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Generative AI as a Creative Partner: Qualitative Perspectives on Sustainability-Oriented Design Solutions

Monira Yesmin Tuli^{*1}; Safayed Hossain¹; Kazi Abdul Mannan²

The rapid evolution of generative artificial intelligence (AI) is reshaping contemporary design practices by positioning AI as a collaborative creative partner rather than a passive tool. This study examines the role of generative AI in sustainability-oriented design, focusing on how human-AI co-creation enhances innovation, efficiency, and environmental responsibility. Adopting a qualitative research methodology based on secondary data, the study synthesises insights from academic literature, industry reports, and documented case studies. The findings reveal that generative AI significantly expands ideation processes, supports data-driven optimisation, and accelerates iterative design cycles, thereby contributing to more sustainable design outcomes. However, the study also identifies critical challenges, including ethical concerns, algorithmic bias, lack of transparency, and the environmental cost of AI computation. Drawing on creative systems theory, socio-technical systems theory, and sustainability transition theory, the research proposes an integrated conceptual framework that situates generative AI as a mediator of creativity within sustainability-focused design ecosystems. The study concludes that while generative AI offers transformative potential, its effective integration requires responsible governance, interdisciplinary collaboration, and sustained human oversight to ensure alignment with long-term sustainability goals.

Keywords: Generative AI, Sustainable Design, Human-AI Collaboration, Computational Creativity, Socio-Technical Systems, Environmental Innovation, Design Optimisation

¹Department of Graphic Design & Multimedia

²Department of Business Administration

Shanto-Mariam University of Creative Technology. Dhaka, Bangladesh

*Corresponding author: Monira Yesmin Tuli, Email: monira.yesmin025@gmail.com

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1. Introduction

The rapid advancement of artificial intelligence (AI) technologies has fundamentally transformed the nature of creative work, particularly in design disciplines. Among the various AI paradigms, generative AI systems capable of producing novel outputs such as images, text, simulations, and design prototypes have emerged as a powerful force in reshaping how designers conceptualise and implement solutions. Unlike traditional computational tools that primarily assist in execution, generative AI operates as an active collaborator, capable of proposing alternatives, generating design variations, and contributing to the ideation process itself (Goodfellow et al., 2014; McCormack et al., 2019).

This transformation is particularly significant in the context of sustainability-oriented design. Sustainability has become a central concern across disciplines due to escalating environmental challenges, including climate change, biodiversity loss, and resource depletion. Designers are increasingly expected to create solutions that not only meet functional and aesthetic requirements but also minimise environmental impact and contribute to long-term ecological balance (Bocken et al., 2016; Geissdoerfer et al., 2017). However, sustainability-oriented design is inherently complex, requiring the integration of diverse data sources, lifecycle considerations, and interdisciplinary knowledge.

Generative AI offers new possibilities for addressing this complexity. By leveraging large datasets and advanced algorithms, AI systems can simulate environmental scenarios, optimise resource usage, and generate innovative design alternatives that may not be immediately apparent to human designers. For example, AI-driven generative design tools in architecture and product development can explore thousands of design permutations, identifying configurations that maximise efficiency while minimising material consumption (Brown et al., 2020). This capability positions generative AI as a potentially transformative tool in advancing sustainable design practices.

At the same time, the integration of generative AI into creative processes raises critical questions about the nature of creativity, authorship, and human agency. Traditionally, creativity has been understood as a uniquely human capacity, rooted in intuition, experience, and cultural context. The emergence of AI systems capable of generating original content challenges this assumption, suggesting that creativity may be a distributed process involving both human and machine contributions (Csikszentmihalyi, 1996; Boden, 2004). This shift necessitates a re-evaluation of the designer's role, moving from sole creator to co-creator or curator of AI-generated outputs.

Moreover, the use of generative AI in sustainability-oriented design introduces ethical and environmental considerations that must be critically examined. While AI can support sustainable outcomes, the computational resources required for training and deploying AI models can have significant

environmental impacts, including high energy consumption and carbon emissions (Strubell et al., 2019). Additionally, issues related to data bias, transparency, and accountability may influence the reliability and fairness of AI-generated design solutions (Floridi et al., 2018).

Given these opportunities and challenges, there is a growing need to understand how generative AI functions as a creative partner in sustainability-oriented design. While existing research has explored AI in design and sustainability separately, fewer studies have examined their intersection from a qualitative perspective. This study seeks to address this gap by analysing how generative AI influences design processes, enhances sustainability outcomes, and reshapes human-AI collaboration.

The research adopts a qualitative methodology based on secondary data, synthesising insights from academic literature, industry reports, and case studies. This approach enables a comprehensive examination of the evolving role of generative AI in design, drawing on diverse sources to identify patterns, themes, and implications.

The objectives of this study are threefold. First, it aims to explore the role of generative AI in enhancing creativity and innovation in sustainability-oriented design. Second, it seeks to analyse the dynamics of human-AI collaboration and their impact on design practices. Third, it aims to identify the ethical, environmental, and socio-technical implications of integrating generative AI into sustainable design processes.

By addressing these objectives, the study contributes to the broader discourse on AI and sustainability, offering a conceptual framework that integrates creativity, technology, and environmental responsibility. The findings are expected to inform designers, researchers, and policymakers about the potential and limitations of generative AI as a creative partner, highlighting the importance of responsible and ethical AI use in achieving sustainable development goals.

2. Literature Review

Generative AI has gained increasing attention in design research due to its ability to produce novel and diverse outputs based on learned patterns from large datasets. Techniques such as generative adversarial networks (GANs), variational autoencoders (VAEs), and transformer-based models have enabled the creation of complex visual, textual, and structural designs (Goodfellow et al., 2014; Brown et al., 2020). These technologies have been applied across various design domains, including architecture, industrial design, fashion, and urban planning.

In design practice, generative AI shifts the role of designers from creators to facilitators or curators of machine-generated content. McCormack et al. (2019) argue that AI systems can act as creative collaborators, offering suggestions and alternatives that expand the designer's creative space. This co-creative process allows designers to explore a wider range of possibilities, enhancing innovation and reducing cognitive constraints.

Furthermore, generative design tools enable iterative exploration by rapidly generating and evaluating multiple design options. This capability is particularly valuable in complex design problems where multiple objectives—such as cost, performance, and sustainability—must be balanced. As a result, generative AI is increasingly seen as a key enabler of advanced design methodologies.

2.1 Creativity and Computational Systems

The integration of AI into creative processes has led to new perspectives on the nature of creativity. Traditional theories of creativity emphasise human cognition, imagination, and cultural context (Csikszentmihalyi, 1996). However, computational creativity research suggests that machines can also exhibit creative behaviours by generating novel and valuable outputs (Boden, 2004).

Boden (2004) distinguishes between different types of creativity, including combinational, exploratory, and transformational creativity. Generative AI systems are particularly effective in combinational and exploratory creativity, where they recombine existing elements or explore predefined design spaces. While transformational creativity—creating entirely new paradigms—remains largely human-driven, AI can still contribute by expanding the boundaries of exploration.

The concept of co-creativity has emerged as a key framework for understanding human-AI interaction. In this context, creativity is viewed as a collaborative process involving both human and machine contributions. Studies indicate that AI can enhance human

creativity by providing inspiration, reducing cognitive load, and enabling rapid prototyping (Daugherty & Wilson, 2018). However, concerns remain about the potential loss of human agency and the risk of over-reliance on AI systems.

2.2 Sustainability-Oriented Design

Sustainability-oriented design focuses on minimising environmental impact while promoting social and economic well-being. It encompasses various approaches, including eco-design, circular design, and regenerative design (Geissdoerfer et al., 2017). These approaches emphasise resource efficiency, lifecycle thinking, and systemic integration.

Bocken et al. (2016) identify sustainable business model archetypes that guide the development of environmentally responsible solutions. These archetypes include maximising material efficiency, creating value from waste, and adopting renewable resources. Designers play a critical role in implementing these principles, as design decisions significantly influence environmental outcomes.

Despite its importance, sustainability-oriented design presents several challenges. Designers must consider complex and often conflicting factors, such as environmental impact, cost, and user needs. Additionally, the lack of accessible data and tools can limit the ability to make informed decisions. This complexity highlights the need for advanced technologies that can support sustainable design processes.

2.3 AI for Sustainable Design

The application of AI in sustainable design has been explored in various contexts. AI-driven optimisation algorithms can improve energy efficiency in buildings, reduce material usage in products, and enhance resource management in urban systems. For example, generative design tools in architecture can optimise building structures to minimise energy consumption and material waste (Brown et al., 2020).

AI can also support lifecycle assessment by analysing large datasets and identifying patterns that inform sustainable decision-making. This capability enables designers to evaluate the environmental impact of different design options and select the most sustainable solutions.

However, the use of AI in sustainability is not without challenges. Strubell et al. (2019) highlight the environmental cost of training large AI models, which can result in significant carbon emissions. This paradox raises questions about the sustainability of AI itself and underscores the need for energy-efficient algorithms and practices.

2.4 Human-AI Collaboration in Design

Human-AI collaboration is a central theme in contemporary design research. Daugherty and Wilson (2018) propose that the future of work lies in the integration of human and machine capabilities, where each complements the other's strengths. In design, this collaboration enables more efficient and innovative processes.

AI systems excel at processing large datasets, identifying patterns, and generating alternatives, while humans provide contextual understanding, ethical judgment, and creative intuition. This complementary relationship enhances decision-making and problem-solving.

Nevertheless, collaboration also introduces challenges related to trust, transparency, and accountability. Designers must understand how AI systems generate outputs and ensure that these outputs align with ethical and sustainability goals. The lack of transparency in some AI models, often referred to as the "black box" problem, can hinder trust and adoption (Floridi et al., 2018).

2.5 Ethical and Socio-Technical Considerations

The integration of generative AI into design processes raises important ethical and socio-technical issues. Floridi et al. (2018) emphasise the need for ethical frameworks that address issues such as data privacy, bias, and accountability. In sustainability-oriented design, these concerns are particularly significant, as design decisions can have far-reaching environmental and social impacts.

Socio-technical systems theory provides a useful lens for understanding these challenges. It highlights the interconnectedness of social and technological elements, emphasising that technological innovations must be aligned with social values and institutional structures (Trist, 1981).

In addition, the environmental impact of AI technologies must be considered. While AI can support sustainable outcomes, its energy

consumption and resource requirements may offset some of these benefits. This tension underscores the importance of developing sustainable AI practices that minimise environmental impact.

3. Theoretical Framework

The exploration of generative artificial intelligence (AI) as a creative partner in sustainability-oriented design requires an interdisciplinary theoretical grounding that captures the complexity of human creativity, technological mediation, and sustainability transitions. This study adopts an integrated theoretical framework combining creative systems theory, socio-technical systems theory, and sustainability transition theory. Together, these perspectives provide a comprehensive lens for understanding how generative AI reshapes design practices and influences sustainable outcomes.

3.1 Creative Systems Theory

Creative systems theory, as articulated by Csikszentmihalyi (1996), conceptualises creativity as a systemic phenomenon emerging from the interaction between three components: the individual (creator), the domain (cultural knowledge), and the field (social institutions that validate creativity). This perspective challenges the notion of creativity as an isolated cognitive process and instead emphasises its distributed and socially embedded nature.

In the context of generative AI, creative systems theory is particularly relevant because it allows for the inclusion of AI as part of the creative system. Rather than viewing AI as merely a tool, it can be

conceptualised as an active participant that contributes to idea generation and exploration. Generative AI systems, trained on vast datasets, effectively embody aspects of the “domain,” as they encode patterns, styles, and knowledge from existing design practices (Boden, 2004). When designers interact with these systems, they engage in a co-creative process that expands the boundaries of the design space.

Furthermore, computational creativity research suggests that AI can perform combinational and exploratory creativity by recombining existing elements and navigating design possibilities (Boden, 2004). While AI may not possess intentionality or consciousness, its ability to generate novel outputs challenges traditional definitions of creativity and supports the notion of distributed creativity. In sustainability-oriented design, this expanded creative capacity enables designers to explore innovative solutions that address complex environmental challenges.

3.2 Socio-Technical Systems Theory

Socio-technical systems theory provides a framework for understanding the interaction between social and technological elements within complex systems. Originating from the work of Trist (1981), the theory emphasises that technological innovations cannot be understood in isolation but must be analysed in relation to social structures, organisational practices, and human values.

In the case of generative AI, socio-technical systems theory highlights the importance of considering not only the capabilities of AI technologies but also the contexts in which

they are deployed. Design practices are embedded within organisational, cultural, and institutional environments that shape how AI tools are used and interpreted. For example, the adoption of generative AI in sustainable design may depend on factors such as organisational priorities, regulatory frameworks, and professional norms.

This perspective also underscores the importance of human agency in AI-mediated systems. While generative AI can produce design alternatives and optimise solutions, human designers remain responsible for interpreting outputs, making decisions, and ensuring alignment with sustainability goals. As Daugherty and Wilson (2018) argue, the most effective outcomes arise from a complementary relationship between human and machine capabilities, where each enhances the other's strengths.

Moreover, socio-technical systems theory draws attention to issues of power, ethics, and accountability. The use of AI in design raises questions about who controls the technology, whose values are embedded in the algorithms, and how decisions are justified. These considerations are particularly critical in sustainability-oriented design, where decisions can have significant environmental and social impacts (Floridi et al., 2018).

3.3 Sustainability Transition Theory

Sustainability transition theory focuses on the systemic changes required to move from unsustainable to sustainable modes of production and consumption. Geels (2002) introduces the multi-level perspective (MLP), which conceptualises transitions as interactions between three levels: niches

(innovations), regimes (established systems), and landscapes (broader socio-economic context).

Generative AI can be understood as a niche innovation that has the potential to disrupt existing design regimes. By enabling new forms of creativity, optimisation, and decision-making, AI technologies can challenge traditional design practices and contribute to more sustainable outcomes. For example, generative design tools can optimise resource use and reduce waste, aligning with the goals of the circular economy and sustainable development (Geissdoerfer et al., 2017).

However, the integration of generative AI into sustainability transitions is not automatic. It requires alignment with existing systems, including policies, institutions, and cultural practices. Additionally, the environmental impact of AI technologies themselves must be considered, as high energy consumption and resource demands may offset sustainability benefits (Strubell et al., 2019).

Sustainability transition theory also emphasises the role of interdisciplinary collaboration and innovation in achieving systemic change. The integration of generative AI into design practices requires collaboration between designers, engineers, policymakers, and other stakeholders. This interdisciplinary approach is essential for addressing the complex and interconnected challenges of sustainability.

3.4 Integrated Conceptual Framework

Drawing on these theoretical perspectives, this study proposes an integrated conceptual framework in which generative AI functions as a creative mediator within a socio-technical system oriented toward sustainability transitions. In this framework:

- **Generative AI** acts as an enabler of creativity and innovation, expanding the design space and supporting data-driven decision-making.
- **Human designers** serve as interpreters, curators, and ethical decision-makers, ensuring that AI-generated outputs align with contextual and sustainability considerations.
- **Sustainability goals** provide the guiding principles that shape the direction and evaluation of design solutions.

This integrated framework highlights the dynamic interplay between human creativity, technological capabilities, and sustainability objectives. It underscores the importance of maintaining human oversight and ethical responsibility while leveraging the capabilities of generative AI.

4. Research Methodology

This study adopts a qualitative research design grounded in interpretivist epistemology, which emphasises the understanding of complex phenomena through the interpretation of meanings and experiences (Creswell & Poth, 2018). Given the exploratory nature of the research and the

emerging status of generative AI in sustainability-oriented design, a qualitative approach is appropriate for capturing nuanced insights and identifying patterns across diverse contexts.

The research employs secondary data analysis, focusing on existing literature, case studies, and industry reports. This approach allows for a comprehensive synthesis of knowledge from multiple sources, enabling the identification of trends and themes that may not be evident in individual studies.

4.1 Data Sources and Selection Criteria

The study draws on a wide range of secondary data sources, including:

- Peer-reviewed journal articles from databases such as Scopus and Web of Science
- Conference proceedings related to AI, design, and sustainability
- Industry reports from technology and design organisations
- Documented case studies of generative AI applications in design

To ensure relevance and quality, the following inclusion criteria were applied:

- Publications focusing on generative AI, computational creativity, or AI-assisted design
- Studies addressing sustainability, eco-design, or circular design
- Sources published in English between 2010 and 2025
- Peer-reviewed or reputable industry publications

Exclusion criteria included sources lacking methodological rigour, outdated technologies, or limited relevance to the research objectives.

4.2 Data Collection Procedure

Data collection involved a systematic search strategy using keywords such as “generative AI,” “sustainable design,” “AI creativity,” “human-AI collaboration,” and “computational design.” Boolean operators (AND, OR) were used to refine search results and ensure comprehensive coverage.

The initial search yielded a large number of sources, which were then screened based on titles and abstracts. Relevant studies were selected for full-text review, resulting in a curated dataset of high-quality sources. This process aligns with best practices in qualitative secondary research and ensures transparency and replicability (Johnston, 2017).

4.3 Data Analysis Method

The study employs thematic analysis, a widely used qualitative method for identifying, analysing, and interpreting patterns within data (Braun & Clarke, 2006). The analysis followed a six-step process:

- **Familiarisation:** Reading and re-reading selected sources to gain an overall understanding
- **Coding:** Identifying relevant concepts and assigning codes to key segments of text
- **Theme Development:** Grouping codes into broader themes related to generative AI and sustainability

- **Reviewing Themes:** Refining themes to ensure coherence and relevance
- **Defining and Naming Themes:** Clearly articulating the meaning of each theme
- **Interpretation:** Relating themes to the theoretical framework and research objectives

Thematic analysis enables the integration of diverse perspectives and supports the development of a comprehensive understanding of the research topic.

4.4 Validity and Reliability

Ensuring the rigour of qualitative research is essential for producing credible and trustworthy findings. This study employs several strategies to enhance validity and reliability:

- **Triangulation:** Using multiple data sources to corroborate findings and reduce bias
- **Transparency:** Clearly documenting data collection and analysis procedures
- **Reflexivity:** Acknowledging the researcher’s role in interpreting data
- **Consistency:** Applying systematic coding and analysis methods

These measures align with established criteria for qualitative research quality (Lincoln & Guba, 1985).

4.5 Ethical Considerations

As a study based on secondary data, this research does not involve direct human participants and therefore does not require ethical approval for primary data collection.

However, ethical considerations remain important in terms of data use and representation.

The study ensures proper citation and acknowledgement of all sources, adhering to academic integrity standards. Additionally, care is taken to accurately represent the findings of original studies without misinterpretation or bias (Mannan & Farhana, 2026).

4.6 Limitations of the Methodology

While secondary data analysis offers several advantages, it also has limitations. The study relies on existing literature, which may reflect publication biases or gaps in research. Additionally, the lack of primary data limits the ability to capture firsthand experiences of designers using generative AI.

Despite these limitations, the methodology provides a robust foundation for exploring the research topic and generating insights that can inform future empirical studies.

5. Findings and Analysis

The qualitative thematic analysis of secondary data reveals that generative artificial intelligence (AI) plays a multifaceted role in sustainability-oriented design. The findings are organised into six major themes: generative AI as an ideation catalyst, optimisation and performance-driven sustainability, acceleration of iterative design processes, data-driven sustainability intelligence, human-AI co-creation dynamics, and emerging challenges and systemic limitations.

5.1 Generative AI as an Ideation Catalyst

One of the most prominent findings is the role of generative AI as a catalyst for ideation. Traditional design processes often rely on human cognitive capabilities, which are inherently limited by experience, bias, and time constraints. Generative AI systems, however, can rapidly produce a wide range of design alternatives by leveraging large datasets and probabilistic models (Goodfellow et al., 2014).

In sustainability-oriented design, this capability is particularly valuable because it enables designers to explore unconventional solutions that may not emerge through traditional brainstorming. For example, generative design tools in architecture can propose building forms optimised for natural lighting and ventilation, thereby reducing energy consumption (Brown et al., 2020). Similarly, AI-driven product design can suggest material combinations that minimise environmental impact while maintaining functionality.

From a theoretical perspective, this aligns with the concept of exploratory creativity, where AI systems navigate predefined design spaces to identify novel configurations (Boden, 2004). The findings suggest that generative AI expands the “possibility space” of design, allowing designers to consider a broader range of sustainable solutions.

However, the analysis also indicates that the quality of AI-generated ideas depends heavily on the training data and algorithms used. Biases in datasets can limit the diversity of outputs, potentially reinforcing existing

design paradigms rather than challenging them. Therefore, while generative AI enhances ideation, it does not fully eliminate the need for critical human evaluation.

5.2 Optimisation and Performance-Driven Sustainability

Another key finding is the role of generative AI in optimising design solutions for sustainability. AI systems can analyse complex datasets and simulate multiple scenarios, enabling designers to evaluate the environmental performance of different design options.

For instance, in architectural design, generative algorithms can optimise building structures to minimise material usage while maintaining structural integrity. This not only reduces resource consumption but also lowers carbon emissions associated with construction (Geissdoerfer et al., 2017). Similarly, in product design, AI can optimise manufacturing processes to reduce waste and energy consumption.

The findings highlight that generative AI facilitates a shift from intuition-based decision-making to data-driven optimisation. This aligns with the principles of sustainable design, which emphasise evidence-based approaches and lifecycle thinking (Bocken et al., 2016).

However, the analysis also reveals a potential tension between optimisation and creativity. While AI-driven optimisation can identify efficient solutions, it may prioritise quantifiable metrics over qualitative aspects such as aesthetics, cultural relevance, and user experience. This underscores the

importance of balancing algorithmic efficiency with human judgment.

5.3 Acceleration of Iterative Design Processes

The ability of generative AI to accelerate iterative design processes is another significant finding. Traditional design workflows often involve time-consuming cycles of prototyping, testing, and refinement. Generative AI streamlines this process by enabling rapid generation and evaluation of multiple design alternatives.

This acceleration is particularly beneficial in sustainability-oriented design, where timely responses to environmental challenges are critical. For example, AI-driven simulations can quickly assess the environmental impact of different design scenarios, allowing designers to make informed decisions more efficiently.

The findings suggest that generative AI enhances productivity and reduces the time required to develop sustainable solutions. This aligns with the broader trend of digital transformation in design, where advanced technologies are used to improve efficiency and innovation (Daugherty & Wilson, 2018).

However, the increased speed of design processes also raises concerns about the potential for superficial decision-making. Rapid iteration may lead to a focus on short-term efficiency rather than long-term sustainability. Therefore, designers must ensure that speed does not compromise the depth and quality of analysis.

5.4 Data-Driven Sustainability Intelligence

Generative AI also contributes to the development of data-driven sustainability intelligence. By analysing large datasets, AI systems can identify patterns and insights that inform sustainable design decisions.

For example, AI can integrate data from various sources, such as environmental sensors, material databases, and lifecycle assessments, to provide comprehensive insights into the environmental impact of design choices. This capability enables designers to make more informed decisions and align their work with sustainability goals.

The findings indicate that generative AI enhances the ability to manage complexity in sustainability-oriented design. This is particularly important in addressing “wicked problems” that involve multiple stakeholders and conflicting objectives (Geels, 2002).

However, the reliance on data also introduces challenges related to data quality, accessibility, and transparency. Inaccurate or incomplete data can lead to flawed conclusions, while the “black box” nature of some AI models can make it difficult to understand how decisions are made (Floridi et al., 2018).

5.5 Human-AI Co-Creation Dynamics

A central theme in the findings is the evolving nature of human-AI collaboration. Generative AI is increasingly viewed not as a tool but as a creative partner that contributes to the design process.

This shift is reflected in the changing roles of designers, who are becoming curators and facilitators of AI-generated content. Designers guide the AI system by defining parameters, selecting outputs, and refining solutions. This collaborative process enhances creativity by combining human intuition with machine-generated insights (McCormack et al., 2019).

The findings also highlight the importance of trust and transparency in human-AI collaboration. Designers must understand how AI systems generate outputs to effectively integrate them into their workflows. Lack of transparency can undermine trust and limit the adoption of AI technologies.

Furthermore, the analysis suggests that human-AI collaboration can lead to new forms of creativity that are neither purely human nor purely machine-generated. This hybrid creativity represents a significant shift in design practice.

5.6 Emerging Challenges and Systemic Limitations

Despite its potential, generative AI presents several challenges and limitations in sustainability-oriented design.

One of the most significant challenges is the environmental impact of AI technologies. Training and deploying large AI models require substantial computational resources, resulting in high energy consumption and carbon emissions (Strubell et al., 2019). This paradox raises questions about the sustainability of AI itself.

The use of generative AI also raises ethical concerns related to bias, accountability, and intellectual property. AI systems may reflect biases present in training data, leading to inequitable outcomes. Additionally, the question of authorship in AI-generated designs remains unresolved (Floridi et al., 2018).

Another limitation is the potential over-reliance on AI systems. While generative AI can enhance creativity, excessive dependence may reduce human critical thinking and innovation.

Finally, integrating generative AI into existing design workflows can be challenging due to technical, organisational, and cultural barriers. Successful integration requires not only technological capabilities but also changes in mindset and practice.

6. Discussion

The findings of this study provide important insights into the role of generative AI as a creative partner in sustainability-oriented design. This section discusses the implications of these findings in relation to the theoretical framework and broader literature.

6.1 Reconfiguring the Nature of Creativity

The integration of generative AI into design processes challenges traditional conceptions of creativity as an exclusively human attribute. Drawing on creative systems theory, creativity can be understood as a distributed phenomenon emerging from interactions between humans, technologies,

and cultural contexts (Csikszentmihalyi, 1996).

The findings suggest that generative AI contributes to creativity by expanding the design space and enabling new forms of exploration. This aligns with Boden's (2004) concept of exploratory creativity, where novel ideas emerge through systematic exploration of possibilities.

However, the role of human designers remains central. While AI can generate ideas, humans are responsible for interpreting, evaluating, and contextualising these ideas. This underscores the importance of maintaining human agency in AI-mediated creative processes.

6.2 Enhancing Sustainability Through Data-Driven Design

The study highlights the potential of generative AI to enhance sustainability by enabling data-driven design. AI systems can analyse complex datasets and optimise design solutions for environmental performance, aligning with the principles of sustainable design (Bocken et al., 2016).

From a sustainability transition perspective, generative AI can be seen as a niche innovation that has the potential to transform design practices and contribute to broader systemic change (Geels, 2002). By enabling more efficient and sustainable solutions, AI can support the transition to a circular economy and a low-carbon society.

However, the environmental impact of AI technologies must also be considered. The energy consumption associated with AI raises important questions about its overall

sustainability (Strubell et al., 2019). This highlights the need for developing energy-efficient AI systems and integrating sustainability considerations into AI development.

6.3 Human-AI Collaboration as a Socio-Technical System

The findings reinforce the importance of viewing human-AI collaboration as a socio-technical system. This perspective emphasises that the effectiveness of AI in design depends not only on technological capabilities but also on social and organisational factors (Trist, 1981).

Designers must develop new skills to effectively collaborate with AI systems, including data literacy, critical thinking, and ethical awareness. Organisations must also create environments that support experimentation and innovation.

Furthermore, the socio-technical perspective highlights the importance of aligning AI technologies with human values and sustainability goals. This requires ongoing dialogue between designers, engineers, policymakers, and other stakeholders.

6.4 Ethical and Governance Implications

The integration of generative AI into sustainability-oriented design raises significant ethical and governance challenges. Issues related to bias, transparency, and accountability must be addressed to ensure that AI systems are used responsibly (Floridi et al., 2018).

In addition, the question of authorship in AI-generated design remains unresolved. As AI

systems become more autonomous, it becomes increasingly difficult to attribute creative ownership. This has implications for intellectual property and professional practice.

To address these challenges, there is a need for robust ethical frameworks and governance mechanisms that guide the use of AI in design. These frameworks should prioritise transparency, fairness, and sustainability.

6.5 Balancing Innovation and Responsibility

A key theme emerging from the discussion is the need to balance innovation with responsibility. While generative AI offers significant opportunities for enhancing creativity and sustainability, it also introduces risks that must be carefully managed.

Designers must adopt a critical approach to AI, recognising both its potential and its limitations. This involves questioning the assumptions embedded in AI systems, evaluating their outputs, and ensuring alignment with sustainability goals.

Moreover, the development of generative AI should be guided by principles of responsible innovation, which emphasise ethical considerations, stakeholder engagement, and long-term impact.

6.6 Implications for Future Research and Practice

The findings of this study have several implications for future research and practice. First, there is a need for empirical studies that examine the experiences of designers

working with generative AI. Such studies can provide deeper insights into the dynamics of human-AI collaboration.

Second, interdisciplinary research is essential for addressing the complex challenges of sustainability-oriented design. Collaboration between fields such as design, computer science, and environmental science can lead to more holistic solutions.

Finally, policymakers and industry leaders must play a role in shaping the development and use of generative AI. This includes establishing standards, regulations, and best practices that promote ethical and sustainable AI use.

7. Conclusion

This study has explored the emerging role of generative artificial intelligence (AI) as a creative partner in sustainability-oriented design through a qualitative analysis of secondary data. The findings demonstrate that generative AI is not merely a technological tool but an active participant in the design process, capable of enhancing creativity, improving efficiency, and supporting environmentally responsible decision-making.

A key contribution of this research lies in its identification of generative AI as a catalyst for expanding the design space. By enabling rapid ideation, iterative exploration, and performance optimisation, AI systems allow designers to address complex sustainability challenges with greater depth and precision. This capability is particularly significant in the context of global environmental concerns, where innovative and scalable solutions are urgently needed. At the same

time, the study highlights that human designers remain central to the process, serving as interpreters, evaluators, and ethical decision-makers who guide AI-generated outputs toward meaningful and contextually appropriate outcomes.

The integration of generative AI into sustainability-oriented design also introduces important challenges. Ethical issues such as data bias, transparency, and accountability require careful consideration, as they can influence the fairness and reliability of design solutions. Additionally, the environmental impact of AI technologies themselves raises critical questions about their overall sustainability, emphasising the need for energy-efficient algorithms and responsible computational practices.

From a theoretical perspective, the study contributes to the understanding of human-AI collaboration by integrating creative systems theory, socio-technical systems theory, and sustainability transition theory. This interdisciplinary framework underscores the dynamic interplay between technological innovation, human agency, and sustainability objectives.

In conclusion, generative AI holds significant promise for transforming sustainable design practices, but its success depends on balanced integration. Designers, researchers, and policymakers must work collaboratively to ensure that AI technologies are developed and applied in ways that align with ethical principles and sustainability goals. Future research should focus on empirical investigations and real-world applications to further validate and refine the insights presented in this study.

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