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BEYOND AUTOMATION: AI'S ROLE IN REDEFINING DESIGN PARADIGMS.

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ABSTRACT | AI's ability to process vast data sets, predict trends, and develop innovative solutions makes it experienced and perceived beyond a simple tool, fostering changes in the design domain in both the theoretical framework and practical applications. This paper aims to explore the significant transformation within the design discipline, increasingly influenced by the integration of Artificial Intelligence (AI) in creative processes.

The contribution critically examines the theoretical and methodological challenges brought by AI, particularly regarding generative content creation. Through the analysis of various aspects of AI integration in design – from how AI algorithms are influencing aesthetic choices to their role in automating and enhancing creative processes – the paper discusses the evolving role of the designer in an AI-integrated environment, contemplating the balance between human creativity and machine intelligence.

This contribution aims to discuss AI as a transformative force that is redefining design processes, encouraging designers to embrace new creative challenges and opportunities in the AI era. Through this exploration, the paper aims to contribute to the broader discourse on the evolving relationship between technology and creative industries, particularly focusing on the dynamic interplay between AI and design.

1. Introduction

Digital technologies permeate every layer of society, mediating interactions between subjects and objects, thereby accelerating a profound transformation of the world, which necessitates a new ontological and epistemological framework across various disciplines (Dufva & Dufva, 2019; Kraus et al., 2021). Enabling technologies, brought by digital transformation (DX), are embedded in creative and business processes, intervening in producing value across numerous human activities, with design, production, and consumption processes directly implicated. The necessity for design to recognise the interdependence between humans and their surrounding environment, encompassing natural, artificial, and digital entities becomes crucial in the era of digital transformation (Escobar, 2018; Forlano, 2017; Irwin, 2015). Design must address the challenge of harmonising technology with the global ecosystem, acknowledging that this transformation is deeply rooted in physical, ecological, and social contexts. It is increasingly important to consider the ethical and environmental impacts of activities, as well as technological innovations. As early as the first decade of the new millennium, Sellen, Rogers, Harper, and Rodden (2009) reflected on emerging paradigms in human interaction with technology, reshaping the boundaries between computers, individuals, and artifacts. The advent of intelligent networks has amplified this dynamic, with non-human entities assuming an increasingly active role in decision-making processes, establishing a symbiotic relationship where humans and software operate collaboratively.

Artificial Intelligence (AI) stands out as one of the most powerful and discussed technological innovations in our era, particularly regarding its potential impact on creative processes (Lubart, 2005; Daniele & Song, 2019; Fujita, 2018; Mazzone & Elgammal, 2019), and the ensuing ethical implications. AI is increasingly permeating design professions due to its proficiency in executing repetitive or challenging tasks for humans, such as analysing and extracting big data, forecasting outcomes, and even generating new content (Anantrasirichai & Bull, 2022).

Recently, innovative tools have utilised Generative Adversarial Networks (GANs) to generate new, previously unseen data that learn from and *creatively* use existing data to generate new outputs, significantly influencing the creative stages. These tools are not merely facilitative; they are transformative, offering the potential to reshape methodologies and processes within design and manufacturing, pushing pivotal questions concerning AI's capacity to shape creativity, creation processes, product development, and the audience's engagement with creative activity (Daniele & Song, 2019; Miller, 2020). Despite the undeniable impact of these powerful technologies on numerous human activities, there are also many misconceptions about AI that are perpetuated through the choice of wording, imagery, or analogy (Kurenkov, 2019).

AI is deeply rooted in the data revolution (Tedeschi & Lombardi, 2018) and anchored to mathematical-logical structures that underpin its ability to process, analyse, and interpret vast volumes of data efficiently. Mathematics provides the foundational structures for AI algorithms, while machine learning and neural networks utilise advanced calculations to 'learn' and improve. Concurrently, logic plays a crucial role in AI decision-making, allowing it to evaluate information, recognise patterns, and make choices based on well-defined criteria (Esling & Devis, 2020). Hence, introducing AI in the design domain can expand creative opportunities while introducing new ethical and methodological challenges (Verganti et al., 2020; Weisz et al., 2023), rewriting the relationship between design and mathematics, and between design and computational geometry.

This scenario transcends mere process automation, fostering multidimensional collaboration to explore previously inaccessible domains. It leads to behavioral models no longer confined to human-computer interaction but evolving into human-computer integration (Farooq & Grudin, 2016), a trajectory that envisions a partnership between humans and computers in the context of AI, meriting holistic consideration. In such a context, Artificial Intelligence (AI) emerges as a powerful catalyst for transformation, profoundly influencing socio-cultural, political, and economic dynamics in the contemporary evolution of design. The design field is facing the need to re-examine its foundations in terms of roles, functions, and approaches, and to weave new disciplinary relationships (Ozmen Garibay et

al, 2023). AI's ability to process vast data sets, predict trends, and develop innovative solutions fosters changes in the design domain in both the theoretical framework and practical applications. Particularly, the advancement in image and morphology generation through generative algorithms enables the creation of high-quality, realistic content in very condensed time frames, thus broadening the scope of creative possibilities while presenting significant ethical and methodological challenges.

This paper aims to critically examine the theoretical and methodological challenges brought by AI, particularly regarding generative content creation. It navigates through various aspects of AI integration in design, from how AI algorithms are influencing aesthetic choices to their role in automating and enhancing creative processes. It discusses the evolving role of the designer in an AI-integrated environment, contemplating the balance between human creativity and machine intelligence. Additionally, the paper investigates the ethical and practical implications of AI in design, addressing how AI-driven design approaches are reshaping expectations and redefining standards. Through this exploration, the paper aims to contribute to the broader discourse on the evolving relationship between technology and creative industries, particularly focusing on the dynamic interplay between AI and design.

2. Designing with AI

As the design discipline dynamically co-evolves with technological and societal shifts, experimentation with AI algorithms catalyses a substantial paradigmatic shift (Kuhn, 1962), offering unprecedented capabilities in exploring novel design possibilities (Daniele & Song, 2019; Fujita, 2018). AI is not a single entity, but rather a set of techniques and ideas (Kurenkov, 2019). It embodies a diverse spectrum of technologies and methodologies that can facilitate the creation of efficient solutions (Abd Aziz et al., 2021) and potentially enhance the design process, improving both the quality and functionality of design outputs (Thompson et al., 2016; Xiong et al., 2019).

New tools enabled by AI can invest both the input (design-management-control methods), as well as the output (product performances and meanings) of design processes, potentially revolutionising the way designers approach their work, offering the ability to verify and simulate various design scenarios. This advancement allows designers to predict outcomes and assess the feasibility of their ideas with greater accuracy than ever before. This not only streamlines the design process but also opens up new avenues for creative exploration, changing the way design innovates and delivers value (Magistretti et al. 2019). As AI progressively permeates daily activities, designers are prompted to explore the challenges of working with AI 'as a new design material' (Holmquist, 2018; Dove et al., 2017; Yildirim et al., 2022), considering AI not only as a tool or technology but as an integrated component of the creative process, a perspective that brings with it specific anomalies and opportunities. For instance, AI-driven tools can simulate the environmental impacts of in-progress designs, a capability that aligns with the growing need for sustainable design practices. They can also model user interactions, thereby enhancing user experience design, and evaluate the long-term sustainability of a design, ensuring that products are both environmentally and economically viable in their lifecycle.

AI has reached a significant level of maturity, both as a scientific discipline and as a technology. In recent years, a growing number of studies have focused on examining the challenges, benefits, and potential impacts of AI in achieving the Sustainable Development Goals (Goralski & Tan, 2020; Truby, 2020; Vinuesa et al., 2020). In this regard, the environmental impact of training AI models, particularly large-scale ones, has become a prominent concern (Nishant et al., 2020). The process of developing advanced AI systems, which involves extensive computational power and data processing, results in significant carbon emissions (Wu et al., 2022). This environmental cost raises critical questions about the sustainability of current AI practices (van Wynsberghe, 2021), especially as the demand for more sophisticated and larger models grows.

The integration of AI into design processes has the potential to radically transform the discipline, bringing significant changes across three main key areas:

1. **Streamlined Prototyping and Simulation:** The advent of AI is redefining design processes, allowing for ultra-rapid prototyping, real-time testing, and fast refinement of design concepts. AI's ability to quickly analyse and simulate various scenarios can enable designers to explore different kinds of proposals and iterate designs in real-time, significantly accelerating the design development process and enhancing its adaptability to changing requirements and user feedback.
2. **Enhanced Customisation and Predictive Capabilities:** AI's proficiency in dissecting and interpreting user data leads to unprecedented levels of personalisation, allowing designs to be precisely tailored to individual user profiles. Furthermore, AI's predictive abilities equip designers to not only address current trends but also anticipate future developments, thereby future-proofing design outputs.
3. **Collaborative Dynamics in Human-AI Interaction:** The relationship between human designers and AI systems is evolving into a synergistic partnership. AI's computational strength in processing and analysing large data sets offers insights and perspectives that can - to some extent - augment human creativity. This collaboration has the chance to expand the realm of creative possibilities, enhances problem-solving, and facilitates informed decision-making, merging human intuition with AI's analytical strength.

Despite this shift burgeons unprecedented creative opportunities, it concurrently unveils fundamental challenges (Verganti et al., 2020; Weisz et al., 2023) concerning potential impact on creative and cultural products, which are not simply consumer goods but they act as genuine devices of symbolic and cultural mediation (Branzi, 2007; Kubler, 2008). With AI in creative processes, these products are now being shaped by or within any potential AI's bias and perspectives.

Indeed, the literature widely acknowledges that digital technologies like AI have agency, this means that they transform, translate, distort, and modify the meaning of elements they are supposed to carry (Latour, 2007). In addition, ethical data management, bias mitigation (Harrison et al., 2019; Ntoutsis et al., 2020; Siau & Wang, 2020) and decision-making transparency, as well as designers' role as involuntary and often unwitting 'trainers' of 'learning machines' will probably have a profound impact on the future of design practice. This evolution in design, where the underlying rules and algorithms take precedence over the creation of artifacts, signifies a profound departure from the conventional paradigm of computer-aided design to a realm of digitally mediated design. The implications of this transition are multifaceted and far-reaching. Designers are now required to engage with the complex and often opaque algorithms that drive AI-based tools. This necessitates a deeper understanding of AI technologies, not just as instruments of efficiency or creativity but as active agents that can shape the outcome of the design process in significant ways. This recalls an expansion in the skill sets required for design professionals, with a comprehensive understanding of AI, data analytics, and programming. These skills are essential for effective interaction with AI systems and for leveraging AI-driven insights in the design process. This new dynamic challenges designers to maintain a balance between their creative intuition and the data-driven insights provided by AI. It requires a nuanced understanding of how AI processes and interprets data, and an awareness of how these interpretations can influence design outcomes.

Furthermore, this transition brings to the forefront the broader ethical and cultural implications of design work that need further investigation. In the realm of this contribution, it is important to highlight that systems are fed with data that may carry inherent biases, designers with AI should be (and know how to be) vigilant about the potential for these biases to be reflected in their designs. This raises ethical questions about representation, inclusivity, and the societal impact of design.

In summary, the shift to a digitally mediated design process redefines the essence of design practice. It requires designers to be interpreters and custodians of the complex interplay between human creativity and machine intelligence. This paradigm shift presents an opportunity for designers to explore new creative frontiers, while also imposing a responsibility to ensure that their work remains ethical, culturally sensitive, and socially responsible in an increasingly AI-driven world.

3. Changes and Challenges

The shift from traditional and human-centric design processes to digitally mediated and algorithmically-driven practices demands a critical exploration into the role, value, and nature of human thought, creativity, and ethical considerations within the AI-augmented design landscape. Following this streamline, recent studies in the creative research field, highlight the profound impact of AI on creativity, transforming its five core elements: actor, process, outcome, domain, and space (Wingström et al., 2023). With AI's integration, actors now include both humans and machines; processes are influenced by algorithms; outcomes merge human and AI contributions; domains extend into digital realms; and creative spaces blend the physical with the virtual. In essence, AI is becoming a partner, an extension, a material, and a medium, reshaping the very essence of creative practices (Särmäkari & Vänskä, 2022).

In the 'traditional' design process, creativity dynamically emerges, often marked by 'creative leaps' that transition ideas from conception to realisation (Dorst & Cross, 2001). Designers explore possibilities through iterative sketching, prototyping, and refinement, navigating various solution pathways and overcoming creativity obstacles (Boden, 2004; Cross, 2006; McKelvey & Munslow, 2011; Hopkins, 2021). Moreover, scholars acknowledge that 'traditional' design approaches are deeply rooted in human intuition and experience (Cross, 2004; Lawson & Dorst, 2013; Särmäkari, 2021; Bruce et al., 2002), and the ability to envision beyond the tangible and the explicit through tacit and technical knowledge. Despite its advanced capabilities, AI still lacks essential elements of creativity, such as intention, motivation, self-assessment, and the capacity to interpret outcomes or discern innovation (Davis, 2013; Aoki, 2021; Mitchell et al., 2019). This brings forth the intricate debate surrounding consciousness and whether AI can genuinely manifest it. However, it is essential to note that AI does not necessarily need to be 'intelligent' to contribute to the creative process. Design can still uncover novel and intriguing possibilities through collaboration with AI. This perspective aligns with posthumanist theories, where the creative product is a joint endeavour, co-constructed through the symbiotic interaction between design and AI (Ihde, 1990; Latour, 2013; Rose, 2017).

Hence, while it is not possible to decelerate technological advancement, comprehending it becomes crucial to navigating it in orientation. It is significant, thereby, harnessing the potential of AI to enhance, rather than undermine, the cultural and creative processes intrinsic to design practices. This means recognising the growing influence of the tech-computational domain, advocating collaboration over replacement, studying processes and establishing frameworks that steer technology integration in an informed, ethical manner and are aware of its broader impacts, especially in domains intersecting with cultural and social identity, such as design (Symbola Foundation, 2023).

Those challenges underscore the significance of multidisciplinary collaboration in tackling a multifaceted issue that instigates ontological and epistemological reorientations. The burgeoning weight characterised by the technological-computational realm also envelops the sphere of problem-solving, increasingly entrusted to AI, data, and computational capacity. Consequently, it becomes crucial to embrace the transformation through disciplinary collaboration between the mathematical-computational and design fields to address various emerging questions in this new scenario, which pushes the question: 'What kind of thinking is left to humans in innovation?' (Verganti et al., 2020, p. 224).

3.1 Human-Centricity vs. Algorithmic Design

The integration of AI into design practices marks a significant transition from human-centricity to algorithmic design, a change that presents a wide array of ethical and social challenges. This shift is not merely about adopting new technologies but fundamentally rethinking the design process itself. Design approaches, which have predominantly centred around human intuition, experience, and creativity, are now evolving to incorporate algorithmically-driven methodologies that leverage AI's computational power.

This pivotal shift necessitates a deep dive into several critical areas. First and foremost among these is the ethical management of data. As AI systems rely heavily on data for learning and decision-making, the integrity and fairness of this data become paramount. This recalls the works of Harrison et al. (2019),

Ntoutsis et al. (2020), and Siau & Wang (2020), who pointed out the importance of bias mitigation in AI systems. The risk of AI inheriting and amplifying existing biases present in the data is a significant issue, which, if unaddressed, can lead to skewed and unfair outcomes.

Additionally, the transparency of decision-making in AI-driven design is a crucial concern. As design processes become more reliant on algorithms, understanding the rationale behind AI-generated decisions is essential. This transparency is not only important for the designers to retain control over the design process but also for end-users and stakeholders who need to trust and understand the products created through these methods. As AI takes on more responsibilities in the design process, there is a risk of underestimating the unique qualities that human designers bring to the table like empathy, contextual understanding, and creative intuition that are, as of yet, beyond the reach of AI.

In essence, the integration of AI into design practices is not just about harnessing a new set of tools; it is about striking a balance between the efficiency and capabilities of AI and the irreplaceable value of human insight and creativity. This balance is crucial in maintaining the integrity, ethicality, and quality of design in an age increasingly influenced by algorithmic methodologies.

3.2 Integrating AI in Design Cultures

While the role of AI is prominent in the industrialisation phases of design production processes, its application in the ideational and creative phases remains less explored. This expansion of AI's application requires a careful examination of its potential to contribute to every stage of the design process, acknowledging that AI can offer more than just efficiency and automation and recognising that every stage of the design process is potentially computable.

One of the critical areas in this exploration is understanding the impact of AI on authorship in design. As AI systems can generate design elements autonomously, questions arise about the originality and ownership of such creations. This challenge necessitates a redefinition of authorship in the context of AI-generated content, where the role of the designer may shift from being the sole creator to a curator or editor of AI-generated options. Copyright issues also emerge as AI becomes more involved in creative processes. The legal framework surrounding AI-generated content is still evolving, and there's a need for clarity on how copyright laws apply to designs partially or wholly created by AI (Pasa, 2023). This area requires ongoing dialogue among legal experts, designers, and technologists to establish clear guidelines and standards. Furthermore, the agency of AI in design, where AI systems make decisions or suggest design alternatives, poses a challenge. This situation calls for a balance between leveraging AI's computational power and maintaining the designer's creative control and judgment. It involves understanding and setting the appropriate boundaries for AI's role in the design process, ensuring that AI acts as an enhancer of human creativity rather than a replacement.

Integrating AI into design cultures is not just about adopting a new set of tools; it's about navigating a complex landscape of ethical, legal, and creative challenges. It requires designers to adapt and develop new ways of working, where AI is a collaborator that brings computational power to the creative process, but human creativity, judgement, and ethical considerations remain at the forefront.

3.3 Avoiding the AI Black Box

Addressing the issue of the AI Black Box is critical in the context of design practices. The term 'AI Black Box' refers to situations where the decision-making process of AI systems is opaque (Castelvecchi, 2016; von Eschenbach, 2021), leading to a lack of transparency and understanding about how AI algorithms arrive at certain conclusions or design solutions. This opacity can be problematic, particularly in fields like design, where the rationale behind each decision can significantly impact the final product.

To navigate and mitigate the challenges posed by the AI Black Box, it's essential to prioritise the development and use of AI systems that are transparent and interpretable. This means designing AI

algorithms in a way that their decision-making processes can be easily understood and explained, not just by AI specialists but also by designers and stakeholders involved in the design process. Transparency in AI facilitates a more collaborative and trustful relationship between human designers and AI systems, ensuring that AI is a tool that enhances, rather than obscures, the creative process. One approach to avoiding the AI Black Box in design is to implement explainable AI (XAI). XAI refers to techniques and methods that make the outputs of AI systems more understandable to humans. This involves creating AI systems that can provide understandable reasons for their decisions or suggestions, allowing designers to make informed choices about whether to follow these suggestions or take a different path. Moreover, as anticipated, avoiding the AI Black Box also involves educating designers about the basics of AI and machine learning. By understanding how AI systems learn, process data, and make decisions, designers can better anticipate and interpret the outputs of these systems. This knowledge is crucial for effectively integrating AI into the design process in a way that is both productive and responsible.

Furthermore, there is a need for continuous monitoring and evaluation of AI systems to ensure that they function as intended and do not inadvertently introduce biases or errors into the design process. Regular audits and updates can help in identifying and correcting any issues that arise, maintaining the integrity and reliability of AI-assisted design processes.

4. Conclusions

The integration of Artificial Intelligence (AI) into the design discipline marks a significant paradigm shift, bringing forth complex challenges and new opportunities. As we delve deeper into this era of digital transformation, the relationship between human creativity and algorithmic processes becomes increasingly intertwined, necessitating continuous study and adaptation.

The evolving dynamics of human-AI interaction in design highlight a transformative shift from traditional, human-centric methodologies to more algorithmically driven practices. This transition is not just about harnessing a new set of tools; it represents a fundamental rethinking of the design process itself. It demands a critical exploration into the ethical management of data, bias mitigation, and decision-making transparency. These aspects are crucial in maintaining the integrity and authenticity of design outputs in an increasingly AI-dominated landscape. It is evident that the technical possibilities offered by computational technologies have consequences beyond the technical area. They intervene in thoughts, approaches, and generation of ideas determining new ways of defining things and their relations. Hence, AI intervenes substantially in the methods and tools to 'make' artifacts, i.e. on the entire design process, raising critical questions about the ways design designs (Giaccardi & Redstrom, 2020).

Moreover, the necessity to continue studying this integration is crucial. As AI technologies evolve, so too must our understanding and methodologies. The field of design must embrace this change, fostering an environment where AI is not seen as a replacement for human creativity but as a collaborator that enhances and expands creative possibilities. This requires a balance, ensuring that AI's computational power is harmonised with human intuition and creativity.

Educational and professional frameworks within the design discipline must evolve to accommodate these changes. This includes integrating AI literacy into design curricula and professional development programs, ensuring that upcoming generations of designers are equipped to navigate this new landscape. Additionally, interdisciplinary collaboration becomes vital, bringing together expertise from fields such as computer science, cognitive psychology, and ethics to address the multifaceted nature of AI in design. Furthermore, the ethical and cultural implications of AI integration in design need continuous scrutiny. As AI systems increasingly influence the creative process, it becomes essential to ensure that these technologies are used responsibly, respecting cultural diversity and social values.

Hence, the journey of integrating AI into design is ongoing and dynamic. It presents a world of possibilities, redefining the essence of creativity and innovation in the design field. However, it also poses significant challenges that must be thoughtfully addressed. In fact, despite the suggestive more-than-human

experiences provided by AI, we are still experimenting with it, often producing risky, concerning, and undesired results (Taddeo & Floridi, 2018). The future of design in the AI era is not just about technological advancement; it's about shaping a future where technology enhances human creativity in ethical, responsible, and culturally sensitive ways.

References

- Aziz, N. A., Adnan, N. A. A., Wahab, D. A., & Azman, A. H. (2021). Component design optimisation based on artificial intelligence in support of additive manufacturing repair and restoration: Current status and future outlook for remanufacturing. *Journal of Cleaner Production*, 296, 126401. <https://doi.org/10.1016/j.jclepro.2021.126401>
- Anantrasirichai, N., & Bull, D. (2022). Artificial intelligence in the creative industries: A review. *Artificial Intelligence Review*, 55, 589–656. <https://doi.org/10.1007/s10462-021-10039-7>
- Cantamessa, M., Montagna, F., Altavilla, S., & Casagrande-Seretti, A. (2020). Data-driven design: The new challenges of digitalization on product design and development. *Design Science*, 6. <https://doi.org/10.1017/dsj.2020.25>
- Castelvecchi, D. (2016). Can we open the black box of AI? *Nature*, 538(7623), 20–23. <https://doi.org/10.1038/538020a>
- Cross, N. (2004). Expertise in design: An overview. *Design Studies*, 25(5), 427–441. <https://doi.org/10.1016/j.destud.2004.06.002>
- Cross, N. (2006). Designerly ways of knowing. In *Springer eBooks* (pp. 1–13). https://doi.org/10.1007/1-84628-301-9_1
- Daniele, A., & Song, Y. Z. (2019). AI + Art = Human. <https://doi.org/10.1145/3306618.3314233>
- Dove, G., Halskov, K., Forlizzi, J., & Zimmerman, J. (2017). UX design innovation. <https://doi.org/10.1145/3025453.3025739>
- Dufva, T., & Dufva, M. (2019). Grasping the future of the digital society. *Futures*, 107, 17–28. <https://doi.org/10.1016/j.futures.2018.11.001>
- Esling, P., & Devis, N. (2020). Creativity in the era of artificial intelligence. *arXiv Preprint*, arXiv:2008.05959.
- Fujita, M. (2017). AI and the future of the brain power society: When the descendants of Athena and Prometheus work together. *Review of International Economics*, 26(3), 508–523. <https://doi.org/10.1111/roie.12310>
- Giaccardi, E., & Redström, J. (2020). Technology and more-than-human design. *Design Issues*, 36(4), 33–44. https://doi.org/10.1162/desi_a_00612
- Harrison, T., Luna-Reyes, L. F., Pardo, T., De Paula, N., Najafabadi, M., & Palmer, J. (2019). The data firehose and AI in government. <https://doi.org/10.1145/3325112.3325245>
- Holmquist, L. E. (2017). Intelligence on tap. *Interactions*, 24(4), 28–33. <https://doi.org/10.1145/3085571>
- Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. *SAGE Open*, 11(3), 215824402110475. <https://doi.org/10.1177/21582440211047576>

Kuhn, T. (1962). The nature and necessity of scientific revolutions. In T. Kuhn, *The Structure of Scientific Revolutions* (pp. 92–110). Chicago University Press.

Lawson, B., & Dorst, K. (2013). *Design expertise*. Routledge. <https://doi.org/10.4324/9781315072043>

Lubart, T. (2005). How can computers be partners in the creative process: Classification and commentary on the special issue. *International Journal of Human-Computer Studies*, 63(4–5), 365–369. <https://doi.org/10.1016/j.ijhcs.2005.04.002>

Magistretti, S., Dell’Era, C., & Petruzzelli, A. M. (2019). How intelligent is Watson? Enabling digital transformation through artificial intelligence. *Business Horizons*, 62(6), 819–829. <https://doi.org/10.1016/j.bushor.2019.08.004>

Mazzone, M., & Elgammal, A. (2019). Art, creativity, and the potential of artificial intelligence. *Arts*, 8(1), 26. <https://doi.org/10.3390/arts8010026>

Miller, A. I. (2020). Creativity in the age of AI: Computers and artificial neural networks are redefining the relationship between art and science. *American Scientist*, 108(4), 244–249. <https://doi.org/10.1511/2020.108.4.244>

Nishant, R., Kennedy, M., & Corbett, J. (2020). Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *International Journal of Information Management*, 53, 102104. <https://doi.org/10.1016/j.ijinfomgt.2020.102104>

Ntoutsis, E., Fafalios, P., Gadiraju, U., Iosifidis, V., Nejd, W., Vidal, M. E., Ruggieri, S., Turini, F., Papadopoulos, S., Krasanakis, E., Kompatsiaris, I., Kinder-Kurlanda, K., Wagner, C., Karimi, F., Fernandez, M., Alani, H., Berendt, B., Kruegel, T., Heinze, C., & Staab, S. (2020). Bias in data-driven artificial intelligence systems—An introductory survey. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, 10(3), e1356. <https://doi.org/10.1002/widm.1356>

Pasa, B. (2023). A.I., fashion design and the law. *Fashion Highlight*, 2, 30–43. <https://doi.org/10.36253/fh-2498>

Siau, K., & Wang, W. (2020). Artificial intelligence (AI) ethics: Ethics of AI and ethical AI. *Journal of Database Management (JDM)*, 31(2), 74–87. <https://doi.org/10.4018/JDM.2020040105>

Stolterman, E. (2008). The nature of design practice and implications for interaction design research. *International Journal of Design*, 2(1), 55–65. <http://umu.diva-portal.org/smash/record.jsf?pid=diva2:207410>

Symbola Foundation. (2023). *Rapporto 2023*. <https://symbola.net/wp-content/uploads/2023/07/io-sono-cultura-2023-def-1.pdf>

Taddeo, M., & Floridi, L. (2018). How AI can be a force for good. *Science*, 361(6404), 751–752. <https://doi.org/10.1126/science.aat5991>

Tedeschi, A., & Lombardi, D. (2017). The algorithms-aided design (AAD). In *Springer eBooks* (pp. 33–38). https://doi.org/10.1007/978-3-319-53135-9_4

Thompson, M. K., Moroni, G., Vaneker, T., Fadel, G., Campbell, R. I., Gibson, I., Bernard, A., Schulz, J., Graf, P., Ahuja, B., & Martina, F. (2016). Design for additive manufacturing: Trends, opportunities, considerations, and constraints. *CIRP Annals*, 65(2), 737–760. <https://doi.org/10.1016/j.cirp.2016.05.004>

Verganti, R., Vendraminelli, L., & Iansiti, M. (2020). Innovation and design in the age of artificial intelligence. *Journal of Product Innovation Management*, 37(3), 212–227. <https://doi.org/10.1111/jpim.12523>

Van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI and Ethics*, 1(3), 213–218. <https://doi.org/10.1007/s43681-021-00043-6>

Von Eschenbach, W. J. (2021). Transparency and the black box problem: Why we do not trust AI. *Philosophy & Technology*, 34(4), 1607–1622. <https://doi.org/10.1007/s13347-021-00477-0>

Weisz, J. D., Muller, M., He, J., & Houde, S. (2023). Toward general design principles for generative AI applications. *arXiv Preprint*, arXiv:2301.05578. <https://doi.org/10.48550/arxiv.2301.05578>

Wensveen, S., & Matthews, B. (2014). Prototypes and prototyping in design research. In *Routledge eBooks* (pp. 262–276). <https://doi.org/10.4324/9781315758466-25>

Wingström, R., Hautala, J., & Lundman, R. (2022). Redefining creativity in the era of AI? Perspectives of computer scientists and new media artists. *Creativity Research Journal*, 1–17. <https://doi.org/10.1080/10400419.2022.2107850>

Wu, C. J., Raghavendra, R., Gupta, U., Acun, B., Ardalani, N., Maeng, K., Chang, G., Behram, F. A., Huang, J., Bai, C., Gschwind, M., Gupta, A., Ott, M., Melnikov, A., Candido, S., Brooks, D., Chauhan, G., Lee, B., Lee, H. H. S., & Hazelwood, K. (2021). Sustainable AI: Environmental implications, challenges and opportunities. *arXiv Preprint*, arXiv:2111.00364. <https://doi.org/10.48550/arxiv.2111.00364>

Xiong, Y., Duong, P. L. T., Wang, D., Park, S. I., Ge, Q., Raghavan, N., & Rosen, D. W. (2019). Data-driven design space exploration and exploitation for design for additive manufacturing. *Journal of Mechanical Design*, 141(10). <https://doi.org/10.1115/1.4043587>

Yildirim, N., Kass, A., Tung, T., Upton, C., Costello, D., Giusti, R., Lacin, S., Lovic, S., O'Neill, J. M., Meehan, R. O., Loideáin, E., Pini, A., Corcoran, M., Hayes, J., Cahalane, D. J., Shivhare, G., Castoro, L., Caruso, G., Oh, C., & Zimmerman, J. (2022). How experienced designers of enterprise applications engage AI as a design material. *CHI Conference on Human Factors in Computing Systems*. <https://doi.org/10.1145/3491102.3517491>

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