LEONARDO

WHITE PAPER

Human-centric factories

Shaping the future of industrial engineering
and management education

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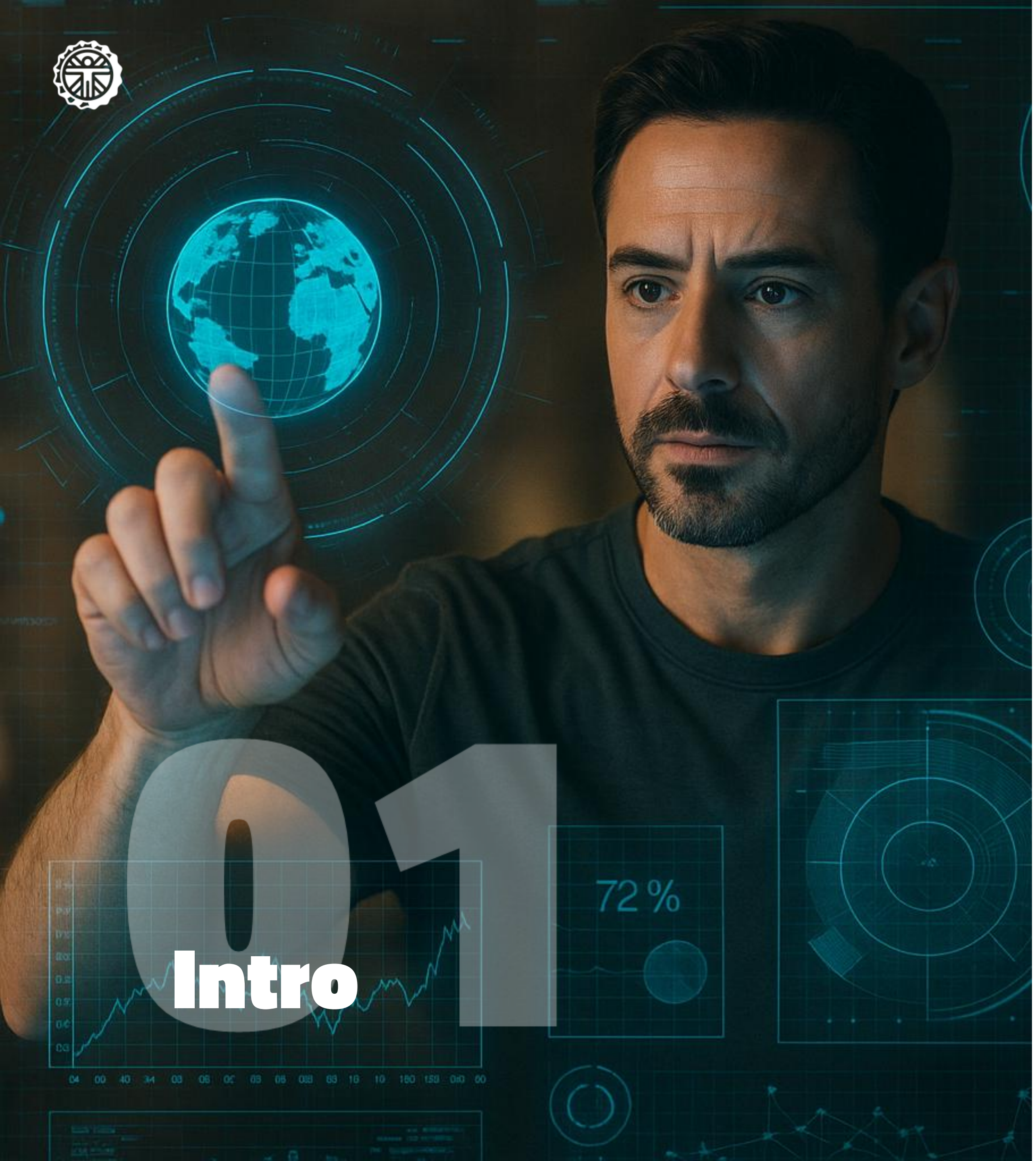


01 Intro

The industrial world is undergoing a profound metamorphosis. We have moved beyond the era of the factories depicted in Modern Times, where Charlie Chaplin is literally swallowed by the machinery of mass production. And yet, the satirical force of that film remains strikingly relevant. Today's workplaces still raise the same essential question: What is the role of the human being in a world increasingly shaped by automation, artificial intelligence, and digital systems?

This is where the vision of **Industry 5.0** marks a paradigm shift. Rather than displacing humans, it calls for a renewed **alliance between human intelligence and technological power**. Industry 5.0 values not only efficiency and automation, but also creativity, ethics, empathy, and critical thinking – the distinctly human qualities that machines cannot replicate (or not yet).

The **engineer of tomorrow** must be more than a technical expert. They must be a systems thinker, an ethical decision-maker, and an orchestrator of collaboration – between humans, intelligent machines, and digital platforms. They must be equipped not only to optimize processes, but to **understand the broader social and organizational implications of technology**, ensuring that innovation serves people, not the other way around.

As digital transformation continues to redefine production, logistics, and decision-making, the education system – especially in university-level engineering and management programs – must evolve with equal urgency. Traditional models of education are no longer sufficient. We need learning environments that prepare students to **navigate complex socio-technical systems**.

In an age where **asynchronous digital education platforms** are proliferating, traditional universities remain essential by offering something irreplaceable: presence, collaboration, and embodied experience. It is in classrooms, labs, and project teams that students learn to work together, apply concepts to real-world problems, and develop the soft skills—like leadership, empathy, and ethical judgment—that are indispensable for tomorrow's industrial leaders. Universities must therefore be seen not just as educational institutions, but as catalysts of change, shaping a generation of professionals ready to guide industries toward an **industrial humanism** and a **harmonic innovation**.

Yet this transformation must also be seen through a geopolitical and demographic lens. **Peripheral universities**, particularly in regions facing youth outmigration and population aging, are at a crossroads. As major metropolitan centers and online education platforms draw students away, these institutions must reinvent themselves to attract and retain talent. The future of such regions depends on their ability to offer high-quality, future-ready education that is both rooted in local needs and connected to global innovation trends. Attracting bright, motivated students to these institutions is not only a matter of academic competitiveness—it is a strategic imperative for social cohesion, regional development, and industrial renewal. By creating cutting-edge programs that blend digital innovation with human values, universities—especially those outside major urban centers—can become anchors of opportunity, reversing brain drain and cultivating the next generation of leaders, creators, and changemakers.

And yet, while industry moves fast, universities often lag behind. The gap between academic offerings and the real demands of the labor market continues to grow. Many programs remain tied to **outdated structures**, overloaded with theory, and slow to adapt. In a world that rewards agility and interdisciplinary thinking, the educational system often behaves like a giant machine—slow to turn and difficult to adapt. This rigidity is due to multiple factors: the entrenchment of academic silos, resistance to change among faculty, and bureaucratic hurdles that make updating curricula or introducing new teaching methods painfully slow. In today's culture of performance metrics and standardized assessments, students are rarely given permission to experiment, make mistakes, and learn through failure. Yet these are precisely the conditions where resilience, creativity, and innovation take root. Universities must reimagine themselves—not as factories of credentials, but as **living laboratories** where students grow through challenge, experimentation, and reflection.

02 Towards a smart, resilient and sustainable workforce

The world of manufacturing is no longer defined solely by output, efficiency, and cost reduction. Instead, the factories of today – and especially those of tomorrow – must be smart, resilient, and sustainable. These three pillars represent the **new foundation of industrial competitiveness and social responsibility**. But achieving this vision depends on the capabilities of the people inside those factories. This is why the next generation of engineers must not only design and manage advanced technologies—they must also understand the **evolving nature of the workforce** itself.

McKinsey & Company (2024, December). Developing a resilient, adaptable workforce for an uncertain future. Online article available at: https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/developing-a-resilient-adaptable-workforce-for-an-uncertain-future

According to the World Economic Forum's Future of Jobs Report 2025, the most critical skills for the future go beyond coding or machine learning. They include **analytical thinking**, **leadership and social influence**, **creative thinking**, **motivation and self-awareness**, **technological literacy**, **empathy and active listening**. These are the pillars for training future managers and engineers who can assess not just how to implement new technologies, but whether they should – and how they can do so in ways that support people, not marginalize them. **Ethical judgment**, **social awareness**, and **emotional intelligence** are just as essential as technical expertise.

World Economic Forum (2025, January). The Future of Jobs Report 2025. Available at: https://www.weforum.org/publications/the-future-of-jobs-report-2025/

The engineers and managers we educate today must not only master advanced tools – they must understand how to shape the future of work:

- A **smart workforce** is one that works in harmony with digital technologies. These are workers equipped to collaborate with AI, data systems, and automation tools –not to be replaced by them, but to be empowered by them. Smart workers are mutually learning with AI, digitally literate, and agile in using information to make better decisions.
- A **resilient workforce** is capable of adapting to disruption – whether due to pandemics, supply chain shocks, technological change, or global crises. Resilience involves not just technical flexibility but emotional intelligence, collaboration, and problem-solving under pressure.
- A **sustainable workforce** refers to both human sustainability (well-being, inclusion, work-life balance) and environmental responsibility. This means building a culture that values people, supports long-term growth, and contributes to responsible human-centered transformation.

In short, the factories of the future will only be as intelligent, adaptive, and humane as the people who design and manage them.

And it begins in the classroom—where we must teach not just what engineers *can* do, but what they *should* do.

Preparing engineers for this responsibility means breaking down the barriers between technical and human knowledge.

Designing smart, resilient, and sustainable systems requires more than engineering – it demands an understanding of how technology, people, and organizations interact in complex, often unpredictable ways. Future engineers must be equipped not only with skills in math, physics, and computing, but also with insights from social sciences, psychology, ethics, and organizational studies. Understanding how people think, work, and relate is just as important as knowing how machines function.

We must move beyond the outdated view of engineers as purely technical experts. They must become **translators of human values** into operational solutions—professionals who build systems that reflect both technological excellence and social responsibility.

Ambrogio, G., Filice, L., Longo, F., & Padovano, A. (2022). Workforce and supply chain disruption as a digital and technological innovation opportunity for resilient manufacturing systems in the COVID-19 pandemic. Computers & Industrial Engineering, 169, 108158.

Longo, F., Padovano, A., & Umbrello, S. (2020). Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future. Applied Sciences, 10(12), 4182.

03 Human-centricity pillars

As observed in many cases globally, excessive automation does not always lead to better outcomes. While technology has transformed industry, removing the human touch entirely can create new problems – ranging from reduced flexibility and innovation to a loss of worker engagement and trust. According to the European Commission, human-centricity is founded on four core principles: **prioritizing human welfare**, **technology serving humanity**, **upholding human rights**, and **ethical integration of technology**. These principles are already transforming the job positions industrial engineers, managers and analysts. This doesn't mean rejecting technology, but rather ensuring that **innovation serves people** – not the other way around. In this framework, human agency is preserved, skills development is prioritized, diversity and inclusion are promoted, health and safety are protected, and workers are directly involved in shaping the technologies they use.

European Commission: Directorate-General for Research and Innovation, ERA industrial technologies roadmap on human-centric research and innovation for the manufacturing sector, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/0266

In practice, these principles are not just theoretical ideals. For **large companies**, adopting a human-centric approach helps ensure compliance with EU regulations, supports workforce engagement, and enhances reputation. It also positions them well for funding opportunities and sustainability goals. For **SMEs**, the benefits are equally tangible. Engaging employees in digital transformation reduces resistance to change, makes implementations more effective, and ensures that innovations align with the company's real-world needs. Moreover, EU programs increasingly support SMEs that prioritize human-centric innovation.

Next-generation IEM students demand an education that equips them with these necessary competencies to align their skills with the evolving needs of the job market and these principles. This white paper provides a set of themes for targeted education and training within three pillars: **empowerment and inclusivity**, **empathetic and social workplaces**, **ethical and responsible engineering of assistive technologies**.

Empowerment and inclusivity

Individuals are now enabled (with or without aid of technology) to make informed decisions, operate systems and develop the skills and confidence to pursue their goals. All individuals, regardless of their background, identity or abilities, have equal access to opportunities, resources and participation within the industrial setting.

Augmenting technologies for assisted work

Augmenting technologies empower workers by enhancing their physical, cognitive, and sensory capabilities. In smart factories, tools like exoskeletons, AR interfaces, and AI-driven assistants support tasks that are repetitive, complex, or physically demanding – promoting efficiency, safety, and inclusivity while ensuring humans remain central to industrial processes.

Inclusivity and diversity in production systems

Today's workforce is significantly changing—it is more diverse, increasingly aged, and equipped with varied skillsets. Inclusivity in production systems means designing environments that adapt to these shifts. By embracing universal design and assistive technologies, smart factories can ensure all workers, regardless of age, background, or ability, can contribute effectively.

Anthropometry, biomechanics, ergonomics and usability engineering

Integrating anthropometric data, biomechanical modeling, and usability engineering into production system design enables task optimization, reduces musculoskeletal risk, and boosts worker efficiency. Ergonomically engineered workstations and interfaces not only minimize injury-related downtime but also enhance precision and throughput – delivering measurable ROI through improved performance, safety compliance, and workforce satisfaction.

Lifelong learning and skills development

Continuous skills development is essential as industrial roles evolve with digitalization and automation. Implementing structured lifelong learning programs – through AR/VR training, upskilling platforms, and human-machine interaction modules – enables a future-ready workforce. This not only reduces skill gaps and turnover but also enhances adaptability, innovation capacity, and long-term operational resilience.

Remote working (or work at a distance)

Remote working in industrial settings leverages IoT, digital twins, and XR technologies to enable supervision, diagnostics, and collaboration from afar. This flexibility reduces travel costs, ensures business continuity, and expands access to specialized talent – supporting agile operations and resilient production models in increasingly decentralized manufacturing ecosystems.

Empathetic and social workplaces

Organizations are challenged to create a supportive work environment where employees feel valued, understood and connected to one another. Moreover, as humans work alongside machines and AI systems in future factories, promoting social and empathetic interaction (H2H, H2M and M2M) becomes vital for effective collaboration, mutual learning and understanding, and building human-centric workplaces.

Social engineering design at the workplace

Social engineering design in the workplace focuses on structuring environments that foster collaboration, trust, and inclusive behavior. By applying principles from organizational psychology and human factors engineering, companies can optimize team dynamics, reduce conflict, and enhance worker engagement—driving productivity, innovation, and retention in high-performance industrial settings.

Generative AI and human-AI collaboration

Generative AI enables real-time design, decision support, and content creation, augmenting human capabilities in industrial contexts. Human-AI collaboration streamlines complex problem-solving, enhances creativity, and accelerates innovation cycles. By embedding explainable and user-aligned AI systems, organizations can boost productivity while maintaining human oversight, accountability, and strategic control.

Emotional intelligence and empathy-driven AI system

Empathy-driven AI systems equipped with emotional intelligence capabilities enhance human-machine interaction by recognizing and responding to users' emotional states. In industrial settings, this fosters better user experience, reduces cognitive strain, and supports mental well-being—driving engagement, safety, and acceptance of automation in increasingly human-centric production environments.

Adaptive and intuitive human-robot interaction

Adaptive and intuitive human-robot interaction enables seamless collaboration by aligning robotic behavior with human intent and context. Leveraging real-time perception, learning algorithms, and multimodal interfaces, these systems minimize training time, reduce errors, and improve safety—driving operational efficiency and user acceptance in dynamic, human-centric manufacturing environments.

Social sustainability and social leadership

Social sustainability and leadership involve fostering inclusive, fair, and resilient workplace cultures. By prioritizing worker well-being, equity, and participatory governance, organizations build trust and long-term value. Strong social leadership drives engagement, reduces turnover, and aligns industrial performance with ESG goals, enhancing both reputation and operational sustainability.

Ethical and responsible engineering of assistive technologies

Technology engineers must commit to uphold fundamental human rights, values and dignity of users and stakeholders, prioritize transparency and accountability, while also considering the broader societal implications of technology innovation, including sustainability and environmental impacts.

Ethical and human-centered AI

Ethical and human-centered AI prioritizes transparency, accountability, and fairness in algorithmic decision-making. In industrial contexts, it ensures AI systems respect human rights, avoid bias, and maintain user trust. Embedding ethical principles from design to deployment enhances compliance, social acceptance, and the long-term sustainability of AI-driven operations.

Ethical audits, risk assessments

Human augmentation technologies—such as wearables, neurointerfaces, and exoskeletons—raise complex ethical questions around autonomy, consent, and equity. Responsible adoption requires clear governance frameworks to balance performance gains with workers' rights, ensuring enhancements are supportive, voluntary, and aligned with individual dignity and long-term social well-being.

Well-being and work-life balance

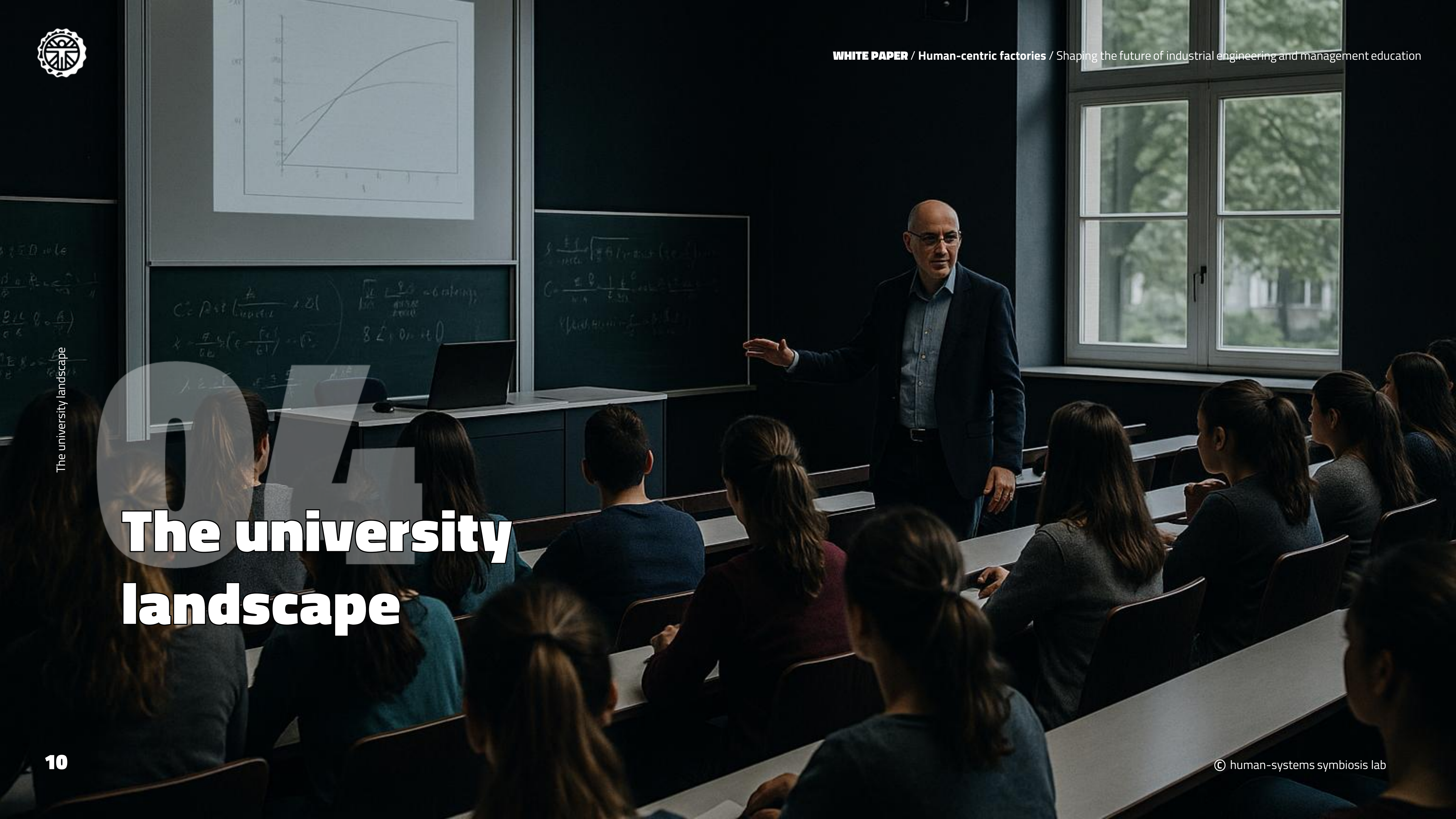
Promoting well-being and work-life balance in industrial environments enhances employee retention, productivity, and resilience. By integrating flexible scheduling, supportive digital tools, and health-oriented workplace design, organizations foster sustainable performance. Prioritizing mental health and work-life integration is not just ethical – it's a strategic imperative for long-term operational success.

Ethical governance and technology regulation, fairness and accountability

Ethical governance ensures that emerging technologies in industry operate transparently, fairly, and within regulatory bounds. Establishing clear accountability structures, inclusive decision-making, and compliance with frameworks like the EU AI Act helps organizations mitigate risk, build trust, and align innovation with societal values and legal responsibilities.

Ethical technology design for values

Ethical technology design embeds human values – such as autonomy, dignity, and justice – into the development process from the outset. In industrial settings, this approach ensures that digital systems align with societal expectations, user needs, and ethical norms, fostering trust, long-term adoption, and responsible innovation across production ecosystems.

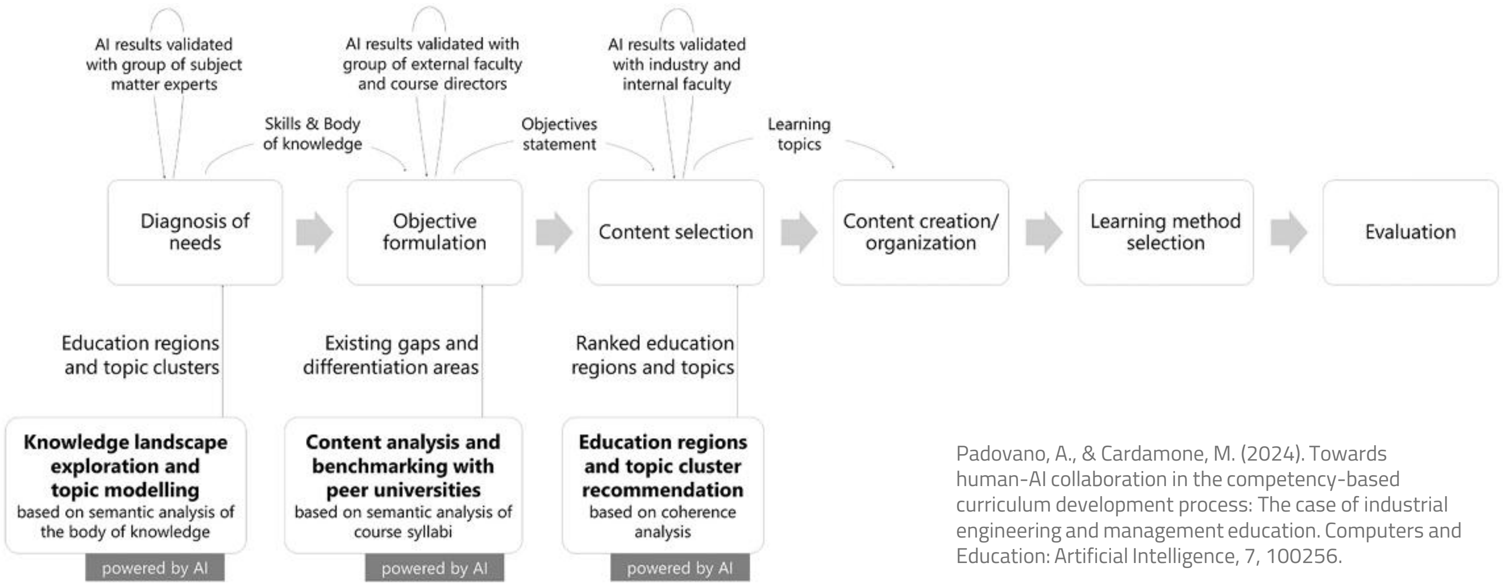


04 The university landscape

Artificial intelligence as a change-maker for adaptive, ethical, and strategic curriculum design in education.

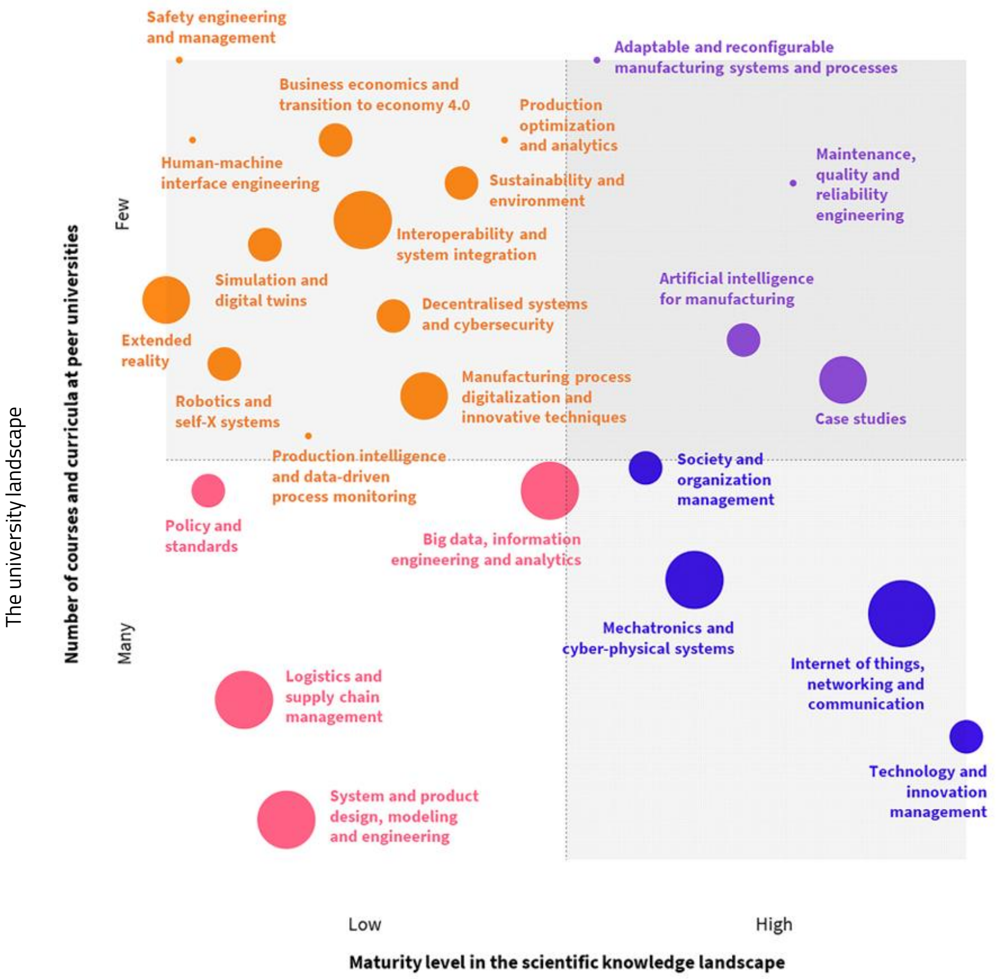
Universities face unique challenges in attracting students, particularly amid **demographic decline** and **global competition**. Research suggests that **curriculum relevance and differentiation play a pivotal role in student decision-making**—often more than the reputation of individual degree programs. For these institutions, **AI-supported curriculum design** offers a strategic advantage. It enables smaller universities to diversify their academic portfolio, tailor offerings to local industry needs, and reduce duplication with national curricula – thereby enhancing their comparative attractiveness.

The methodology illustrated below becomes strategic for institutions with limited staff capacity. It allows them to conduct comprehensive curricular analyses, benchmark against evolving industry standards, and position their programs strategically within the higher education landscape. In doing so, they can bridge the academic-industry skills gap while reinforcing their regional relevance and appeal. AI and data-driven approaches offer substantial advantages over traditional expert-only methods in designing curricula for rapidly evolving domains such as the "industry of the future". By leveraging **natural language processing**, **machine learning**, and **semantic analysis**, AI provides a scalable and systematic means to process large volumes of heterogeneous data—including academic literature, course syllabi, and project outcomes (e.g., from Erasmus+). This enables **comprehensive mapping of the knowledge landscape** that would be infeasible for human experts alone.



Padovano, A., & Cardamone, M. (2024). Towards human-AI collaboration in the competency-based curriculum development process: The case of industrial engineering and management education. Computers and Education: Artificial Intelligence, 7, 100256.

The university landscape



Padovano, A., & Cardamone, M. (2024). Towards human-AI collaboration in the competency-based curriculum development process: The case of industrial engineering and management education. Computers and Education: Artificial Intelligence, 7, 100256.

The quadrant-based matrix appeared in a recent scientific study outlines four strategic approaches for curriculum development in emerging industrial education:

- **Quadrant I – Innovate and Pioneer (Low maturity, Few courses)** features emerging topics with low scientific maturity and limited existing courses. This quadrant invites bold, innovative curriculum design to address underdeveloped areas such as interoperability, simulation and digital twins, extended reality, and decentralized systems. It holds the highest number of topics, highlighting the need for foundational educational content.
- **Quadrant II – Specialize and Develop (High maturity, Few courses)** includes scientifically mature topics that remain underrepresented in curricula. These areas, such as AI in manufacturing, adaptable systems, and reliability engineering, offer strong potential for advanced and specialized courses.
- **Quadrant III – Monitor and Expand (High maturity, Many courses)** contains mature fields with well-established educational coverage, including IoT, cyber-physical systems, and innovation management. The focus here is on updating and enriching existing curricula with the latest developments.
- **Quadrant IV – Explore and Enhance (Low maturity, Many courses)** covers relatively new yet already popular topics like big data, system design, and supply chain management. The strategy involves monitoring trends and enhancing current offerings to meet demand.

Quadrants I and II are prime areas for curriculum innovation, while Quadrant III supports continuous improvement. Quadrant IV, despite high course presence, may require less focus unless unmet educational needs are identified.


© human-systems symbiosis lab

The **integration of AI into competency-based education (CBE)** represents a shift toward more adaptive and continuously evolving curricula. Findings confirm that AI acts as an excellent "***curriculum design assistant***" capable of analyzing multimodal data and recommending optimal learning content based on real-world trends and academic standards.

However, overreliance on AI risks overlooking contextual, cultural, or pedagogical nuances that only human educators can provide. Therefore, a **human-AI collaborative model** is essential – where AI delivers data-driven insights, and educators provide critical interpretation, ethical oversight, and value alignment.

> **Move beyond disciplinary boundaries and embrace interdisciplinary curriculum design and hybrid educational pathways**

The effective integration of AI tools requires not only technical alignment but also **pedagogical and institutional readiness** – including a shift toward interdisciplinary education models. As AI systems increasingly influence what and how we teach, it becomes clear that curriculum development cannot remain confined within traditional disciplinary boundaries. Instead, the design of future-oriented, competency-based programs must bring together diverse fields—merging technical expertise in areas like industrial engineering and management with insights from the social sciences, ethics, and human-centered design.

This interdisciplinary approach is key to equipping students with the skills and sensibilities needed to thrive in AI-mediated, socio-technical systems. In doing so, universities can better align their offerings with the demands of future industries and contribute more effectively to **socially sustainable and inclusive digital transformation**.

05

The evolution of learning in the era of AI

In today's rapidly shifting technological landscape, artificial intelligence is not just enhancing learning—it is fundamentally transforming it. From content creation and personalized tutoring to real-time feedback and intelligent systems integration, AI is reshaping the way knowledge is delivered, accessed, and applied. This transformation compels educators and institutions to reflect on how learning has evolved and what it must become to remain impactful. A recent study demonstrated that AI-powered virtual tutoring using GPT-4 significantly improved English learning outcomes among secondary students. While we are definitely living the 5th era of learning (or **Learning 5.0**), this synergy should be approached with caution.

The evolution of learning – from experiential observation to AI-assisted education – reflects how knowledge acquisition adapts to technological and societal change. Each stage has expanded access, deepened personalization, and reshaped the learner's role. For modern universities, recognizing this evolution is essential to remain relevant, responsive, and inclusive. It calls for rethinking curricula, pedagogy, and institutional structures to embrace adaptive, interdisciplinary, and technology-integrated education that prepares students for complex, human-centered futures.

Martin Elias De Simone; Federico Hernan Tiberti; Maria Rebeca Barron Rodriguez; Federico Alfredo Manolio; Wuraola Mosuro; Eliot Jolomi Dikoru. From Chalkboards to Chatbots : Evaluating the Impact of Generative AI on Learning Outcomes in Nigeria (English). Policy Research Working Paper;RRR;People;Impact Evaluation Series Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/099548105192529324

The evolution of learning

1

Learning 1.0

This stage represents the most intuitive and experiential form of learning, where individuals acquired knowledge by ***observing*** natural phenomena, ***mimicking*** animal behaviors, and ***interacting*** directly with their environment. It was unstructured but deeply immersive and contextual. Learning was holistic and integrated into daily survival, creativity, and community life. While primitive by modern standards, this form of learning emphasized curiosity, observation, and adaptation – qualities still essential in today's educational systems.

2

Learning 2.0

With the invention of writing and the printing press, knowledge became ***codified*** and ***transferable*** across time and space. Books, encyclopedias, and manuals provided a structured, formalized way to disseminate information. This stage marked the rise of ***institutionalized education***, where learning became associated with schools and academic systems. The key feature here was access to curated and reliable information, which laid the foundation for widespread literacy and the development of disciplines.

3

Learning 3.0

Learning 3.0 introduced digitized learning tools, enabling faster, multimedia-rich, and interactive access to knowledge. ***CD-ROMs*** and ***digital encyclopedias*** represented early efforts to enhance engagement and broaden educational reach beyond print. This era signaled the beginning of ***edtech***, introducing learners to nonlinear navigation, multimedia integration, and personalized pacing. It also prepared the ground for more connected and flexible learning models.

4

Learning 4.0

This phase marks the digital transformation of education through the rise of the internet, ***e-learning platforms***, ***MOOCs***, and ***virtual classrooms***. Learning 4.0 enables access to global knowledge networks, expert-led video instruction, and collaborative learning experiences. It reflects a shift from teacher-centered to learner-centered paradigms, supporting self-paced, location-independent education. However, it also highlights challenges such as digital inequality, attention fragmentation, and a need for new pedagogical frameworks.

5

Learning 5.0

It's the era of ***AI-assisted and personalized learning***, where virtual tutors, chatbots, and generative AI tools (like GPT-based assistants) tailor content to individual needs, goals, and contexts. This stage blends human cognition with machine intelligence, enabling adaptive learning pathways, real-time feedback, and inclusive educational access. It supports lifelong learning, enhances learner autonomy, and opens new frontiers for hybrid human-machine collaboration in education. It also raises questions around ethics, data privacy, and the role of human educators in a tech-driven landscape.

06

The LEONARDO smart brewing learning factory

Beyond Industry 4.0 learning factories

In line with key EU priorities, there is an urgent need to provide appropriate education and training to **mitigate skills shortages and mismatches in the field of human-centric industrial engineering and management**. At the same time, the EU calls for the development of "sandboxes" – dedicated technical environments that support experimentation, co-creation, and dialogue around purpose-driven and ethically grounded technology development at the organisational level.

Traditional **learning factories**, while considered a "gold standard" for **hands-on engineering education**, often come with substantial limitations. They are typically **expensive to build and maintain**, they **operate in closed, physically bound environments**, limiting flexibility and real-world adaptability. Their technological setup can be **too complex to operate for non-specialists**, creating steep learning curves for students and discouraging broader, interdisciplinary engagement.

The LEONARDO initiative aims to transcend these barriers by reimagining the concept of learning factories through human-centric, accessible, and digitally enhanced educational experiences. LEONARDO emphasizes **open, interoperable, and ethically grounded systems** that allow students not only to operate machinery but also to **understand the broader socio-technical implications of digital transformation in manufacturing and supply chains**.

An unconventional learning factory

LEONARDO smart brewing learning factory goes beyond industrial automation, smart manufacturing and technical skills. Learning with fun adds a layer of motivation and stimulation. Brewing is an engaging, enjoyable and rewarding process that encourages innovation, entrepreneurship and curiosity.

A focus on human-centric industrial engineering and management

Through the integration of AI, XR, and human-AI collaboration, LEONARDO empowers learners to engage with complex socio-technical systems, develop collective intelligence, and explore the long-term effects of technological decisions aligned with the demands of Industry 5.0.

Multidisciplinary collaboration

LEONARDO fosters multidisciplinary collaboration by integrating engineering, social sciences, and ethics, enabling learners to co-create responsible, human-centric solutions for complex industrial challenges in line with EU priorities.

A playground for experimentations and innovative teaching

Hands-on teaching to integrate theory with practice in tech-enhanced environments where learners and educators co-create, test and refine human-centric industrial solutions (e.g. ethical development of technologies, AI for workers with disabilities, digital twins for sustainable development)

> **LEAF is more than a pilot plant—it is a sandbox for learning, innovation, and co-creation, enabling students to experience the intersection of technology, process, and human roles in modern manufacturing**

The **Learning and Experimenting open-Access Factory (LEAF)** is a compact, digitally enhanced brewing system—spanning from malt milling to bottling—designed as a hands-on educational platform and incubator for human-centric student innovation. Fully automated and digitalized, LEAF integrates technologies like TULIP, Node-Red, and Grainfather, with AI-driven analytics powered by Python, OpenCV, and YOLOv8 for real-time monitoring, predictive modeling, and root cause analysis. A simulation-based digital twin build in AnyLogic allows students to experiment with process scenarios and remote operations, while an augmented reality tool developed for Microsoft Hololens with Unity provides intuitive guidance, live visualizations, and interactive work instructions.

Watch the video

By integrating AI, XR, and co-creation practices, **LEONARDO democratizes access to advanced learning environments**, promotes interdisciplinary collaboration, and nurtures a new generation of learners who are not just technically skilled but also socially and ethically aware. In doing so, it addresses the core weaknesses of traditional learning factories – transforming them from static, resource-intensive setups into **adaptive, scalable, and truly engaging educational ecosystems fit for Industry 5.0**.

CASE STUDY
Enhancing process monitoring and decision making with a simulation based digital twin

Students engage with a simulation-based digital twin of a brewery, designed to support real-time process monitoring, predictive analysis, and remote management. The digital twin mirrors the physical brewing process allowing students to visualize operations, test interventions, and evaluate the consequences of different decisions through what-if scenarios. Students step into the role of brewery manager, using the digital twin to monitor live process data, identify inefficiencies or anomalies, and make informed decisions on corrective actions. A key learning point involves the *interaction between AI-enhanced decision support and managerial accountability*. While the system augments human cognition by suggesting optimal paths or predicting outcomes, students must critically assess these recommendations, taking responsibility for final decisions. This provokes reflection on the limits of AI autonomy, the role of human judgment, and the ethical and operational implications of shared accountability in human-AI collaboration. Through this hands-on experience, students develop competencies in digital operations management, AI-supported decision-making, and human-centric process supervision, while also engaging with broader questions of trust, responsibility, and control in digitally transformed industrial systems.

CASE STUDY
Empowering brewers and technicians with AR-based digital work instructions

Students explore how augmented reality (AR) can be used to support brewers and technicians in performing operational and maintenance tasks. The users—brewers and technicians—often come from diverse backgrounds and possess varying levels of technical literacy. This scenario challenges students to consider how digital instructions can be delivered in ways that are intuitive, accessible, and ergonomically optimized. They assess how to design AR interfaces that minimize cognitive overload, accommodate different user profiles, and ensure instructions are clear, actionable, and context-sensitive. Students role-play as both designers and users, experimenting with different AR interactions, evaluating usability, and simulating workplace scenarios. They also engage in documenting procedures, troubleshooting steps, and maintenance activities to create a reliable digital knowledge base that supports long-term operational consistency and knowledge transfer. A central theme is the *human-centered design of AR solutions* - ensuring that technology enhances, rather than complicates, the worker's task. Students reflect on the trade-offs between technological sophistication and practical usability, gaining insights into how ergonomics, interface design, and inclusive communication are critical to successful adoption on the shop floor.

CASE STUDY
Improving trend identification and product quality with AI-based predictive analytics

Students work with an AI-driven system designed to enhance quality control by identifying anomalies, forecasting product outcomes, and conducting root cause analysis in the brewing process. The users - brewers and product managers - rely on this system to anticipate issues, improve product consistency, and optimize decision-making through predictive and prescriptive analytics based on real-time and historical data. A critical area of exploration for students is the *ethical and regulatory landscape surrounding industrial data use*. As the system processes sensitive production and performance data, questions arise around data ownership, privacy, and transparency. Students are asked to consider the implications of compliance with data protection regulations (e.g., GDPR), especially when AI recommendations influence operational decisions or consumer-facing product claims. They explore the balance between algorithmic efficiency and regulatory compliance, learning how to design data-driven systems that are not only effective but also ethically sound and legally responsible. Through this case, students gain practical experience in data governance, AI ethics, and regulatory risk management, equipping them with the knowledge to implement predictive technologies responsibly in quality-driven manufacturing environments.

07

an **Industry X.0** teaching and research lab

At the **human-systems symbiosis (USS) lab**, we conduct interdisciplinary research in the area of industrial systems engineering and management to support organizations throughout their digital transition to become human-centric, resilient and sustainable.

Through scientific research and education, we shape the future of industry building a **synergistic partnership between humans and intelligent systems**, and empowering individuals and organizations to thrive in a rapidly evolving landscape.

A research laboratory of University of Calabria

human-systems symbiosis lab

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DIMEG | DIPARTIMENTO DI INGEGNERIA MECCANICA, ENERGETICA E GESTIONALE

Transforming tomorrow: where minds and machines unite for progress

The lab brings extensive expertise in exploring **human-(digital) technology interfaces** and the **ethics of technology in manufacturing and supply chains**. Its research focuses on the complex relationships within the system of **human-technology-process**, emphasizing the development of **human-AI collective intelligence** to enhance collaboration and decision-making in industrial contexts. The lab also investigates the **long-term secondary effects of human-technology interaction**, ensuring that innovation in manufacturing and logistics aligns with societal values. By fostering organisational and social innovation, the lab supports the co-creation and adoption of new industrial practices and business models that embed social considerations at their core.

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Founding year

~1MLN€
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