 0.2 GWh/year). **Economic:** Strong in payments, growing DeFi use, backed by Ripple's resources. **Technological:** High throughput, but lacks robust smart contract support.	4.5
Ethereum	ETH	Smart Contract Platform	**Environmental:** Post-Merge PoS (2022), reduced energy use (approximately 0.03 GWh/year). **Economic:** Dominant DeFi platform, high	4.3

			adoption, but high fees remain a challenge. **Technological:** Scalable with rollups, resilient but complex upgrades.	
Maker	MKR	Stablecoin Protocol	**Environmental:** Relies on Ethereum, inherits its PoS efficiency. **Economic:** Dai's stability and integration ensure long-term relevance. **Technological:** Dependent on Ethereum's infrastructure, adaptable governance.	4.1
Aave	AAVE	Lending / Borrowing	**Environmental:** Runs on Ethereum, benefits from PoS efficiency. **Economic:** Strong lending market, multi-chain expansion, profitable for users. **Technological:** Flexible, but tied to Ethereum's scalability limits.	4.0
Uniswap	UNI	Decentralized Exchange	**Environmental:** Ethereum-based, leverages PoS efficiency post-Merge. **Economic:** High trading volume, but fee competition from newer DEXs poses risks. **Technological:** Multi-chain, but reliant on Ethereum's ecosystem for core dominance.	3.9

Source: Developed by authors.

Sustainability Analysis

1. Cardano (ADA) — Score: 4.8

- Strengths: Extremely energy-efficient due to PoS, designed with sustainability in mind. Its focus on scalability (Hydra) and low fees supports long-term DeFi growth.
- Weaknesses: DeFi ecosystem is still developing, lagging behind Ethereum in adoption.

2. Stellar (XLM) — Score: 4.6

- Strengths: SCP is one of the most energy-efficient consensus mechanisms. Stellar's payment focus ensures economic relevance, with a lightweight DEX enhancing DeFi utility.
- Weaknesses: Limited smart contract functionality restricts broader DeFi applications.

3. XRP (XRP) — Score: 4.5

- Strengths: XRP Ledger's low energy use and high transaction speed make it sustainable. Growing DeFi integration and Ripple's backing add economic stability.
- Weaknesses: Centralized perception and limited smart contract support hinder full DeFi potential.

4. Ethereum (ETH) — Score: 4.3

- Strengths: Post-Merge PoS slashed energy consumption by approximately 99.95% (from PoW days). DeFi dominance ensures economic viability.
- Weaknesses: High gas fees and complexity of upgrades (e.g., sharding) pose ongoing challenges.

5. Maker (MKR) — Score: 4.1

- Strengths: Inherits Ethereum's improved sustainability. Dai's role as a stablecoin ensures economic staying power.
- Weaknesses: Fully tied to Ethereum's infrastructure, limiting independent resilience.

6. Aave (AAVE) — Score: 4.0

- Strengths: Benefits from Ethereum's PoS efficiency and expands across chains, enhancing economic sustainability.
- Weaknesses: Dependence on Ethereum's ecosystem limits its standalone scalability.

7. Uniswap (UNI) — Score: 3.9

- Strengths: Post-Merge efficiency and multi-chain presence bolster sustainability. High usage supports economic viability.
- Weaknesses: Competition from cheaper DEXs and reliance on Ethereum's fees slightly undermine its long-term edge.

Environmental Impact: Cardano, Stellar, and XRP lead due to their inherently low-energy designs. Ethereum's PoS transition elevates it above its former PoW self, while Uniswap, Aave, and Maker ride its coattails. These differences in design are not only environmental but also economic. As Catalini and Gans (2019) explain, blockchain technologies fundamentally alter two key costs: the cost of verification and the cost of networking. PoS mechanisms reduce both by removing the need for energy-intensive validation and enabling more scalable and trust-efficient networks, reinforcing their sustainability from both a technical and economic standpoint.

Economic Viability: Ethereum's DeFi dominance gives it an edge, but Cardano, XRP, and Stellar's focus on efficiency and utility (payments, scalability) make them strong contenders. Uniswap, Aave, and Maker thrive within Ethereum's ecosystem.

Technological Resilience: Cardano and Ethereum excel with scalable designs, while XRP and Stellar prioritize speed over smart contract depth. Uniswap, Aave, and Maker are robust but constrained by Ethereum's limits.

Scoring: Scores (1–5) reflect a weighted balance of these factors, with slight preference for environmental efficiency given the sustainability focus.

Financial Impact:

Market Leadership: Ethereum's $500B market cap and $100B TVL dwarf others, with Uniswap ($5B TVL), Aave ($3B), and Maker (Dai's $10B) leading DeFi (CoinMarketCap, 2025; DeFi Pulse, 2025). Cardano's $50B cap and

XRP's $2.45 price (March 2025) signal growth (Forbes, 2025). Economic Viability: PoW's $50/MWh mining cost contrasts with PoS's affordability, enhancing scalability (e.g., Cardano's Hydra, Ethereum's rollups). In Table 4 it can be seen the financial metrics.

Table 4 summarises the financial status of seven leading cryptocurrency projects as of April 2025, featuring three core financial metrics:

- **1. Market Cap:** Represents the total market value of each cryptocurrency, expressed in billions of US dollars. It is calculated by multiplying the current market price by the circulating supply, indicating the overall valuation of the cryptocurrency;
- **2. Total Value Locked (TVL):** Indicates the total value locked in the DeFi protocols associated with each cryptocurrency, also expressed in billions of US dollars. TVL reflects the level of financial activity and utilization within the cryptocurrency's ecosystem;
- **3. Token Price:** Shows the price of a single unit of each cryptocurrency, expressed in US dollars.

Table 4: Financial Metrics (April 2025).

Project	Market Cap ($B)	TVL ($B)	Token Price ($)
Ethereum	500	100	4
Uniswap	15	5	20
Aave	10	3	150
Maker	8	10	2
Cardano	50	1	1.5
XRP	120	0.5	2.45
Stellar	15	0.2	0.6

Source: Developed by authors.

5. Results and Discussion

PoW emits approximately 90 Mt CO_2 annually (Bitcoin), while PoS cuts this by 99.95% (Ethereum). DeFi's $150B TVL highlights financial growth, but Ethereum's 20-30 GWh load contrasts with Stellar's 0.1 GWh. Regulatory pressures (e.g., MiCA) and risks ($600M DeFi losses) shape the future.

The analysis reveals a stark divide: PoW's environmental cost versus PoS's efficiency. Bitcoin's 150 TWh and 90 Mt CO_2 dwarf Stellar's 0.1 GWh and negligible emissions (Digiconomist, 2025). Ethereum's Merge cut its footprint by 99.95%, yet DeFi sustains 20-30 GWh (CCRI, 2025). Cardano, XRP, and Stellar offer sustainable models, but their DeFi ecosystems trail Ethereum's maturity. In Decentralized Finance (DeFi), understanding key metrics is crucial for making informed decisions. One of the most important metrics is Total Value Locked (TVL). This indicator represents the total value of cryptocurrencies deposited in a specific DeFi protocol, effectively showing the amount of assets "locked" within the platform. Analysing TVL provides valuable insights into the health and adoption of different DeFi protocols.

Financially, DeFi's $150B TVL—led by Ethereum—signals robust growth (DeFi Pulse, 2025). Uniswap, Aave, and Maker anchor this ecosystem, while Cardano's scalability and XRP/Stellar's low fees ($0.0001/tx) broaden access (Ripple, 2025). PoW's high costs limit scalability, unlike PoS's efficiency (e.g., Solana's 65,000 tx/s vs. Bitcoin's 7 tx/s) (Solana Labs, 2025). Security remains a trade-off: PoW's resilience versus PoS's stake risks (Wood, 2021).

Energy Intensity of Proof-of-Work (PoW):

- Bitcoin and Ethereum (pre-merge) rely on PoW consensus, consuming approximately 91–150 TWh annually when compared to nations like Argentina (Cambridge CBECI, 2023). High energy demand directly increases carbon footprints where mining uses fossil fuels (e.g., coal in Kazakhstan).

Carbon Emissions and Financial Valuation:

- Studies correlate Bitcoin's price surges with increased energy use (≈400–500 kgCO_2 per transaction), as miners scale operations during bull markets (Joule, 2021). Market cap growth thus amplifies emissions.

Geographic Externalities:

- Mining hotspots (e.g., Texas, Inner Mongolia) strain local grids, raising electricity prices and diverting renewable capacity from public use (Nature Energy, 2022). These externalities distort regional economies.

Ethereum's Post-Merge Reduction:

- Ethereum's shift to Proof-of-Stake (PoS) cut energy use by 99.95%, demonstrating that protocol changes can decouple financial activity from emissions (CCAF, 2023).

Carbon Pricing and Crypto Taxes:

- Proposed carbon taxes on mining could internalize environmental costs, reducing profitability by 20–30% if priced at \$50/tonCO_2 (IMF, 2021). This may suppress speculative trading.

Renewable Energy Myths:

- While 39% of mining uses renewables (CBECI, 2023), competition with other industries (e.g., manufacturing) limits net-zero claims. Hydro-dependent regions (e.g., Sichuan) face seasonal shortages.

Investor ESG Pressures:

- Institutional investors (e.g., BlackRock) now screen crypto assets for ESG compliance, depressing valuations of high-emission coins (Journal of Sustainable Finance, 2022).

Alternative Consensus Mechanisms:

- PoS, DAGs, and other low-energy protocols (e.g., Algorand, Cardano) show 99% lower emissions, but adoption lags due to security trade-offs (IEEE Access, 2023).

Macroeconomic Climate Risks:

- Crypto's energy demand could delay national decarbonization goals, increasing sovereign climate liabilities (e.g., US NDCs) and regulatory backlash (OECD, 2022).

Policy Scenarios:

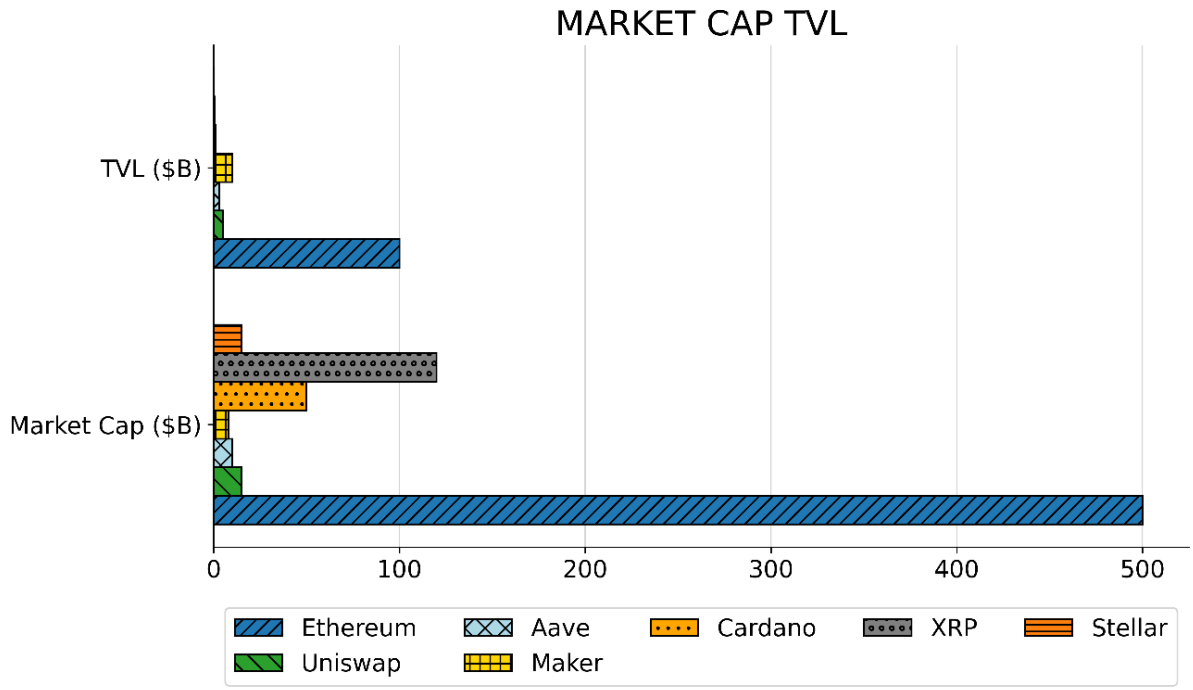
- A global PoW ban (as proposed by the EU's MiCA) might reduce crypto's climate impact by 60%, but drive mining to unregulated jurisdictions (Science, 2023).

Table 5: Transaction Costs and Speeds (2025).

Project	Tx Cost ($)	Tx Speed (tx/s)	Notes
Bitcoin	5 - 20	7	High cost, low speed
Ethereum	1 - 10	30 (post -rollups)	Variable gas fees
Cardano	0.17	250 (Hydra)	Scalable PoS
XRP	0.0001	1500	Payment focused
Stellar	0.0001	1000	DEX-enabled

Source: Developed by authors.

Figure 3: Evolution of market cap and TVL from 2019 to 2025.



Ethereum's curve rises sharply to $100B, Cardano/XRP/Stellar grow modestly to $1B/$0.5B/$0.2B, reflecting ecosystem maturity.

Why Is TVL So Important?

TVL serves as a key indicator of a DeFi platform's activity and stability. A high TVL generally reflects strong user confidence and an active market, which in turn attracts more liquidity and participation, creating a positive feedback loop.

Conversely, a declining TVL may suggest that users are withdrawing their funds or losing trust in the platform. However, TVL is not the only factor to consider, as market volatility can also have a significant impact on it.

Regulatory pressures (e.g., EU's MiCA targeting PoW by 2026) and risks ($600M DeFi losses in 2024) add complexity (European Commission, 2024; Chainalysis, 2025). Sustainable innovation—hybrid models or carbon-neutral mining—could bridge these gaps.

Key Findings:

- Energy Costs & Carbon Emissions:
- Bitcoin mining consumes approximately 91 TWh/year (CBECI, 2023), costing €4.5 billion annually (at €0.05/kWh EU average).
- Each Bitcoin transaction emits approximately 400 $kgCO_2$, equivalent to €20 in carbon costs (at EU ETS price of €50/$tonCO_2$).

Financial Market Impact:

- Mining profitability declines if carbon taxes apply: A €50/$tonCO_2$ tax could reduce mining revenues by €1.5 billion/year in the EU (IMF, 2021).
- Investor ESG shifts: 30% of EU institutional investors avoid high emission cryptos, potentially depressing market caps by €50 billion+ (Journal of Sustainable Finance, 2022).

Regulatory & Policy Costs:

- EU's MiCA regulations may impose €10–30 million compliance costs per mining firm (OECD, 2022).
- Subsidies for green mining: Germany's proposed €500 million renewable-energy mining grants could cut emissions by 25% but require taxpayer funding.

Case Study: Ethereum's Merge (2022):

- Reduced energy use by 99.95%, saving €2.1 billion/year in global energy costs (CCAF, 2023).
- Market reaction: ETH's price stabilized post-merge, avoiding €5 billion+ in ESG-driven selloffs.

Table 5: Economic inputs (Euro examples).

Factor	Estimated Cost/Impact (EUR)	Source
Annual EU Bitcoin mining energy cost	€ 4.5 billion	CBECI (2023)
Carbon cost per BTC transaction	€ 20	EU ETS (2023)
Potential EU mining revenue loss (carbon tax)	€ 1.5 billion/year	IMF (2021)
Investor-driven crypto devaluation (ESG)	€ 50 billion+	JSF (2022)
MiCA compliance costs per firm	€ 10–30 million	OECD (2022)
Ethereum's annual energy savings post-merge	€ 2.1 billion	CCAF (2023)
Avoided ETH sell-offs (ESG)	€ 5 billion+	Market data

Policy & Market Recommendations:

Carbon Pricing:

- A €50/tonCO_2 tax on mining could cut EU emissions by 15% but requires cross-border enforcement.

Green Mining Incentives:

- €500 million in EU subsidies for renewable-powered mining could attract €2 billion in private investments.

Investor Transparency:

- Mandatory ESG disclosures (cost: €5M/firm) could prevent €50B+ in market volatility.

6. Conclusion

As of April 2025, the digital assets economy stands at a crossroads, balancing compelling financial promise with escalating environmental costs. The environmental disparity between consensus mechanisms is especially stark: energy-intensive Proof-of-Work (PoW) systems like Bitcoin consume over 150 TWh annually and emit approximately 90 Mt of CO_2, while Proof-of-Stake (PoS) alternatives such as Stellar operate at vastly greater efficiency, requiring only around 0.1 GWh. Despite this contrast, high-emission platforms persist—Bitcoin alone generates an estimated €4.5 billion in energy costs and €20 per transaction in carbon liabilities—posing significant sustainability challenges.

Ethereum's transition from PoW to PoS via the Merge has marked a pivotal moment, enabling a drastic reduction in energy use while driving the decentralized finance (DeFi) ecosystem forward with a Total Value Locked (TVL) exceeding €150 billion. Alongside Ethereum, sustainable platforms like Cardano, XRP, and Stellar offer low-cost, scalable blockchain infrastructure, although they lag in DeFi maturity and user adoption, despite transaction costs below €0.0001. These discrepancies highlight a central tension: while PoS offers a greener path forward, its ecosystem remains less developed compared to PoW incumbents.

This study underscores the urgent need for differentiated regulatory approaches across consensus mechanisms. PoW networks require strong environmental constraints, whereas PoS systems call for enhanced governance frameworks to address emerging risks. Regulatory instruments such as the EU's Markets in Crypto-Assets (MiCA) framework and proposed carbon taxes (e.g., €50/ton CO_2) reflect a broader effort to internalize externalities, potentially reducing miner profitability in Europe by up to €1.5 billion annually. However, such measures also risk displacing mining activities to less regulated jurisdictions, raising geopolitical and environmental concerns.

To support informed decisions by regulators and institutional investors, this study introduces a sustainability scoring framework that integrates environmental efficiency, economic viability, and technological resilience. Such tools are increasingly vital as ESG-driven capital reallocation reshapes crypto valuations—high-emission assets may face €50 billion in market cap losses due to ESG screening trends, such as those implemented by BlackRock. Mandatory ESG disclosures could help mitigate an estimated €50 billion in market volatility, improving transparency and aligning the sector with decarbonization goals.

Technological innovation will also play a critical role in this transition. The integration of Artificial Intelligence (AI) into blockchain consensus mechanisms represents a transformative opportunity, enhancing network efficiency, adaptability, and security (Rizal & Kim, 2025). This aligns with emerging literature emphasizing the importance of customer trust and sustainability in influencing cryptocurrency adoption (George et al., 2025), advancing theories in sustainable finance, technology adoption, and behavioral economics.

Security remains a major concern across both consensus models. In 2024, the DeFi sector suffered over $600 million in losses due to exploits and vulnerabilities (Chainalysis, 2025). PoS mechanisms, while energy-efficient, also present unique challenges, as analyzed by Goodell et al. (2023) in *Science*. Hybrid consensus models and policy innovations—such as Germany's €500 million in renewable energy mining grants—may offer a bridge between performance and sustainability, as suggested by Truby (2022) in the *Journal of Sustainable Finance*.

Looking forward, only through adaptive regulation, sustainable technological innovation, and ESG-aligned investment can the digital asset economy evolve into a sustainable pillar of the global financial system. This evolution demands not only technical advancements but also proactive legal and fiscal frameworks. As Truby (2018) argues, instruments such as differentiated taxation and energy-linked incentives can redirect blockchain development away from PoW and toward low-impact models like PoS.

In this context, RegTech and SupTech solutions—leveraging AI, distributed ledger technology (DLT), and blockchain—provide regulators with powerful tools to enhance compliance, traceability, and systemic sustainability (Grassi & Lanfranchi, 2022). These same tools can support the evolution of sustainability scoring frameworks tailored for DeFi platforms, enabling better risk assessment and ESG alignment.

Finally, understanding the interaction between crypto-assets and broader markets is crucial. Recent studies show that sustainable cryptocurrencies exhibit significant volatility interconnections with major crypto tokens and energy indices (Sengiu et al., 2025). These dynamics reinforce the importance of continued interdisciplinary research to support investor decision-making and policy innovation. In sum, achieving long-term economic and environmental sustainability in crypto hinges on hybrid innovation models, location-sensitive regulation, and the alignment of financial incentives with global decarbonization objectives.

7. Future Work

Future research should explore hybrid consensus mechanisms combining PoW's security with PoS's efficiency to optimize sustainability. Investigating real-world adoption rates of DeFi across diverse economies could reveal scalability limits. Assessing the long-term security of PoS under high-stake conditions is critical to address centralization concerns. Developing carbon-neutral mining technologies could mitigate PoW's environmental impact. For example, the use of renewable energy (Hakimi et al, 2024). Finally, modelling the economic effects of regulatory frameworks like MiCA on cryptocurrency markets would inform policy and innovation strategies.

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Scenario projection and envisioning techniques for SMEs and startups: Insights from the DC4DM project

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Abstract

This study explores future forecasting methodologies through a qualitative, exploratory lens, bridging theoretical constructs with applied strategies in entrepreneurial ecosystems. Anchored in literature review and selected case analyses, it draws on insights from the Design Competences for Digital Maturity (DC4DM) project to illustrate how trend analysis, business modelling, and envisioning techniques can be operationalized by SMEs and startups to cultivate strategic resilience and future-readiness. Emphasizing the integration of foresight tools into both academic curricula and entrepreneurial practice, the findings reveal the transformative potential of scenario-based thinking for innovation and adaptability. The paper identifies critical gaps in empirical validation and proposes pathways for future research to refine and scale such approaches in diverse organizational and cultural contexts.

Keywords: DC4DM; Future Forecasting; Scenario Projection; SMEs; Startups.

1. Introduction

In today's increasingly volatile, uncertain, complex, and ambiguous (VUCA) global environment, small and medium-sized enterprises (SMEs) and young ventures frequently find themselves frozen, off course, or even forced to fold. Although digital tools and data have never been more accessible, many of these organizations still lack a clear, systematic way to spot emerging shifts and build forward-looking strategies.

Scenario planning has long been touted as a potent approach for imagining multiple possible futures and getting ready for them (Schwartz, 1997; Schoemaker, 1995). Rather than just crunching numbers, scenarios spark the kinds of strategic dialogues that foster shared insights and strengthen an organization's ability to adapt (Van der Heijden, 1996; Fildes, 1998).

Yet, while foresight methods are well established in large corporations and government bodies, their hands-on use by entrepreneurs remains surprisingly rare and under-researched (Magistretti et al., 2019). This paper aims to fill that gap by examining how forecasting and visioning tools were put to work in the Design Competences for Digital Maturity (DC4DM) project. Rather than dwell on theory alone, we combine a critical literature review with a close look at real deliverables from DC4DM.

We show how techniques like trend spotting, business-model innovation, and creative envisioning can be embedded in both teaching programs and daily practice to boost strategic flexibility and drive innovation. By weaving these methods into the fabric of SME and startup operations, it becomes possible to nurture more resilient, sustainable visions of what lies ahead.

The article unfolds as follows. First, we survey the key literature; next, we outline our qualitative, conceptual approach; then, we analyse selected DC4DM outputs; and finally, we discuss our theoretical contributions, practical take-aways, study limitations, and avenues for future research.

Small and Medium-Sized Enterprises and Startups: Projecting the Future of Businesses

In the European Union SMEs make up over 99% of business. In recent years, the performance of SMEs has been impacted by several unprecedented external events, such as the COVID-19 pandemic, which has led to price increases and difficulties in human resources. More recently, in 2022, SMEs were affected by the Ukraine conflict leading to an increase in inflation, energy costs, raw materials (Bella et al., 2023).

The importance of future forecasting for SMEs and startups, and techniques for scenario projection, constitute an important aspect of business existence. According to recent research, business ideas do not survive the first few years in the market as small businesses, generally startups. The main reason for this failure is the lack of planning and forecasting of future scenarios.

In fact, paraphrasing Thiel (2014), co-founder of PayPal, companies that did not predict the future are trapped in a world that no longer exists. They are doomed to stay in the past and eventually disappear. Moreover, Thiel (2024) argues that no one can predict the future exactly, but it's going to be different, and it must be rooted in today's world.

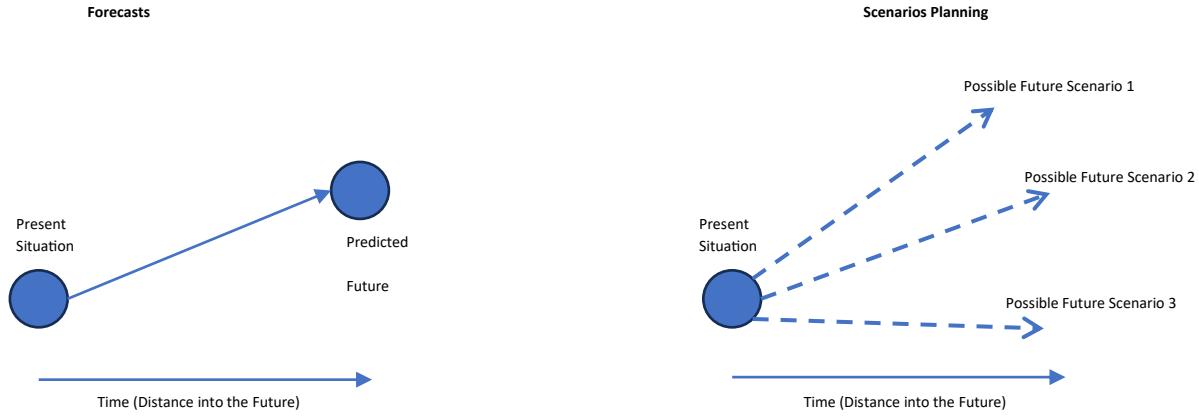
However, the future itself holds a lot of uncertainty, and the question arises: how to develop a mindset for prediction and benefit from the use of existing technologies and those that will be created soon? The 2020 Future of Jobs report tells us that to develop this mindset, it is necessary to be constantly informed about technological trends and innovations, as well as be open to experimentation and adaptation (World Economic Forum, 2020).

In the same vein, Diamandis (2012), founder of the XPRIZE Foundation, adds: "The future is created by those who see something that does not yet exist and make it real.". And according to Kotler (2016) accurately forecasting the future is a cornerstone of business success. Without this ability, companies risk falling behind, constantly struggling to keep up with the pace of change.

This all relates to entrepreneurship and a certain profile of professional open to risk, equipped with technical skills. Different available tools are referred to in the literature (Abdelkarim, et al., 2019). Among them is the trend analysis technique for projecting future business scenarios, which involves identifying patterns in past and current data to predict possible future outcomes.

Scenario planning is a strategic methodology that can be applied in predicting various future situations over a medium-term horizon. Unlike other strategic planning tools supported by extrapolating trends and patterns to make a forecast, the objective is to elaborate different possible images to support conscious decision-making. It should be noted that a scenario can be defined as a consistent and plausible description of a future reality (Dean, 2019) (Figure 1).

Figure 1: Comparison between single-point forecasts and scenarios planning.



Source: Dean (2019).

Another technique is business modelling, which allows for the creation of simulations to test possible future scenarios. Business modelling provides organizations with the necessary flexibility, so that executives can test their strategies under economic, regulatory and competitive uncertainties in a context of rapid change (Nwoke, 2025; Oluwafemi Oloruntoba, 2024).

3. Future Scenario Projection

Scenario planning presents itself as a technique that has been developed for more than 40 years (Lehr et al., 2017) and researched, taught and applied by management professionals (Ramírez & Wilkinson, 2016).

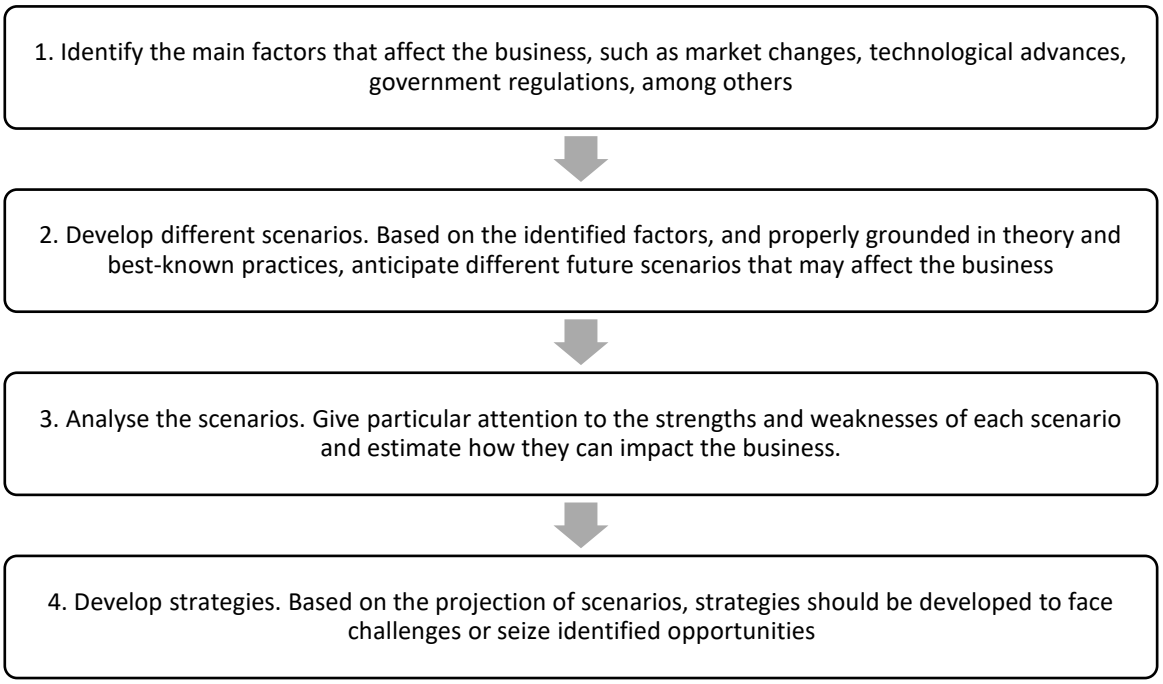
There are several definitions of scenario planning, such as that of Schwartz (1997) who states that the projection of future scenarios is not an attempt to predict the future, but rather a way to anticipate the possibilities of the future that may become a reality (Schwartz, 1997). According to Lindgren & Bandhold (2009), the aim of scenario projection is to construct plausible and convincing stories of the future that can be used to support informed and strategic decision-making. Or we can consider more recent views, such as that of MacKay and McKieman (2018), who define scenario thinking as a cognitive process concerned with imagining how the future can unfold in various ways through analysis and consideration of the effects of the actions and reactions of the modelling forces.

Thus, the technique of estimating future scenarios is a methodology that does not focus on a single prediction but instead integrates a diversity of possible scenarios that help managers make decisions and guide the company. Wright (2025) warns that scenario planning was developed based on the assumption of an uncertain future, which serves as a basis for learning about the importance of distinguishing between predictors and uncertainties. The former (predictors) being events that have already occurred (or will occur with a high degree of certainty), but the consequences have not yet developed, and the latter (uncertainties) should be considered from an additional perspective to gain a greater understanding of their importance for the future thinking.

In fact, the projection of future scenarios is an analytical methodology that allows companies to anticipate and prepare for the challenges of uncertainty. In practice, this technique involves creating different scenarios based on various factors, such as technological, political, economic, and social trends. The projection of future scenarios can be applied across various areas of the company, with particular interest in strategic planning and risk management. Through the projection of future scenarios, companies can identify potential opportunities and threats and develop expansion and contingency plans, respectively, in cases of immediate response to opportunities or setbacks.

Like most methodologies, the technique of projecting future scenarios as a support for decision-making in anticipation of the future requires a sequence of at least four stages as shown in Figure 2.

Figure 2: Stages of decision-making.



Source: Authors.

There are cases of successful use of the scenario projection methodology with several years of application. For example, Shell has adopted this technique since the 1970s to anticipate possible futures in the energy market, allowing them to develop adaptation strategies to changes in the sector, regarding the transition from the fossil fuel-based energy paradigm to sustainable energy. As Wright (2025) points out, what Shell´s organization presents on its website are not predictions or expectations of what will happen, or should happen, but explorations of how the world could evolve underpinned by different sets of assumptions.

4. The Communication of Future Scenarios and the Potential of Technology

Based on the previous sections, there is no doubt that projecting future scenarios is essential for the survival of companies and organizations, and technology is accelerating its adoption. Martino (2007) supports the first part of this statement, concluding that there is no doubt that technology has a considerable influence on the decision-making process in many areas, being considered a critical factor in building future scenarios. He adds that this is relevant for both the private and public sectors.

Regarding the potential of technology, Porter and Cunningham (2005) state that new technologies, such as text mining, network analysis, data modelling, and visualization, offer unprecedented potential for future scenario projection and strategic analysis, providing organizations with an extraordinary ability to anticipate emerging trends and gain competitive advantages.

Effective adoption of communication of this exploratory potential of the future, assisted by technology, must be well communicated. For this purpose, it should be included in strategic documents and clearly and accessible to all stakeholders, both in the vision, mission, and values of companies, so that strategic decisions are informed. Saunders (2009) states that this situation may be further aggravated by the fact that not all elements have the necessary skills to communicate effectively and therefore the scenarios are inherently biased in relation to the information provided element. It should be noted that scenarios are not predictions, but plausible stories that are constructed to challenge our perceptions and prejudices, allowing us to explore the implications of different possible futures (Ramírez and Selin, 2014).

Scenarios can be presented using various methodologies (Richter et al., 2021). For instance, they can be displayed through graphs, tables, narratives (Steenberg et al., 2019) and images (Löfström et al., 2020), among others approaches. It is crucial to communicate the message effectively to avoid misleading and creating false hopes. Therefore, communication follows some basic rules, such as:

- Use of simple and direct language to facilitate understanding. Despite the richness of technical management language, communication of future scenarios should be clear and objective while avoiding the use of jargon.
- Use of visual resources such as graphs, tables, and infographics, as they are more easily memorable images and more likely to better illustrate the expected results of future scenarios.
- Presentation of different perspectives on future scenarios so that those involved can have a holistic view of the implications.
- Use of technology for data visualization, such as virtual reality and other technologies that can provide an immersive experience.

Best practices have already revealed successful cases of communication of future scenarios. One of them is Unilever's "The Future I Want" campaign (Unilever, 2021). The company uses virtual reality to simulate life experiences in different future scenarios, showing the implications of each scenario, relating scenarios to options, and stimulating awareness of the impact of these options on the future of the planet and human life.

Another example of best practices is presented to us by Toyota (2021). Under the slogan "2030: Long Range Planning," the company uses data and technology to anticipate changes in the automotive market and develop more efficient and sustainable vehicles.

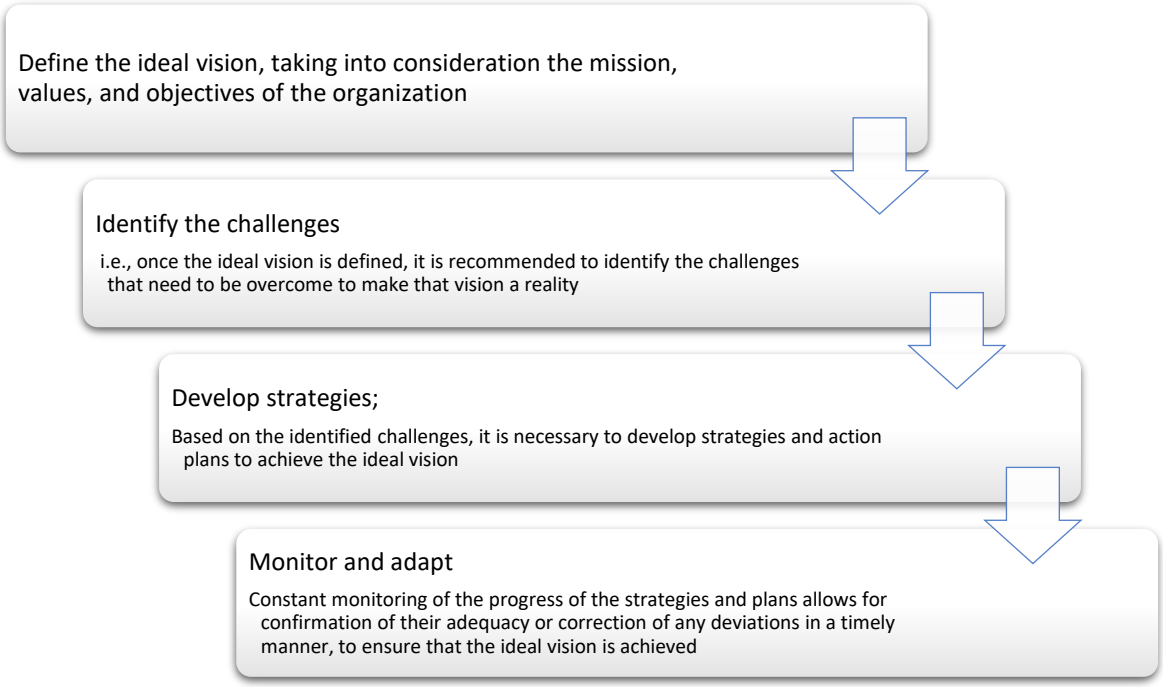
5. Envisioning

According to Slaughter (1996), the ability to visualize alternative futures is not an intellectual luxury, but a practical requirement for surviving in the complex and rapidly changing society we live in.

One of the main techniques for visualizing the future in the English-speaking world is called envisioning. According to Vizcaino & Sridharan (2013), the concept of envisioning does not mean predicting the future but rather creating it. Thus, envisioning is seen as a strategic planning technique that involves creating ideal visions or scenarios of the future for a company or organization. This technique is based on the idea that by creating visions, it is possible to have a clearer understanding of what needs to be done to achieve them and make more informed, knowledge-based strategic decisions (Capatina et al., 2024). This perspective aligns with recent contributions in educational foresight, which emphasize how envisioning methodologies can profoundly reshape curricula and pedagogical strategies by fostering anticipatory thinking and transformative learning processes (Milojević & Inayatullah, 2023). In heinous literacy, there is a combination of foresight (Rooyen et al., 2025), strategic design (Bühring & Liedtka, 2018) and digital tools (e.g. Nweke, 2025), to stimulate long-term visualizations, technological roadmaps and sustain strategic decision-making for SMEs.

In the practical application of envisioning, it is relevant to consider the following sequential steps shown in Figure 3.

Figure 3: Steps for practical application of envisioning.



Source: Authors.

Apple is a good example of the best envisioning practices, creating the ideal vision of being the leading company in innovation and design of consumer electronics. The company focused on developing innovative and appealing products that revolutionized the market, such as the iPhone and iPad. Through these devices, Apple created a culture of innovation that became the company's brand image (Podolny & Hansen, 2020).

6. Alternative Approaches

Beyond the technological forecasting techniques, there are other methods and techniques that can be considered to anticipate the future of technological evolution. Below are some additional approaches, as well as descriptions of some of the advantages and disadvantages of using these methods and techniques.

a) **Patent analysis**

Patent analysis presents itself as a tool for technology foresight and strategic innovation for both startups and SMEs (Vecchiato et al., 2024). The study of patents registered by areas is a technique used to identify technological trends, market opportunities, and anticipate future innovations, evaluate the competition and avoid risks of obsolescence, since the patents represent an indication of the investment in R&D of companies with a commercial focus (Hassanabadi, 2019; Lee et al., 2014; Salamzadeh et al., 2022). However, patent analysis has limitations, since many technological innovations are kept secret, without patent registration, precisely to avoid industrial espionage.

b) **Technology surveillance**

SMEs are increasingly turning to technology surveillance to increase their predictive capabilities (Halima et al., 2022). Technology surveillance is a process of constant alert and systematic collection of data, analysis, and dissemination of information about technologies relevant to a company or organization. This technique can be useful for identifying new technological trends, as well as threats and opportunities in the market. It allows startups and SMEs to be constantly updated on scientific advances, market trends and innovations, which leads to more agile and adjusted strategic decision-making. In the most recent publications, there is a focus on automatic methods using Big Data analysis, AI and tools such as roadmapping, biblical analysis and competitor

monitoring (Burroughs, 2020; Capatina et al., 2024; Oladele, 2025). Nevertheless, technology surveillance can be limited by the availability of information, which may vary depending on the sector and country in question.

c) **Prospective scenarios**

Despite limited resources, startups and SMEs building prospective scenarios has become essential to address complexity and uncertainty in the current market context (Salamzadeh et al., 2022). Prospective scenarios are a technique used to anticipate possible futures by creating narratives that describe different paths that technology can follow. Prospective scenarios are a technique used to anticipate possible futures by creating narratives that describe different paths that technology can take. Methods such as scenario planning, backcasting and alternative narratives have been used to test whether the strategies configure the necessary robustness. This vision is presented as useful in the digital transformation, sustainability, and innovation that most startups and SMEs aim for (Kim & Seo, 2023; Salamzadeh et al., 2022; Vecchiato et al., 2024). This approach can be useful for helping companies prepare for different scenarios, as well as identifying potential opportunities and threats. However, prospective scenarios can be limited by the fact that the future is uncertain and can be influenced by a variety of unpredictable factors.

d) **Artificial intelligence and machine learning**

The implementation of predictive analytics in decision-making has been widely adopted in business in various markets. Predictive analytics underpinned by the integration of AI and Machine Learning (ML) facilitates real-time decision-making (Nweke, 2025). AI and ML are techniques that can be used to predict technological trends based on analyses of large data sets.

The most recent literature highlights the use of tools such as explainable AI (XAI), deep neural networks, and integration with business intelligence systems for scenario planning, innovation, and digital transformation (Blake & Asghar, 2024; Chotisarn & Phuthong, 2025; Kim & Seo, 2023; Sreenivasan & Suresh, 2022; Yadav et al., 2024). This approach can be useful for identifying patterns and trends that may not be perceptible through other techniques. However, the accuracy of predictions may depend on the quality of the data and algorithms used.

While the literature provides comprehensive frameworks for future forecasting, envisioning, and strategic innovation, the practical implementation of these concepts remains a significant challenge. To address this gap, the DC4DM project offers a valuable set of experimental outputs which will be analysed in this study.

7. Methodology

The present work is grounded in a qualitative and exploratory research approach, following established academic guidelines. According to Prodanov & Freitas (2013), exploratory research aims to provide more information on the subject being investigated. Similarly, Gil (2017), states that exploratory research aims to provide greater familiarity with the problem, with a view to making it more explicit or building hypotheses. Consistent with this perspective, exploratory studies often take the form of bibliographic research, relying on existing materials such as books, scientific articles, and case studies. The literature review conducted here explored the topic from multiple angles, considering not only theoretical frameworks but also practical applications of future forecasting and scenario planning techniques. In line to Gil (2017), the primary sources utilized in this work were drawn from bibliographic surveys and focused on pre-existing materials prepared by recognized experts in the field. Furthermore, as Yin (2018) notes, case studies are particularly effective in investigating complex, contemporary phenomena in depth. Embracing this approach, the present study adopts a conceptual review methodology, aimed at synthesizing and critically analysing key techniques related to future forecasting and scenario planning as they pertain to SMEs and startups. This research presents a review of selective academic literature on forecasting, strategic innovation and digital transformation. To achieve the proposed objective, sources were identified through academic databases (e.g., Scopus, Web of Science) and selected based on relevance, citation impact, and cross-sectoral application. Finally, this paper examines several outputs from the DC4DM project, synthesizing their principal theoretical and practical contributions. To mitigate potential bias, interpretations and

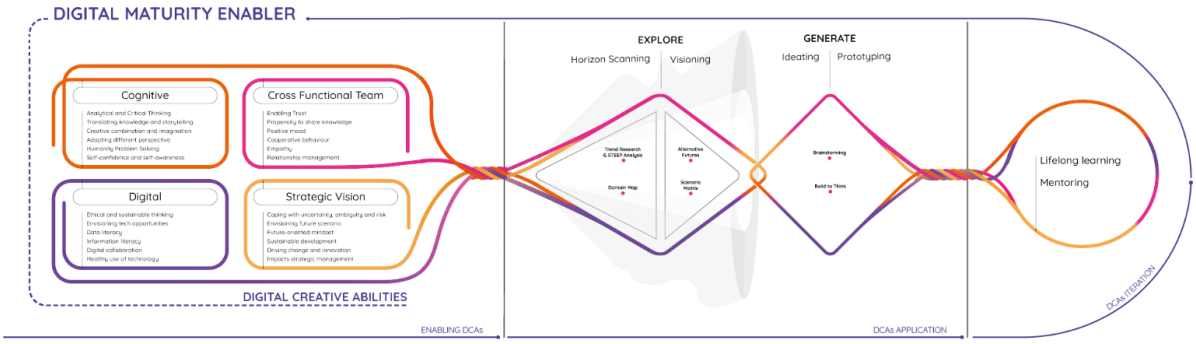
findings were triangulated with input from other project stakeholders, ensuring analytical validity. The findings lay the foundation for future empirical studies and offer practical insights for implementation in educational and strategic design contexts.

8. Applied Analysis of DC4DM Outputs

The European project the Digital Creativity for Developing Digital Maturity Future Skills (DC4DM), funded by the Erasmus+ program, emerged in 2020 with the aim of empowering professionals and future professionals with the necessary skills to face the challenges of digital transformation. It comes from a Consortium between several higher education institutions, startups, small and medium-sized enterprises and business incubators from different European countries. Evolving from its inception between 2020 and 2023, the DC4DM model has progressed from theoretical groundwork to practical implementation, offering a valuable educational framework for educators, businesses, and individuals seeking to foster Digital Creativity. Through thorough testing in Learning Labs (LLabs), the DC4DM toolkit is now poised for widespread adoption. Participation in programs such as the Digital Creativity for DC4DM, supported by the Erasmus+ program, can yield significant benefits for businesses, particularly SMEs and startups (Digital Creativity for developing Digital Maturity future skills, 2025).

The DC4DM educational model, focused on human, allows individuals and teams to envision and communicate future scenarios and design responses; it comprises a curated collection of freely accessible learning materials hosted on the dynamic EDU Box virtual platform, adaptable to the changing digital landscape and educational requirements (Vezzani et al., 2023). They sought to create a digitally mature community, foster the exchange of knowledge (Figure 4).

Figure 4: Digital Maturity Enabler.



Source: Digital Creativity for developing Digital Maturity future skills (2025).

The flexibility and adaptability of the DC4DM model render it suitable for diverse educational settings, effectively preparing participants for the challenges of the digital workforce. Engaging in initiatives like the Digital Media Learning Lab further enhances participants' readiness to tackle real-world challenges by integrating theoretical knowledge with practical application, equipping them to navigate uncertainty and competition in today's market. To empirically ground the conceptual discussion, four key outputs from the DC4DM project were selected and analysed as case studies. Each publication offers unique insights into the practical challenges and opportunities of applying future forecasting techniques within the entrepreneurial and educational ecosystems.

Bruno et al. (2024) suggest a training program on creativity and digital maturity. The DC4DM model was presented and applied in a real educational context - LLabs. The program was developed for both the academic context and the market, such as startups and incubators, to support digital entrepreneurship in the development of their ideas. Despite the small adjustments made, the program was considered replicable to different contexts, which allows strengthening the skills necessary for responsible innovation in a constantly evolving digital context. They suggest the implementation of this program in different realities in the labour market.

Ferreira et al. (2024) reflected on how to incorporate ethical considerations into the design of digital applications for health. They also sought to highlight the importance of thinking about how higher education curricula should

be aligned with the needs of the real market, startups and SMEs. They highlighted the role of DC4DM LLabs as a space for the exchange of knowledge between specialized startups and international student teams. They concluded that, even though several industries are already in the digitalization process, particularly the health industry, there are some barriers that must be overcome, namely the need to expand knowledge in the digital area. They found that programs such as DC4DM are important and make a great contribution to academia, so they recommend that the theoretical curricula of higher education institutions be aligned with practical applications.

Rana (2024) describes the Agile Future Creation (AFC) methodology, a novel innovation process designed to guide startups towards future-proof solutions. It's a future-proof approach that can help analyse changes in society to find signs. On the assumption that an external agent or facilitator is needed to contribute to the literacy of entrepreneurs, he considered that initial innovation workshops such as the one organized by DC4DM's LLabs can help develop the necessary knowledge.

Vezzani et al. (2023) sought to describe the DC4DM educational model and reflect on the experience of three test sessions, called DM Learning Labs, 10-days design-led workshops involving a great diversity of university students, diverse for country of origin and study background, start-ups, and several local mentors and stakeholders to co-design compelling future tech-scenarios. Seek to collect information on how to participate in the DM Learning LAB has impacted on the participants. Feedback from participants consistently underscores the benefits of a collaborative environment, instructor support, and opportunities for experimentation and exploration of emerging technologies.

The analysis of the outputs allowed us to understand the practical applicability of future projection approaches in SMEs and startups. The conclusions drawn are discussed in the following section, in the light of the literature reviewed and the results obtained.

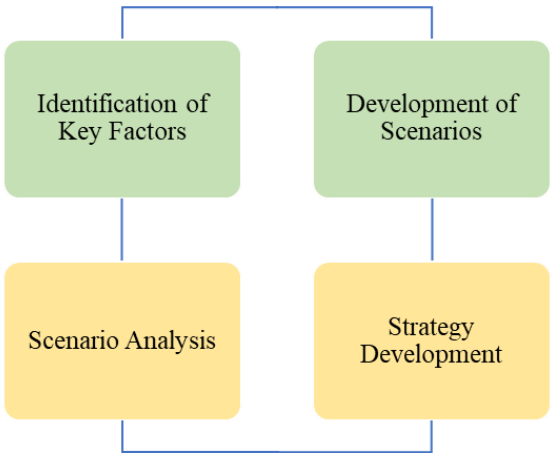
9. Conclusion, Theoretical and Practical Implications, Limitations and Future Research

To consolidate the concepts developed in the literature review and exemplify their practical application, this section analyses the main results obtained within the scope of the Design Competences for Digital Maturity (DC4DM) project. Through the synthesis of the outputs and good practices identified, it seeks to illustrate how future projection, and strategic thinking can be operationalized to strengthen the innovation capacity and resilience of SMEs and startups in contexts of high uncertainty.

In this paper, the importance of future prediction for SMEs and startups was explored, highlighting the need for a forecasting mindset and the use of future scenario projection techniques as vital to the survival of organizations. It was found that the concept of envisioning is fundamental to equipping startups and SMEs with the necessary skills to outline their future (Capatina et al., 2024). Planning for the future emerges as a strategic pillar for the entrepreneurial fabric. New methodologies (e.g. Magistretti et al., 2020) have been increasingly applied in combination with digital tools (e.g. Hokmabadi et al., 2024; Nweke, 2025), which enhances and amplifies strategic planning.

Future scenario projection was analysed as an analytical methodology that allows companies to anticipate and prepare for the challenges of uncertainty. In particular, at least four key steps were described: identification of key factors affecting the business, development of different scenarios, scenario analysis, and strategy development. These stages are visually represented in Figure 5 below.

Figure 5: Steps for future scenario projection.



Source: Authors.

The present research provides a practical and accessible framework for evaluating scenario projections. The practices of foresight and participatory design discussed, in line with recent literature (e.g., Abdelkarim et al., 2019; Bühring & Liedtka, 2018; Lehr et al., 2017), reinforce the thesis that the combination of critical thinking, scenario anticipation, and ethical sensitivity is essential to shape sustainable futures in the European entrepreneurial ecosystem.

In this context, the Design Competences for Digital Maturity (DC4DM) project emerges as a concrete example of how future literacy can be integrated into both educational and business environments. The analysed outputs demonstrate that methodologies such as foresight and envisioning not only empower students and professionals but also promote the creation of innovation-driven communities of practice within the entrepreneurial ecosystem (Bruno et al., 2024; Ferreira et al., 2024; Rana, 2024; Vezzani et al., 2023). The project also highlighted the importance of preparing SMEs for uncertain future contexts by promoting training in foresight and strategic envisioning. Scenario techniques allowed startups to visualize possible future trajectories and become more agile and resilient, as proposed in “Designing Future-Ready SMEs”.

From a theoretical perspective, this research contributes to bridging scenario-based design methodologies with entrepreneurial innovation practices—an intersection still underexplored in current foresight research. It extends understanding of how envisioning techniques, such as scenario prototyping and future artifacts, can enhance strategic adaptability in startups and SMEs. By integrating principles from strategic foresight and human-centred design into entrepreneurial education, the study offers a renewed conceptual lens for future-oriented skill development.

On a practical level, the findings offer tested methodologies for fostering collective envisioning processes. Initiatives such as the DC4DM Learning Labs illustrate how these techniques can be embedded in training programs to improve futures literacy and strategic planning. SMEs and startups can leverage these approaches to anticipate market shifts, technological disruptions, and societal changes—thereby improving their resilience and long-term viability. These contributions not only inform academic discourse but also serve as actionable strategies for entrepreneurs, educators, and policymakers aiming to future-proof the entrepreneurial ecosystem.

Still, important limitations remain. The analysis was focused on selected case studies, so generalizations to other contexts should be made with caution. Notwithstanding the valuable insights derived from the DC4DM project, it is important to acknowledge potential limitations. First, the analysis is grounded primarily in case studies from European contexts, many of which reflect design-led initiatives directly involving the project’s own partners. This raises the possibility of selection bias and limits the generalizability of findings to other geographic, economic, or cultural settings. Moreover, the insider perspective—while analytically enriching—requires careful reflection on interpretive subjectivity. These constraints reinforce the need for further empirical studies that test the

transferability of DC4DM-based methodologies in diverse entrepreneurial ecosystems, including those in underrepresented regions or sectors with different levels of digital maturity. In addition, the continuous evolution of emerging technologies imposes a permanent need to update the forecasting methodologies applied.

As directions for future research, it is recommended to carry out longitudinal empirical studies that evaluate the real impact of foresight and envisioning training on the competitiveness of SMEs. At the same time, it would be pertinent to explore the integration of artificial intelligence and machine learning tools (Nweke, 2025; Blake & Asghar, 2024) in supporting scenario projection, to expand the capacity for strategic anticipation in highly volatile environments.

In summary, preparing startups and SMEs for the challenges of the future implies a cultural transformation that goes beyond technological adoption. It is about cultivating a strategic, visionary, and ethically oriented mindset, as advocated in the DC4DM educational model and aligned with the emerging trends of sustainable innovation (Salamzadeh et al., 2022; Halima et al., 2022).

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Building player profiles for strategic analysis in higher education

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Abstract

This article is an original contribution to the development of analytical models applicable to higher education, focusing on the construction of player profiles based on strategic decisions in gamified contexts. The work falls within the field of educational gamification, proposing a conceptual and operational model to create an automated tool for identifying strategic player profiles, based on data collected through a structured questionnaire.

The proposal is based on the foundations of game theory, decision psychology and behavioural analysis, with the central objective of developing a methodology that allows players' strategic profiles to be drawn up in a personalised and automated way in simulated learning environments. The model classifies participants into four distinct profiles—competitive, cooperative, adaptive, and cautious—based on their behaviour when faced with strategic dilemmas.

As part of this article, a pilot test of the tool was conducted with a group of higher education students in the field of tourism, thereby validating the model in a real-world environment. The practical application demonstrated a high level of agreement between the profiles identified by the questionnaire and the behaviours observed later in simulated games, thereby reinforcing the reliability of the proposed methodology.

Based on these preliminary results, it can be concluded that the model is ready to be applied to broader and more diverse samples, including higher education institutions in other countries. Such an expansion will enable the model to be validated in various cultural and pedagogical contexts, thereby contributing to the consolidation of an innovative approach to diagnosing, personalising, and developing strategic skills in gamified educational environments.

Keywords: Education Simulations; Game Theory; Game-Based Learning; Gamification; Strategic Decision-Making.

1. Introduction

The use of simulations and games in higher education has taken on a central role in transforming traditional pedagogical practices. These interactive environments create realistic scenarios that promote active student engagement, enabling them to apply theoretical knowledge in dynamic and challenging contexts (Gee, 2003; Plass, Homer, & Kinzer, 2015). When applied in a structured manner, gamification fosters not only intrinsic motivation but also the development of transversal skills such as decision-making, uncertainty management, cooperation, and strategic thinking (Hamari et al., 2016).

At the same time, games and simulations serve a relevant analytical function by allowing for the automated collection of data during gameplay. This is made possible through mechanisms such as game telemetry and information trails, which enable the continuous and real-time recording of participants' actions, decisions, and behavioural patterns. These data, collected directly within digital environments, allow for a detailed analysis of the learning process, revealing trends associated with problem-solving, decision-making, and adaptation to complex contexts. In this way, games and simulations go beyond traditional approaches focused solely on

outcomes, offering a rich and dynamic view of students' performance progression over time (Loh, Sheng, & Ifenthaler, 2015).

In this context, the construction of player profiles emerges as a valuable tool for pedagogical diagnosis and personalisation. Through the analysis of in-game interactions—whether actions, choices, or strategies—it becomes possible to outline behavioural profiles that reflect cognitive traits such as impulsiveness, caution, adaptability, or social orientation. These profiles allow, on one hand, for the adaptation of pedagogical challenges to the student's style, promoting more effective learning; and on the other, provide the student with a mirror of their decision-making style, fostering self-awareness and metacognitive development (Loh & Li, 2016; Slater et al., 2022).

The relevance of this approach is particularly evident in fields such as tourism, management, economics, or international relations, where professional success involves decision-making under pressure, negotiation with multiple stakeholders, and adaptation to volatile contexts. For example, Yin (2020) demonstrates that a foreign investment negotiation simulation significantly enhances negotiation skills in international business courses; Kim and Prideaux (2006) use game theory to analyse how strategic decisions between South and North Korea, mediated through tourism, influence cooperation and conflict dynamics in the inter-Korean political context. Irrera (2021) demonstrates that simulations like Game of Peace enhance conflict resolution, while Sheng (2011) applies game theory to analyse sustainable competition between tourism destinations, showing that moderate strategies maximise regional benefits.

In sum, identifying player profiles based on gameplay data is not merely a classificatory exercise, but rather an integrative approach to pedagogical diagnosis, support for personalisation, and the development of skills crucial to today's professional world.

2. Literature Review

The identification of player profiles based on behavioural data has been increasingly employed in educational contexts to understand learning styles and enhance the effectiveness of pedagogical interventions. Various authors have contributed distinct methodological approaches, demonstrating the value of analysing decisions and interactions within games to delineate meaningful profiles.

Loh, Sheng, and Ifenthaler (2015) were pioneers in proposing the use of interaction data from educational games to distinguish behavioural profiles. By analysing navigation logs and decision-making patterns, they identified three main profiles:

- **Explorer**: a player who actively explores the game environment before making decisions;
- **Fulfiller**: a player focused on completing tasks and achieving defined goals;
- **Quitter**: a player who tends to abandon the game before completing it.

Their study showed that these profiles are associated with distinct learning patterns, with the Explorer profile demonstrating the highest performance in the cognitive tasks required by the game. The methodology combined similarity measures and sequential analysis of actions to differentiate patterns among players (Loh, Li, & Sheng, 2016).

Loh and Li (2016) further developed this approach by using what they termed GAD profiles (Gameplay Action-Decision) to prescribe individualised training paths in simulation environments. The study confirmed that associating behavioural profiles with personalised training strategies could significantly increase learning effectiveness and reduce training costs. For example, their work demonstrated that players with a Fulfiller profile benefit more from direct reinforcement and structured feedback, whereas Explorers learn better with autonomy and contextual exploration (Loh & Li, 2016).

Bicalho, Baffa, and Feijó (2019) applied data science methods to identify player profiles in gamified educational environments. Using K-means clustering algorithms and decision trees, the authors classified participants according to Bartle's classic model (1996), adapted to educational contexts:

- **Killers** (competitive),
- **Achievers** (goal-oriented),
- **Socialisers** (focused on interaction),
- **Explorers** (motivated by discovery).

The model achieved an accuracy rate of between 75% and 80% in predicting behaviours, revealing that the match between play style and task type directly affects engagement and academic outcomes (Bicalho, Baffa, & Feijó, 2019).

In turn, Mizrahi, Laufer, and Zuckerman (2020) focused on tacit coordination games, where players must align decisions without explicit communication. Through experimental testing, the authors identified cognitive-strategic profiles with a direct impact on the ability to predict others' actions. The study concluded that players with more flexible and cooperative styles were more successful in coordination tasks, highlighting the importance of individual strategic profiles in collective performance (Mizrahi, Laufer, & Zuckerman, 2020).

More recently, Slater et al. (2022) employed Latent Profile Analysis in a physics game to identify two main groups: high- and low-engagement players. These profiles effectively predicted learning outcomes, suggesting that behavioural engagement is a strong indicator for adapting educational support (Slater et al., 2022).

Aydin, Karal, and Nabiyev (2022) demonstrated, in a review of 26 studies, that effective educational games depend on the accurate identification of player profiles. The authors emphasised the use of neural networks and decision algorithms as key techniques for constructing these profiles, which have a direct impact on content adaptation and user experience (Aydin et al., 2022).

Lastly, Zare et al. (2022) confirmed, even in the context of artificial intelligence applied to competitive games (RoboCup), that anticipating opponents' decision-making patterns based on profiles significantly improves system performance. This conclusion reinforces the cross-disciplinary relevance of strategic profiling, even beyond educational contexts (Zare et al., 2022).

These contributions robustly demonstrate that establishing player profiles is crucial for understanding and predicting decision-making, informing pedagogical interventions, and tailoring game dynamics to diverse learning styles.

Recent literature has highlighted the importance of identifying player profiles as a means to understand and analyse decision-making processes in gamified educational environments. This approach enables the recognition of behavioural patterns, the adjustment of learning experiences, and the optimisation of student performance.

Loh, Sheng, and Ifenthaler (2015) proposed an analysis of players' interaction trajectories in digital environments, identifying three distinct profiles: Explorer, Fulfiller, and Quitter. These profiles reflect different cognitive styles, directly influencing engagement and performance. Later, Loh and Li (2018) developed the concept of GAD profiles (Gameplay Action-Decision) to prescribe personalised training, demonstrating that the prior identification of player profiles enables content adaptation, improved efficiency, and reduced intervention costs.

Bicalho, Baffa, and Feijó (2019) employed classification algorithms, including K-means and decision trees, to categorise players according to Bartle's model, demonstrating that behavioural data-based profile identification enhances the accuracy of behaviour and outcome predictions.

In a more recent study, Slater et al. (2022) applied Latent Profile Analysis to identify engagement profiles in an educational physics game, concluding that these profiles significantly predict post-game success. Aydin, Karal, and Nabiyev (2022) demonstrated, in a systematic review, that profile construction is essential for the

effectiveness of adaptive educational games, with data-driven approaches such as neural networks becoming increasingly common. In the context of competitive simulations involving artificial intelligence, Zare et al. (2022) confirmed that recognising decision-making patterns enables systems to improve their performance by anticipating adversarial behaviours.

Finally, Mizrahi, Laufer, and Zuckerman (2020) explored decision-making in tacit coordination games, finding that anticipatory capacity and behavioural flexibility are linked to the player's strategic profile, directly influencing group success.

These contributions consistently demonstrate that profiling not only aids in understanding player behaviour but also enables the personalisation of learning experiences, the adaptation of pedagogical strategies, and the anticipation of behaviours in simulated contexts.

3. Methodology

This study is based on the construction of a structured questionnaire designed to identify player profiles based on decision-making patterns in simulated contexts.

The aim of this exploratory and quantitative study, complemented by qualitative elements, is to build player profiles based on strategic decision-making patterns in gamified educational contexts. The methodology is based on the application of a structured questionnaire, developed on the theoretical basis of classic models of strategic decision-making and behaviour.

The survey's structure was developed using principles from game theory, decision psychology, and educational gamification, enabling the inference of participants' strategic characteristics.

The robustness of the methodology was enhanced through a methodological triangulation strategy encompassing three levels. First, theoretical triangulation was employed by deriving strategic parameters from multiple complementary theoretical frameworks, including game theory, cognitive psychology, and data science applied to games. Second, data source triangulation was implemented by integrating quantitative data—such as closed-ended responses and numerical scoring—with qualitative data, including participants' open-ended descriptions and self-assessments of decision-making style. Third, expert triangulation involved the participation of three independent academic specialists in the conceptual validation of the instrument, ensuring consistency across items, profiles, and strategic literacy constructs. This multilayered triangulation approach reinforces interpretative validity and mitigates biases typically associated with unidimensional or solely self-reported instruments.

The questionnaire consists of 12 questions, 11 of which are multiple-choice and one open-ended. Each question was carefully designed to explore one of the following strategic parameters:

- Orientation toward individual vs. collective gain
- Reaction to competition
- Tendency toward cooperation
- Risk aversion
- Value priorities (e.g., profit, reputation, loyalty)
- Previous experience with games/simulations
- Responsiveness to unexpected situations
- Self-declared competitiveness level
- Self-assessment of decision-making style

Each response was linked to one or more of four predefined profiles: Competitive, Cooperative, Adaptive, and Cautious, with scores attributed according to how well the implicit behaviour matched the traits of each profile.

Structure and Purpose of the Questions

- **Q4. How do you make decisions in competitive situations?** Assesses the tendency to maximise individual gains or seek balance. → Profiles: Competitive, Cooperative, Adaptive, Cautious.
- **Q5. If another player copies your strategy, you...?** Measures reactivity to others' behaviour. → Profiles: Competitive, Adaptive, Cooperative, Cautious.
- **Q6. How often are you willing to cooperate?** Assesses willingness to collaborate and interpersonal trust. → Profiles: Cooperative, Adaptive, Competitive, Cautious.
- **Q7. Do you prefer... (guaranteed vs. uncertain gain)** Measures risk aversion and decision-making style under uncertainty. → Profiles: Cautious, Competitive, Adaptive.
- **Q8. What do you value most as a decision-maker?** Reflects strategic priorities (profit, reputation, loyalty, growth). → Profiles: Cooperative, Competitive, Adaptive, Cautious.
- **Q9. Have you previously participated in simulations/games?** Assesses familiarity and openness to simulated environments. → Profiles: Competitive, Adaptive, Cooperative, Cautious.
- **Q10. How do you react to unexpected events?** Tests resilience, creativity, and planning. → Profiles: Cautious, Cooperative, Adaptive, Competitive.
- **Q11. Do you consider yourself a...?** Self-assessment of competitiveness level. → Profiles: Competitive, Adaptive, Cooperative, Cautious.
- **Q12. Describe your game strategy in a free-form sentence.** Captures strategic style nuances and confirms dominant profile.

The scoring logic was defined through a matrix: 2 points were awarded to the response most representative of a given profile, 1 point for ambivalent answers, and 0 points for non-aligned choices. The final profile is the one with the highest point total; hybrid profiles are allowed in cases of tied scores.

This methodology combines quantitative and qualitative analysis to identify strategic decision-making styles in educational game contexts. The use of games and simulations in higher education has proven effective in promoting skills such as critical thinking, problem-solving, and decision-making in realistic and engaging settings (Gee, 2003; Plass, Homer, & Kinzer, 2015). Quantitative analysis allows for objective classification of profiles based on response patterns. In contrast, qualitative analysis (via open-ended questions) complements the understanding with individual nuances of strategic style (Loh & Li, 2016).

The application of this methodology is especially relevant in fields such as management, tourism, and economics, where decision-making under pressure, adapting to dynamic contexts, and negotiating interests are key competencies (Aydin, Karal, & Nabiyev, 2022). By identifying students' profiles, educators can tailor pedagogical challenges to their preferred strategies, promoting more effective and personalised game-based learning experiences (Slater et al., 2022).

Strategic Profiles Assessed

Below are the four profiles defined based on participants' responses:

- **Competitive**. Focused on individual performance, the competitive player aims to maximise their gains, even at the expense of others' well-being. This profile tends to be impulsive, goal-oriented, and prefers dominance strategies and quick responses to challenges (Gee, 2003). It is effective in high-pressure environments but less so in cooperative games.
- **Cooperative.** This profile seeks balance and mutual benefit. The cooperative player values stable relationships, social reputation, and long-term collaboration. They act empathetically and tend to build sustainable solutions. In educational games, this player stands out for their preference for negotiation and teamwork (Slater et al., 2022).
- **Adaptive** represents the flexible player who can adjust their behaviour according to context and the actions of others. They adapt well to uncertainty and rapid changes, showing strategic versatility. Studies indicate that this profile performs well in complex and dynamic environments (Loh et al., 2016).

- **Cautious** Avoids risk and prefers stability. The cautious player seeks to gather as much information as possible before acting and makes decisions with time and consideration. This profile is suited for games with high cognitive demands and long-term planning (Aydin et al., 2022). While slower, it is reliable and consistent in strategy.

4. Evaluation Table and Profile Determination

To operationalise the classification of participants into player profiles, an evaluation table was constructed that cross-references each questionnaire item with the four defined strategic profiles: Competitive, Cooperative, Adaptive, and Cautious. Each question was designed to elicit a choice that reveals a relevant behavioural inclination. The correspondence between selected options and profiles is based on criteria derived from literature on decision-making and strategic behaviour (Loh et al., 2016; Bicalho et al., 2019; Aydin et al., 2022).

Table Structure The table includes the following columns:

- **Question**: formulation of the strategic scenario
- **Options A to D**: possible responses, each associated with one or more profiles and assigned a score

Each response option was coded as follows:

- **2 points**: if it strongly represents a specific profile;
- **1 point**: if it indicates traits shared between two profiles;
- **0 points**: if it does not represent any dominant profile.

The total score accumulated for each profile throughout the questionnaire allows the calculation of the participant's final profile score. The dominant profile is the one with the highest cumulative score.

Example of Application: Assume a student selects the following answers:

- Q4: c) → Adaptive (2 pts)
- Q5: b) → Adaptive (2 pts)
- Q6: b) → Cooperative (1 pt), Adaptive (1 pt)
- Q7: c) → Adaptive (2 pts)
- Q8: c) → Adaptive (2 pts)
- Q9: b) → Adaptive (2 pts)
- Q10: c) → Competitive (1 pt), Adaptive (1 pt)
- Q11: b) → Adaptive (2 pts)

In this case, the Adaptive profile totals **13 points**, becoming the dominant profile.

Final Profile and Feedback. The dominant profile is automatically recorded in a spreadsheet, where each row corresponds to a respondent. A script developed using **Google Apps Script** calculates the totals, classifies the profile, and sends a personalised email to the participant with:

- The name of the identified profile;
- A brief description of the corresponding strategic style;
- Suggestions on how that style may influence decisions in professional contexts (such as tourism, management, economics).

This approach ensures an objective analysis and provides immediate formative feedback, which is essential for developing students' metacognitive competencies (Plass et al., 2015; Slater et al., 2022).

Table 1: Player profile evaluation table based on the questionnaire.

Question	Option A	Option B	Option C	Option D
Q4: How do you make decisions in competitive situations?	Competitive (2 pts)	Cooperative (2 pts)	Adaptive (2 pts)	Cautious (2 pts)
Q5: If another player copies your strategy, you...?	Competitive (2 pts)	Adaptive (2 pts)	Cooperative (2 pts)	Cautious (2 pts)
Q6: How often do you cooperate with competitors?	Cooperative (2 pts)	Cooperative (1 pt), Adaptive (1 pt)	Competitive (1 pt), Cautious (1 pt)	Competitive (2 pts)
Q7: You prefer...	Cautious (2 pts)	Competitive (2 pts)	Adaptive (2 pts)	Cautious (2 pts)
Q8: What do you value most?	Cooperative (2 pts)	Competitive (2 pts)	Adaptive (2 pts)	Cautious (2 pts)
Q9: Have you participated in games or simulations before?	Competitive (2 pts)	Adaptive (2 pts)	Cooperative (2 pts)	Cautious (2 pts)
Q10: If something unexpected happens, you...	Cautious (2 pts)	Cooperative (2 pts)	Competitive (1 pt), Adaptive (1 pt)	Cautious (2 pts)
Q11: You consider yourself a...	Competitive (2 pts)	Adaptive (2 pts)	Cooperative (2 pts)	Cautious (2 pts)

The system was implemented within the **Google Workspace environment**, utilising automated data collection via Google Forms, automatic calculation in Google Sheets, and personalised result delivery through **Google Apps Script**. This process ensures **scalability**, **personalisation**, and **data confidentiality** in compliance with **GDPR**.

Defined Profiles

Based on questionnaire responses and the behavioural evaluation matrix, four strategic profiles were defined to reflect distinct approaches to decision-making in game, simulation, and gamified educational contexts. These profiles are inspired by models from cognitive psychology, game theory, and strategic behaviour studies (Plass et al., 2015; Mizrahi et al., 2020; Loh & Li, 2018).

Competitive

This profile is centred on individual performance, with a strong drive to win and achieve maximum results, even at the expense of others. This player tends to adopt dominance strategies, exploit opponents' weaknesses, and respond quickly to challenges. Motivated by measurable goals such as profit, scores, or recognition, competitive players exhibit a lower tolerance for cooperation that does not yield clear personal benefits. This profile is standard in high-pressure environments such as corporate or market management. According to Gee (2003), competitive players tend to thrive in contexts with clear rules and direct rewards, but may be less effective in group dynamics that require negotiation or empathy.

Cooperative

This player values a balance between personal and collective interests. Cooperative profiles emphasise building sustainable relationships, fostering mutual trust, and maintaining a good reputation. They seek win-win solutions, even if it means sacrificing short-term gains for long-term stability or group harmony. Studies, such as those by Slater et al. (2022), show that cooperative players are often associated with participatory and collaborative learning environments where social interaction enhances learning. They perform well in simulations where trust, negotiation, and interdependence are essential to achieving shared goals.

Adaptive

The adaptive player is strategically flexible, adjusting decisions based on the behaviour of others and changing contextual conditions. Rather than following a rigid playstyle, this player responds situationally, striking a balance between risk and opportunity. They are particularly effective in games with high variability or unpredictability, where reading the environment and recalibrating strategies is critical (Loh et al., 2016). Pedagogically, adaptive profiles excel in multivariable scenarios, making informed decisions even under ambiguous or rapidly changing conditions (Plass et al., 2015).

Cautious

This profile is characterised by high risk aversion, a preference for safety, and a strong need to gather information before taking action. Cautious players tend to take longer to decide but are more consistent and coherent in their strategies. They are susceptible to uncertainty and prefer scenarios where they can plan, test hypotheses, and retain control. According to Aydin et al. (2022), this profile performs well in games with clear instructional support, step-by-step simulations, or structured feedback systems. While less proactive in direct competition, cautious players are valuable in risk management, strategic analysis, and planning environments.

5. Results

Responses were collected from second-year Management students to a survey on decision-making styles in competitive contexts. The variables analysed included age, frequency of cooperation, preference for types of gains, reaction to unexpected events, self-assessment of competitiveness, and other behavioural indicators. The sample was distributed across four final profiles: Adaptive, Cautious, Competitive, and Cooperative (see Table 2).

Table 2: Modal values by profile.

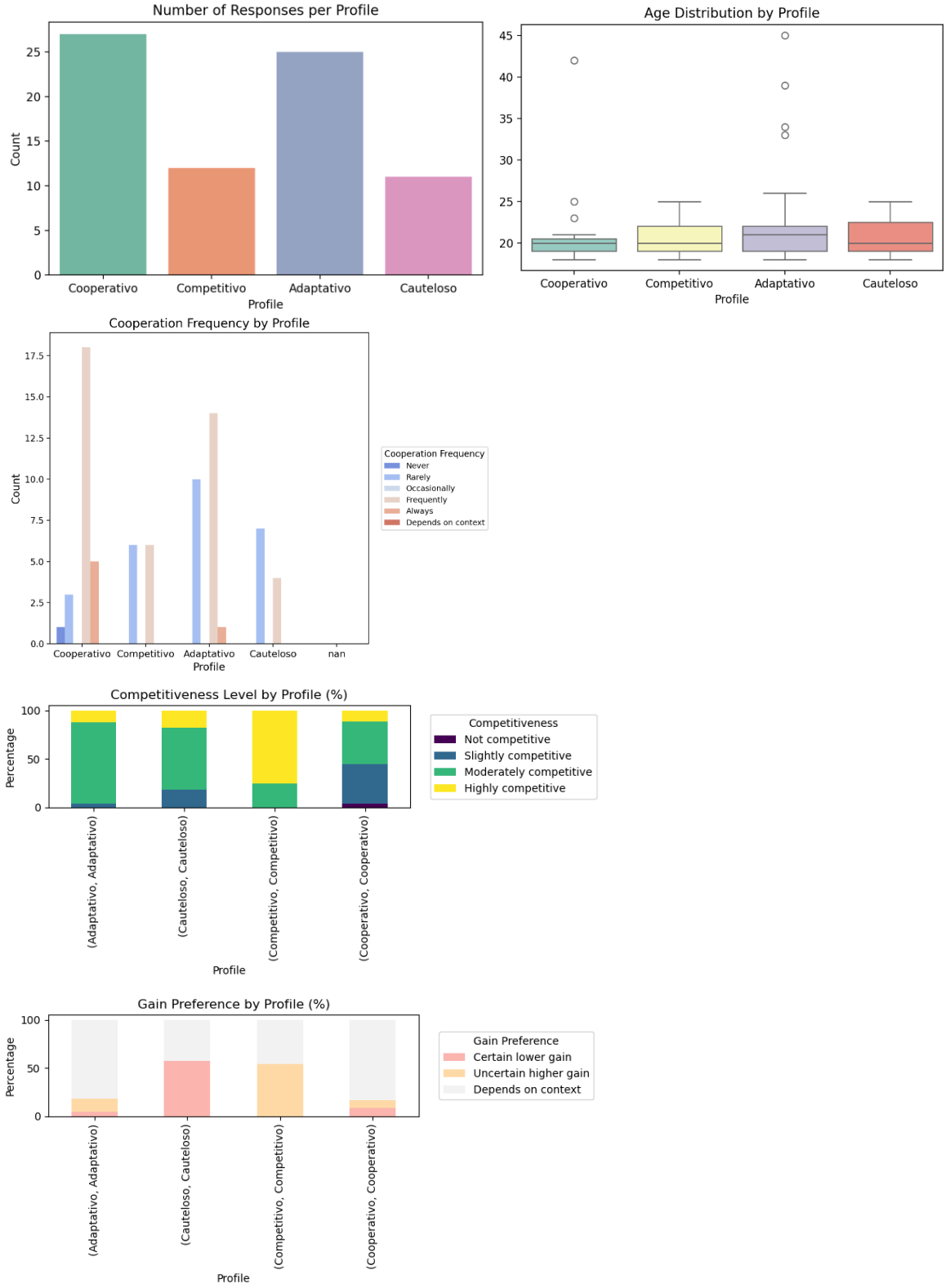
Profile	Adaptive	Cautious	Competitive	Cooperative
Course:	Management	Management	Management	Management
Year of attendance:	2nd year	2nd year	2nd year	2nd year
Do you currently work?	I don't work at the moment	I don't work at the moment	I don't work at the moment	I don't work at the moment
Age:	19	19	19	20
How do you make decisions in competitive situations?	b) I try to find win-win solutions.	b) I try to find win-win solutions.	b) I try to find win-win solutions.	b) I try to find win-win solutions.
If another player or agent copies your strategy, you...	b) I try to differentiate my approach.	b) I try to differentiate my approach.	a) Counterattack with more force.	b) I try to differentiate my approach.
How often are you willing to cooperate with competitors or opponents?	Frequently	Rarely	Frequently	Frequently
Prefer...	c) It depends on the context.	a) A lower guaranteed win.	b) An uncertain but potentially higher gain.	c) It depends on the context.
What do you value most in decision-making?	Long-term growth	Long-term growth	Immediate profit or gain	Long-term growth
Have you participated in simulations, strategic games or group dynamics?	yes, once or twice	No, but I'd like to try it	Yes, several times	No, but I'd like to try it
If an unexpected event arises (e.g. crisis, unforeseen event), you...	b) You evaluate the impact and adjust calmly.	a) You always have an alternative plan.	b) You evaluate the impact and adjust calmly.	b) You evaluate the impact and adjust calmly.
You consider yourself a person...	Moderately competitive	Moderately competitive	Very competitive	Moderately competitive

Simple Summary of Profiles

- **Adaptive** — Frequently cooperates, adjusts to context, displays moderate competitiveness, prefers long-term growth.
- **Cautious** — Rarely cooperates, seeks guaranteed gains and security, shows moderate competitiveness, maintains backup plans.
- **Competitive** — Highly competitive, seeks quick profit and uncertain gains, reacts with counterattacks, cooperates in a confrontational setting.
- **Cooperative** — Frequently cooperates, focuses on long-term goals and balance, responds with "it depends on the context," shows moderate competitiveness, handles unexpected events calmly.

These four lines capture the key traits that distinguish each profile.

Figure 1: Visualisation panel.



Legend: (a) Profile distribution, (b) Age, (c) Cooperation frequency, (d) Competitiveness level, (e) Gain preference.

Main Results

1. **Sample Size** The distribution of respondents (Figure 1-a) shows a slight predominance of the **Cooperative** profile, followed by **the Competitive profile; the Adaptive** and **Cautious** profiles appear less frequently and at similar levels. This asymmetry suggests a greater affinity among students for collaborative approaches.
2. **Age** The box plot (Figure 1-b) highlights a narrow age range (19–20 years). The **Cooperative** profile presents a slightly higher median, indicating that increased maturity may favour more consensus-oriented attitudes.
3. **Frequency of Cooperation** Figure 1-c reveals a clear divide:
    - **Competitive** and **Adaptive** profiles report "frequent" **cooperation**;
    - **Cooperative** respondents split between "frequent" **and** "depends on the context";
    - **Cautious** individuals mainly selected "rarely." This suggests that the propensity to collaborate correlates with risk tolerance and the time horizon for expected returns.
4. **Self-Assessment of Competitiveness** As shown in Figure 1-d, three profiles cluster around “moderately competitive,” while the **Competitive** profile stands out with “very competitive.” This aligns with their preference for immediate gains and counterattack responses when their strategies are copied.
5. **Gain Preference** Figure 1-e reinforces the divergence in risk management:
    - **Cautious** players prioritise guaranteed gains;
    - **Competitive** players prefer uncertain and high rewards;
    - **Adaptive** and **Cooperative** profiles adopt a more contextual approach (“depends on the context”).

Interpretation and Implications

- **Adaptive** — Motivated by joint maximisation and flexibility, demonstrates high cooperation and remains calm in the face of uncertainty. Ideal for teams that require quick adaptation without compromising relationships.

- **Cautious** — Oriented toward safety and stability; cooperates infrequently and prefers certain gains. Valuable in projects requiring risk control, though excessive prudence may hinder innovation.

- **Competitive** — Results-driven and aggressive in competitive scenarios, accepts high risk. Well-suited to dynamic markets where speed and short-term advantage are key, though it may jeopardise long-term alliances.

- **Cooperative** — Prioritises mutual benefits and long-term goals, frequently cooperates, and manages crises with composure. Suited for collaborative projects, building social capital and sustainability, though material gains may take longer to achieve.

The four profiles share a common academic background and a general preference for win-win strategies, but diverge significantly in terms of risk appetite, competitive intensity, and reward timelines. These differences should be taken into account when composing teams, designing incentive structures, and developing simulation games in both academic and corporate settings.

Study limitations

This study is acknowledged to be in an exploratory validation phase. The sample is small and homogeneous, and no formal psychometric analyses have been conducted at this stage. Nevertheless, the application of methodological triangulation ensures internal coherence and a sound theoretical foundation. In a subsequent phase, the model is expected to be applied to multicultural samples, incorporating confirmatory factor analysis, cross-validation procedures, and statistical calibration of the identified profiles.

6. Conclusion

This article represents an original contribution to the development of a model for constructing player profiles based on strategic decision-making, applicable to the context of higher education. The main outcome of this work was the design of an automated tool that, through a structured questionnaire, identifies strategic decision-making styles in gamified learning environments.

The proposed methodology combines principles from game theory, decision psychology, and educational gamification, resulting in an innovative behavioural diagnostic instrument with strong pedagogical potential. The tool offers a systematic approach to personalised learning, allowing educational challenges to be tailored to each student's strategic profile while fostering metacognitive development.

Given the conceptual and technical soundness of the model, the conditions are in place for its large-scale application across diverse institutional contexts, including universities in other countries. Such expansion will enable validation across varied cultural and educational settings, contributing to the advancement of more learner-centred and data-informed teaching practices.

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