WHEN MACHINES DREAM AT WORK

Human-Centered Interaction Design for AI-Augmented Creativity in Industry 5.0

Antonella Varesano1,2 and Paolo Gallina3
1 Asperastra Innovation Lab, Trieste, Italy
2 Avires Lab, University of Udine, Udine, Italy
3 Department of Engineering and Architecture, University of Trieste, Trieste, Italy
antonella.varesano@uniud.it; paolo.gallina@units.it

Abstract

The increasing adoption of Artificial Intelligence (AI), Digital Twin (DT), and immersive technologies in contemporary workplaces is transforming not only workflows and tasks, but also the interaction paradigms through which humans engage with intelligent systems. While Industry4.0 has primarily focused on automation, efficiency, and productivity, this evolution risks marginalizing human agency and well-being if interaction design remains secondary to technical optimization. This paper argues that Industry 5.0 requires a shift from automation-centered approaches toward human-centered and interaction-centered design, where AI and robotic systems are conceived as cooperative and embodied partners rather than autonomous substitutes for human intelligence. Building on Human Work Interaction Design (HWID), Human-Centered Design (HCD), and Science, Technology, Engineering, Arts and Mathematics (STEAM)-oriented innovation practices, this paper conceptualizes Innovation Labs as socio-technical environments for prototyping, testing, and governing human-AI-robot collaboration.

Through the analysis of creative AI practices-particularly neural cinema and generative audiovisual systems-the paper demonstrates how the inclusion of Arts (A) within STEM frameworks functions as a cognitive, perceptual, and interactional enabler. By integrating phenomenological perspectives on technological mediation, the paper emphasizes the intractability of meaning in human-AI interaction and frames this limitation not as a technical deficit but as a structural boundary that must be explicitly addressed in design. The paper ultimately proposes a Human-Centered Interaction Framework for AI- and robotics-augmented work, highlighting well-being, autonomy, embodiment, and human governance as core design requirements for Industry 5.0.

CCS Concepts: Human-centered computing; Interaction design.

Keywords: Human-Work Interaction Design; Human-Centered Design; Industry 5.0; STEAM; Creative AI; Innovation Labs; Well-being.

1. Introduction

The rapid diffusion of Artificial Intelligence (AI), Digital Twin (DT), and immersive environments is redefining the nature of work and the role of humans within socio-technical systems. In many current implementations, intelligent systems increasingly mediate decision-making, creative problem solving, and sense-making activities. This evolution raises critical questions for Human-Work Interaction Design (HWID): how can interaction design ensure that humans remain active agents rather than passive supervisors of opaque automated processes?

Industry 5.0 responds to these concerns by explicitly placing human well-being, sustainability, and social values at the center of technological development [1]. However, translating these principles into practice requires a reconceptualization of interaction design, moving beyond usability and efficiency toward agency, trust, and meaning. This paper argues that interaction design is a central mechanism through which Industry 5.0 values can be operationalized [2].

1.1 Methodological Positioning

This paper adopts a conceptual and design-oriented research approach within the Human-Work Interaction Design (HWID) tradition. Rather than presenting an empirical evaluation, the contribution is twofold: the development of a human-centered interaction framework for AI-augmented work in Industry 5.0, and the use of a situated Innovation Lab as an exploratory design research environment to illustrate and ground the proposed concepts. The Asperastra Innovation Lab Trieste is not presented as a formal case study with controlled evaluation, but as a socio-technical setting for iterative prototyping, participatory experimentation, and reflective observation of human-AI interaction practices. This positioning aligns with design research approaches, where knowledge emerges through the interaction between theory, design practice, and situated experimentation. In this sense, both art and science adopt research-oriented approaches, operating autonomously while pursuing distinct objectives.

2. From Automation to Interaction-Centered Augmentation

Traditional automation-driven systems tend to position humans as monitors or fallback operators. Such models risk cognitive deskilling and reduced engagement. In contrast, augmentation emphasizes cooperation, where human and machine intelligence complement each other through well-designed interaction. In an Industry 5.0 perspective, augmentation is not merely a technical enhancement but an interactional property. Effective augmentation depends on how systems communicate uncertainty, expose reasoning processes, and allow humans to intervene meaningfully. Interaction design thus becomes essential to preserving autonomy and responsibility in AI-mediated work. This perspective aligns with the emerging framework of Human-Autonomy Teaming (HAT), which conceptualizes human-AI collaboration as a dynamic distribution of roles, responsibilities, and decision-making authority between human and artificial agents [4,5]. HAT emphasizes shared situational awareness, mutual predictability, and effective coordination mechanisms.

While HAT often originates from autonomous systems engineering, the approach proposed in this paper extends this perspective by focusing on interaction as a phenomenological and design-driven process. In this sense, collaboration is not only a matter of task allocation, but also of meaning-making, perception, and interpretability within situated human experience. These risks have been extensively analyzed in human factors research on automation [2,3].

3. Human-Centered Design and HWID in Industry 5.0

Human-Centered Design (HCD) extends traditional usability approaches by considering emotional, social, and ethical dimensions of interaction. Within HWID, work is understood as situated, embodied, and collaborative [6]. AI systems introduced into such contexts must therefore be designed to support human sense-making, learning, and trust [7].

Key HCD principles for Industry 5.0 include transparency, explainability, participatory design, and human governance. These principles ensure that intelligent systems remain intelligible and accountable, supporting well-being rather than undermining it.

Based on the previous discussion, this paper proposes a Human-Centered Interaction Framework for AI- and robotics-augmented work. The framework articulates key design dimensions that support meaningful, responsible, and effective human-AI collaboration:

1. Human Agency and Control: AI systems must preserve human intentionality and enable meaningful intervention in decision-making processes.
2. Transparency and Explainability: Systems should communicate their logic, limitations, and uncertainty in ways that are accessible and interpretable.
3. Interaction and Embodiment: Especially in robotics, interaction must account for physical presence, spatial negotiation, and perceptual cues.
4. Meaning Boundary Awareness: AI systems do not generate intrinsic meaning; interaction design must support human interpretation and prevent over-attribution of agency.
5. Well-being and Trust: Interaction should foster psychological safety, engagement, and a sense of purpose in work.
6. Human Governance: Humans must retain oversight, responsibility, and ethical control over AI-mediated processes.

These dimensions are not independent but interconnected, forming a design space where interaction becomes the primary mechanism through which Industry 5.0 principles are operationalized. These principles are widely discussed in human-centered AI literature, particularly in relation to trust, reliability, and human control [7].

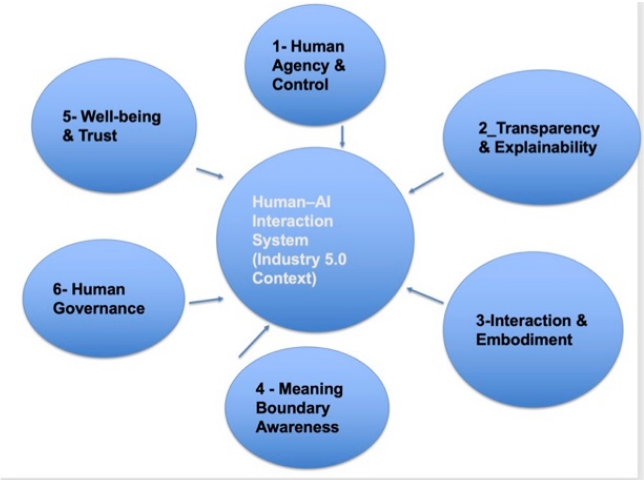

Fig. 1. Human-Centered Interaction Framework for AI- and robotics-augmented work.

4. Innovation Labs as Socio-Technical Interaction Spaces

Asperastra Innovation Labs Trieste function as experimental ecosystems where technologies, practices, and cultures co-evolve. Unlike traditional workplaces, they allow rapid prototyping, participatory co-design, and reflective experimentation. This makes them ideal environments for HWID research and for testing human-centered interaction models. Within Innovation Labs, AI systems can be evaluated not only for performance but for their impact on human behavior, emotional response, and learning. Such environments support the iterative refinement of interaction design before large-scale deployment. This perspective is consistent with HWID approaches that frame work as situated and interactional [8,9].

4.1 Innovation Lab as a Human-Centered STEAM Model

Innovation Lab represents a situated example of how human-centered interaction design principles can be operationalized within Industry 5.0 contexts. Conceived as a cultural and creative innovation environment, the lab integrates Artificial Intelligence, audiovisual media, and digital technologies within a STEAM framework, explicitly including Arts as a cognitive and interactional driver.

Rather than focusing on technological performance alone, the Innovation Lab adopts learning-by-doing methodologies and project-based experimentation to foster human agency, critical thinking, and creative problem solving. AI systems are introduced as dialogic partners within creative and educational processes, making their behavior observable, discussable, and governable by participants. From a Human-Work Interaction Design perspective, Innovation Lab functions as a socio-technical sandbox where interaction design, ethics, and well-being are addressed simultaneously. Activities such as AI-driven audiovisual production, neural cinema experimentation, and participatory workshops enable users to engage with intelligent systems through embodied, narrative, and reflective practices. This approach strengthens trust, supports sense-making, and prevents the delegation of meaning-making to automated systems.

The Asperastra Innovation Lab Trieste model demonstrates how Innovation Labs can serve as mediating spaces between research, education, and industry, enabling the responsible integration of Industry 5.0 technologies while maintaining human control, transparency, and cultural relevance. From an analytical perspective, Innovation Lab enables the observation of concrete interaction patterns aligned with HWID principles. For example, in AI-driven audiovisual workshops and neural cinema, system outputs are intentionally designed to be ambiguous, requiring participants to actively interpret and contextualize machine-generated content [10].

Neural cinema is not yet a formalized field of study; rather, it should be understood as an emerging domain that integrates:

- audiovisual generation driven by artificial intelligence;
- perceptual and cognitive processes informed by neuroscience;
- the language of cinema, including directing, editing, and aesthetic composition.

This reinforces the principle of meaning boundary awareness and prevents passive acceptance of AI outputs. Similarly, in collaborative prototyping sessions, AI systems are positioned as dialogic partners, where users iteratively adjust prompts, evaluate responses, and negotiate outcomes. This process makes uncertainty visible and supports transparency and human control. In robotics-related activities, embodiment becomes central: participants interpret movement, timing, and spatial behavior as communicative cues, highlighting how interaction design extends beyond interfaces into physical co-presence [11]. These practices illustrate how Innovation Labs can function as experimental environments where interaction design principles are not only theorized but enacted, observed, and iteratively refined.

4.2 From Automation to Interaction-Centered Augmentation and Embodied Robotics

Traditional automation-driven systems tend to position humans as monitors or fallback operators. Such models risk cognitive deskilling and reduced engagement. In contrast, augmentation emphasizes cooperation, where human and machine intelligence complement each other through well-designed interaction.

In an Industry 5.0 perspective, augmentation is not merely a technical enhancement but an interactional and embodied property. Effective augmentation depends on how systems communicate uncertainty, expose reasoning processes, and allow humans to intervene meaningfully. When Artificial Intelligence is coupled with robotic systems, interaction design must additionally address embodiment, physical agency, and situated action.

Collaborative and cognitive robotics introduce AI into the physical workspace, transforming interaction from screen-based mediation to human-robot co-presence. Robots become material interfaces through which AI perceives, acts, and negotiates space with humans. This shift reinforces the need for interaction-centered design principles that account for trust, safety, legibility of action, and shared intentionality [12,13]. From a Human-Work Interaction Design perspective, robotics should not be framed as autonomous replacement, but as an embodied augmentation layer that externalizes AI capabilities into the physical world while remaining under human governance.

5. From STEM to STEAM: The Role of Arts in Interaction Design

The integration of Arts into STEM is often perceived as an aesthetic enrichment. This paper argues instead that artistic practices play a fundamental role in interaction design, particularly in AI-mediated systems. Artistic approaches enable metaphor, narrative, and visualization, making complex system behaviors perceivable and interpretable. Creative AI practices, such as neural cinema and generative audiovisual systems, demonstrate how aesthetic engagement can enhance transparency, trust, and reflection. These practices reveal system behavior through experience rather than abstraction, supporting human understanding and control [14].

5.1 Arts, Robotics, and Phenomenology in Interaction Design

In human-robot interaction, artistic and performative strategies play a crucial role in rendering robotic behavior intelligible and relatable. The relationship between art and robotics can be interpreted as a historical and conceptual evolution of the human drive to create and emulate life. From early kinetic art experiments to contemporary robotic systems, this convergence has progressively expanded both expressive and scientific possibilities. Robotic systems used in artistic contexts can be understood not only as creative tools but also as experimental frameworks for investigating human cognition and creativity. At the same time, such practices highlight the role of unpredictability and serendipity in machine-assisted creation, while revealing a fundamental limitation: artistic phenomena remain only partially formalizable and cannot be fully reduced to computational models. This tension positions art and robotics at the intersection between technological rationality and a more elusive aesthetic and experiential dimension.

Movement, timing, gesture, and spatial composition function as interaction cues through which humans interpret robotic intention and agency. In this sense, robotics becomes not only a technical discipline but a cultural and perceptual practice. Drawing on recent reflections by Cappucci published in Noema, technological systems - especially AI and robotics - should be understood as phenomenological mediators rather than autonomous cognitive subjects.

Cappucci emphasizes that meaning does not reside in computational systems themselves, but emerges in the relational field between human perception, technological mediation, and cultural context [15]. From this standpoint, interaction design becomes the primary site where sense-making is negotiated. Within STEAM-oriented interaction design, artistic practices act as phenomenological operators: they expose the limits of machinic cognition, foreground embodiment, and re-anchor interpretation in human experience. Creative AI and robotic systemsthus function as reflective devices that support interpretation rather than replace it. By integrating phenomenological insights into interaction design, STEAM frameworks enable a critical and human-centered approach to AI and robotics in Industry 5.0, ensuring that technological systems remain legible, contestable, and ethically governable [15].

6. Creative AI as Interaction Design Research

Neural cinema and generative audiovisual production provide a valuable research lens for HWID. In these contexts, AI systems act as visible co-creators, and interaction is iterative and dialogic. Authorship and control are continuously negotiated, making interaction dynamics explicit. Design principles emerging from creative AI include the intentional exposure of uncertainty, support for exploratory interaction, and preservation of human intentionality. These principles are transferable to workplace systems, where creativity and discretionary effort are increasingly important [14].

6.1 The Intractability of Meaning in Human-AI Interaction

Despite significant advances in generative and interactive AI systems, a fundamental limitation persists: the problem of meaning. Foundational work in cognitive science and artificial intelligence has consistently distinguished between syntactic symbol manipulation and semantic understanding. Winograd demonstrated that apparent linguistic competence in machines relies on constrained domains and predefined contexts rather than genuine understanding [16]. Papert further emphasized that computational systems operate without experiential grounding and therefore cannot autonomously generate meaning [17]. Chomsky's critique of statistical language models reinforces this position, arguing that probabilistic pattern recognition does not amount to intentionality or comprehension [18]. From a Human-Work Interaction Design perspective, this limitation should not be framed as a technical deficit to be overcome, but as a structural boundary that must be explicitly designed for. Treating AI systems as meaning-bearing agents risks encouraging the abdication of human sense-making, judgment, and responsibility.

Creative AI practices make this boundary visible. In neural cinema and generative audiovisual systems, meaning does not reside in machine output but emerges through human interpretation, contextualization, and narrative framing. These domains demonstrate that the value of AI lies not in semantic autonomy, but in its capacity to support reflection, exploration, and creative negotiation. Recognizing the intractability of meaning is therefore essential to preserving human agency, ensuring ethical governance, and supporting well-being in Industry 5.0 workplaces.

7. Well-Being, Trust, and Human Governance

Worker well-being in AI-mediated environments depends on meaningful interaction, perceived autonomy, and trust. Interaction design plays a decisive role in shaping these factors. Systems that allow questioning, interpretation, and intervention foster psychological safety and engagement [19,20]. The use of affective data and behavioral analytics must be governed through transparent and participatory interaction models. Human governance mechanisms are essential to ensure ethical use and to maintain trust in Industry 5.0 systems [21,22].

8. Implications for STEAM Education and Professional Competencies

Industry 5.0 requires new hybrid competencies combining technical literacy, interaction design skills, ethical awareness, and creative thinking. STEAM-based education, particularly within Asperastra Innovation Labs Trieste, supports learning-by-doing approaches that strengthen agency and adaptability [23]. Such educational models prepare professionals to design, operate, and govern human-AI systems responsibly, aligning technological innovation with human values.

Industry 5.0 will be defined not by smarter machines but by better interactions between humans and intelligent systems [1]. By centering interaction design, Human-Centered Design, and STEAM-oriented creativity, workplaces can evolve toward systems that are efficient, intelligible, and humane [19]. In this perspective, human-AI collaboration can be understood as a form of Human-Autonomy Teaming, where agency, responsibility, and decision-making remain distributed but ultimately governed by human actors. Interaction design becomes the key mechanism through which transparency, interpretability, and ethical accountability are enacted in practice, supporting both individual and collective well-being [21].

9. Conclusion

When machines dream at work, interaction design determines whether humans remain engaged, empowered, and in control. The Innovation Lab approach aligns with recent Human-AI Co-Creation Design Process (HAI-CDP) models [24], where the co-creative process is viewed not as task automation, but as a continuous negotiation between the machine's generative capacityand the human's evaluative judgment. This ensures that, even in complex and layered systems such as neural cinema, the production of meaning remains an exclusive prerogative of the human actor [25]. Recognizing the intractability of meaning by AI is essential for preserving agency, ensuring ethical governance, and supporting worker well-being. Ultimately, when machines "dream" at work, it is interaction design that determines whether humans remain active, empowered protagonists in full control of the processes of creation and production.

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