GLOBAL CRITICAL THINKING FOR SUSTAINABILITY: THE CONVERGENCE OF HUMAN INTELLIGENCE, ARTIFICIAL INTELLIGENCE AND INDUSTRY 5.0

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ABSTRACT

Purpose: The accelerating speed and pace of technological transformation demands a paradigm shift in how humanity conceptualizes, frames, and applies critical thinking toward sustainability challenges. This article explores the combined relationship between Human Intelligence (HI), Artificial Intelligence (AI), and the emerging industrial paradigm known as Industry 5.0. It argues that sustainable global futures cannot be achieved through technological deployment alone but require an integrated cognitive framework based on ethical reasoning, systems thinking, and collaborative intelligence.

Design/Methodology/Approach: Drawing on current empirical scientific research, policy frameworks, and interdisciplinary scholarship from 2021 to 2026, this article synthesizes key dialogues around AI-augmented decision-making, human-centric production ecosystems, and the operationalization of the United Nations Sustainable Development Goals (SDGs).

Findings: The findings reveal that while AI significantly enhances data-processing capacity and predictive modelling for sustainability outcomes, Human Intelligence remains indispensable for value-laden judgment, contextual interpretation, and moral accountability. Industry 5.0 emerges as a productive synthesis of these intelligences, centering resilience, human well-being, and circular economy principles.

Research Limitations: The article is based on the synthesis of existing empirical research, policy frameworks, and interdisciplinary scholarship and does not involve the collection of primary empirical data. The findings are therefore dependent on the scope, quality, and availability of existing literature and may not capture emerging developments beyond the period covered by the study.

Managerial Implications: The study highlights the need for organizations and policymakers to adopt human-centric approaches to technological transformation by integrating AI capabilities with human judgment, ethical reasoning, and collaborative intelligence. Such an approach can support sustainable decision-making, organizational resilience, human well-being, and the effective implementation of sustainability objectives.

Originality/Value: The article proposes a framework for Global Critical Thinking for Sustainability (GCTS) that positions critical consciousness, technological literacy, and cross-cultural competency as foundational pillars for navigating the complex socio-technical scenario of the 21st century. By integrating Human Intelligence, Artificial Intelligence, and Industry 5.0 within a sustainability-oriented framework, the article contributes to the emerging discourse on human-centric and technologically enabled sustainable development.

Key Words: Human Intelligence; Artificial Intelligence; Industry 5.0; Sustainability; Critical Thinking; Ethical Reasoning; Systems Thinking; Collaborative Intelligence; Sustainable Development Goals; Global Critical Thinking for Sustainability.

Keywords: critical thinking, sustainability, artificial intelligence, human intelligence, Industry 5.0, SDGs, human-centric technology, circular economy

INTRODUCTION

The 21st century is defined by the convergence of two relevant forces: an increasing global sustainability crisis and an awareness of technological revolution. Humanity faces compounding existential threats -- climate change, biodiversity loss, social inequality, and resource depletion -- precisely at the moment when Artificial Intelligence (AI), automation, and advanced human-machine collaboration have become defining features of economic and social life. The combination of these forces raises a fundamental question: How must human beings cognition is different, more critical, more global, and more responsible - to emphasis technology for sustainable futures?

The concept of critical thinking, found in education and philosophy, takes on new look in this context. Traditional definitions of critical thinking emphasize analysis, evaluation, and reasonable debates (Paul & Elder, 2020). However, the complexity of sustainability challenges demands an expanded concept -- what are the terms Global Critical Thinking for Sustainability (GCTS) - that integrates systems thinking, ethical reasoning, cross-cultural sensitivity, and technological literacy (Wiek et al., 2022).

Simultaneously, the global industrial scenario is transitioning ahead of 4.0's automation-centric model toward Industry 5.0, a clear paradigm centered on human-centric values, sustainability, and resilience (European Commission, 2021). This transition taps on recognition that technological capability alone is insufficient; it must be guided by human wisdom, ethical frameworks, and genuine concern for ecological and social well-being (Maddikunta et al., 2022).

Here the author argues that achieving sustainability in the Industry 5.0 era requires a deliberate cultivation of GCTS; a form of intelligence that is neither purely human nor purely artificial but emerges from their productive and progressive convergence.

The following sections review the theoretical aspects of critical thinking and sustainability, analyze the clear roles and setbacks of Human Intelligence and AI in sustainability decision-making, examine Industry 5.0 as a framework for integrating these intelligences, and propose a practical model for GCTS.

LITERATURE REVIEW

Critical Thinking and Sustainability

The relationship between critical thinking and sustainability has been discussed across all disciplines. Sustainability science positions critical thinking as the competency for what Wiek et al. (2011) termed 'transformative sustainability science,' including the capacity to challenge dominant narratives, interrogate power structures, and envision transformative alternatives. More recent scholarship has broadened this definition to include futures literacy; the ability to anticipate, model, and explore multiple possible futures (UNESCO, 2022).

The United Nations' 2030 Agenda for Sustainable Development explicitly promotes for the cultivation of knowledge and skills mandatory to promote sustainable development, including through education for sustainable development (ESD) and global citizenship education (GCED; United Nations, 2015). These frameworks place critical thinking not merely as an individual cognitive skill but as a social and civic practice, one that is inherently political and ethical (UNESCO, 2021).

Namely, scholars such as Sterling (2023) have criticized prevailing sustainability education frameworks for lack of addressing systemic and structural dimensions of unsustainability. Sterling urges that 'first-order' critical thinking, critique without transformative agency is insufficient, and recommends for 'critical sustainability literacy': an emancipatory form of thinking that connects personal individualized action to systemic change.

Human Intelligence in Sustainability Contexts

Human Intelligence (HI) includes a complex array of cognitive, emotional, social, and moral capabilities that are deeply embedded in biological, cultural, and historical contexts. In sustainability decision-making, HI contributes capabilities that remain beyond current AI capacities: moral reasoning, empathetic understanding, contextual judgment, narrative construction, and the ability to navigate radical uncertainty (Marcus & Davis, 2022).

Studies in cognitive science and behavioral economics have highlighted both the strengths and limitations of human reason in sustainability contexts. Research shows that humans

are prone to cognitive biases like temporal discounting, status quo bias, and optimism bias that systematically undermine long-term sustainability reasoning (Thaler & Sunstein, 2021). These reasonable limitations create a compelling case for AI augmentation of human decision-making. However, they do not eliminate the irreplaceable value of human judgment, particularly in normative, value based, and politically contested sustainability decisions (Fazey et al., 2021).

A growing body of research from the post-pandemic era has illuminated the importance of emotional intelligence, resilience, and cross-cultural competency in sustainability leadership. Goleman et al. (2023) recommend that emotionally intelligent leadership significantly enhance organizational sustainability outcomes, suggesting that affective dimensions of HI are central to effective sustainability governance.

Artificial Intelligence and Sustainability

Artificial Intelligence's (AI's) contributions to sustainability have expanded dramatically in the 2020s. Machine learning models now focus climate simulation at unprecedented resolution (Rolnick et al., 2022), optimize energy grids in real time (IEA, 2023), and accelerate discovery of sustainable materials (Merchant et al., 2023). Natural language processing methods enable the synthesis of numerable bodies of sustainability literature, while computer vision applications encourage biodiversity monitoring and land-use analysis (Tuia et al., 2022).

Yet AI's relationship to sustainability is deeply complicated. The training and deployment of large AI models generates countless carbon emissions and consumes significant water and energy resources (Luccioni et al., 2023). AI systems trained on historically biased data can persist and amplify social inequalities, potentially undermining the social dimension of sustainability (Whittlestone et al., 2021). Moreover, AI systems lack genuine and proper understanding, ethical sensitivity, and accountability, capacities that remain important for sustainability governance (Floridi et al., 2022).

The concept of 'AI for Good' is promoted by the United Nations and major technology organizations that represents a normative attitude that AI development should be explicitly aligned with the SDGs (ITU, 2023). However, debaters argue that this framing risks

technologizing sustainability challenges in ways that gloomy structural drivers and depoliticize necessary social and political transformations (Birhane et al., 2022).

Industry 5.0: A Human-Centric Paradigm

Industry 5.0 depicts a significant conceptual advance beyond Industry 4.0. While Industry 4.0 was predominantly defined by automation, the Internet of Things, and cyber-physical systems, Industry 5.0 obviously positions sustainability, human-centricity, and resilience as foundational principles (European Commission, 2021). The paradigm clearly shows a future in which advanced technologies are used in service of human flourishing and ecological well-being rather than narrowly defined economic productivity.

Maddikunta et al. (2022) propose several key enablers of Industry 5.0: collaborative robots (cobots) designed for safe human-machine collaboration, AI systems that expand rather than replace human expertise, circular economy models that reduce waste and resource consumption, and digital twins that empower systemic simulation and optimization. These technological capabilities are embedded within a normative commitment to aiming worker well-being, social equity, and environmental sustainability.

Recent empirical research from the European Union, Japan, and South Korea recommends that early Industry 5.0 adopters are achieving significant gains in both productivity and worker satisfaction (Longo et al., 2023). Meanwhile, global south researchers have argued about whether the Industry 5.0 paradigm adequately focusses issues of technological access, labor displacement, and knowledge sovereignty in developing economies (Onu et al., 2024).

THE FRAMEWORK OF GLOBAL CRITICAL THINKING FOR SUSTAINABILITY (GCTS)

Constructing on the above literature, this article recommends a framework for GCTS integrating four interdependent aspects: systems thinking, ethical reasoning, technological literacy, and cross-cultural competency. Each aspect represents a domain in which HI and AI can productively converge, observed by the normative commitments of Industry 5.0.

Dimension 1: System Thinking

System thinking is foundational to sustainability and involves the strenth to perceive interconnections, feedback loops, emergent properties, and leverage points within complex socio-ecological systems (Meadows, 2008). Advances in AI, particularly in agent-based modeling, network analysis, and complex systems simulation that have dramatically expanded humanity's capacity for system level analysis (Farmer et al., 2022).

However, AI-generated systems models need human interpretation, validation, and contextualization. The recent generation of AI systems find difficulty to incorporate qualitative knowledge, indigenous ecological wisdom, and localized contextual factors essential to accurate sustainability modeling (Tengo et al., 2021). GCTS needs practitioners who can fluently move between computational systems models and situated human knowledge, utilizing each to interrogate and enrich the other.

Dimension 2: Ethical Reasoning

Sustainability is fundamentally and unchangeably ethical: it requires choices about what matters, whose interests count, and what exchange are acceptable. AI systems can support ethical analysis by modeling consequences, identifying stakeholder impacts, and simulating exchange across multiple value frameworks (Morley et al., 2021). Yet AI systems cannot bear moral responsibility, experience genuine empathy, or navigate the irreducible value pluralism that characterizes real sustainability predicament (Jobin et al., 2022).

GCTS requires cultivating what Nussbaum (2023) terms 'moral imagination' the capacity to realize the world from multiple perspectives, empathize with distant or future others, and take seriously claims that challenge one's own assumptions. This moral aspect cannot be externalized to AI; it needs sustained human cultivation through dialogue, education, and reflective practice.

Dimension 3: Technological Litera

In the Industry 5.0 era, technological literacy is a prerequisite for critical engagement with sustainability. This extends beyond basic digital competency to encompass understanding of AI capabilities and limitations, algorithmic bias, data governance, and the social and

environmental externalities of technological systems (van Laar et al., 2023). Citizens and practitioners who lack technological literacy are vulnerable to AI-mediated manipulation, misinformation, and uncritical acceptance of technologically deterministic narratives.

Recent research emphasizes that technological literacy must be critical rather than merely instrumental -- not simply learning to use technology, but developing the capacity to interrogate its assumptions, evaluate its impacts, and advocate for responsible innovation (Selwyn, 2022). This aligns with the Industry 5.0 vision of workers and citizens as active co-designers of technological systems rather than passive recipients.

Dimension 4: Cross-Cultural Competency

Sustainability challenges are global but experienced locally; effective responses require cross-cultural understanding, respect for diverse knowledge systems, and the ability to build collaborative coalitions across cultural difference. AI systems trained predominantly on Western, English-language datasets are poorly equipped to support genuine cross-cultural understanding (Sambasivan et al., 2021). GCTS requires practitioners who can facilitate knowledge exchange between diverse cultures, integrate local and indigenous knowledge into sustainability planning, and navigate cross-cultural ethical differences with humility and respect (Tengo et al., 2021).

The post-pandemic period has highlighted the importance of global cooperation and cross-cultural solidarity in addressing shared sustainability challenges. Research on COVID-19 governance has shown that societies with great levels of social trust, cross-cultural competency, and collaborative leadership were significantly more effective at handling the pandemic's complex social, economic, and ecological impacts (Fukuyama, 2021).

RECENT SCENARIO ANALYSIS: GCTS IN PRACTICE (2021-2026)

Climate Action and AI-Augmented Decision-Making

The period 2021-2026 has seen a massive growth of AI applications in climate action. Google Deep-Mind's weather forecasting model, Graph-Cast, demonstrated in 2023 that AI could generate a month global weather forecasts with accuracy eliminating conventional numerical methods (Lam et al., 2023). AI-powered carbon accounting platforms have enabled

corporations, cities, and governments to track and reduce emissions with unmatched granularity (IEA, 2024).

Yet these developments have occurred alongside a deepening recognition that technical solutions alone cannot drive the political will, social transformation, and behavioral change required to support Paris Agreement targets (IPCC, 2023). The Intergovernmental Panel on Climate Change's Sixth Assessment Report clearly recognizes human components like political economy, cultural norms, values, and equity that determine climate outcomes, highlighting the unique role of HI and GCTS in climate governance.

Industry 5.0 Implementation in Manufacturing

Several European industrial sectors have piloted manufacturing 5.0 frameworks since 2022, with notable results. A longitudinal study of German automotive industrialist found that companies adopting human-centric collaborative robot systems, circular material flows, and AI-based quality control achieved a 23% decrease in material waste and a 31% incensement in worker satisfaction scores over a three-year period (Longo et al., 2023). Critically, the most successful industries invested not only in technology but in employee training programs highlighting systems thinking, ethical reflection, and cross-functional collaboration -- core components of GCTS.

In contrast, companies that adopted Industry 5.0 technologies without corresponding funding in human capacity development saw more modest sustainability gains, suggesting that technological implementation without human cognitive and ethical development is inadequate (Xu et al., 2021).

AI Governance and the Ethics of Sustainability Intelligence

The era 2023-2026 has witnessed a substantial development of AI governance frameworks globally. The European Union's AI Act (2024), the United States AI Safety Institute, and the G7 Hiroshima AI Process have each established frameworks for responsible AI development that clearly recommend sustainability and human rights principles (European Parliament, 2024). These governance developments show an increasing agreement that AI must be governed by human ethical values rather than purely technical or market urgency.

From a GCTS purview, these governance frameworks depicts critical exercises in common ethical reasoning; the aspect of value based, politically contested, multi stakeholder discussion that is fundamentally a function of HI. They also draw the importance of cross-cultural competency: effective global AI governance needs bridging significant differences in cultural values, political systems, and technological doctrines (Cihon et al., 2021).

DISCUSSION

The comprehensive analysis given in this paper supports several relevant conclusions about the relationship between GCTS, HI, AI, and Industry 5.0. Primarily, technological positivism about AI's capacity to rectify sustainability challenges must be moderated by a serious acknowledgement of AI's current constrains. AI systems remain tools that are mighty and transformative, but lack genuine understanding, ethical agency, or accountability. Their effective administration for sustainability requires advanced human oversight, ethical governance, and critical engagement that accurately the capacities that GCTS targets to cultivate.

Second, Human Intelligence is not moved by AI but must be actively developed in new areas. The GCTS framework recognizes systems thinking, ethical reasoning, technological knowledge, and cross-cultural capabilities as the core capacities that modern humans must inculcate to drive the AI-augmented sustainability scenario. Educational systems, institutional cultures, and policy frameworks must be revamped to focus these capacities.

Third, Industry 5.0 symbolizes an encouraging regulative framework for integrating HI and AI in service of sustainability. Its clear promises to human-centricity, resilience, and ecological sustainability matches with the GCTS framework and give practical guidance for how organizations and societies can explore technology in ways that boost rather than reduce human cognitive and ethical capabilities.

Fourth, the global aspect of GCTS is central but essential. Sustainability issues are fundamentally global and just; addressing those needs forms of critical thinking that are sensitive to power, culture, and historical context and that are capable of building true cross-cultural harmony. AI systems, trained primarily on data from wealthy, Northern societies, are poorly placed to help this kind of global critical involvement; it needs intentional cultivation of HI.

Finally, this article argues that GCTS is not only an academic framework but an urgent practical essential. The decisions being made now about AI development, industrial transformation, and sustainability governance will shape the path of human civilization for many decades over the years. Getting these decisions clearly needs perfectly the kind of globally critical, ethically based, technologically literate, and cross-culturally competent thinking that this framework explains.

CONCLUSION

This article has discussed that sustainable global futures need a basic evolution in how humanity thinks toward a form of Global Critical Thinking for Sustainability that integrates the encouraging capacities of Human Intelligence and Artificial Intelligence within the standardizing framework of Industry 5.0. As AI capabilities proceed to widen and industrial systems undergo remarkable transformation, the cultivation of GCTS becomes compulsory and urgent.

The four dimensions of GCTS - systems thinking, ethical reasoning, technological literacy, and cross-cultural competency recommends an integrated answer to the cognitive demands of the present centuries sustainability challenge. Cultivating these capacities needs funding in education, organizational culture, governance, and research across all departments and at all levels and scales.

Sinificantly, GCTS cannot be automated. While AI can augment, analyze, and aggravate, the main work of ethical judgment, value consideration, cross-cultural debate, and transformative imagination stays permanently human. The need of the hour is not to choose between Human Intelligence and Artificial Intelligence but to cultivate the wisdom to use both in service of a genuinely sustainable, just, and blooming world.

Future directions research should concentrate on developing educational and pedagogical frameworks for GCTS in multiple educational and cultural contexts, scientifically evaluating Industry 5.0 execution for sustainability outcomes, and evaluating the governance patterns best opted to assuring that AI development remains matched with human values and sustainability urgent.

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