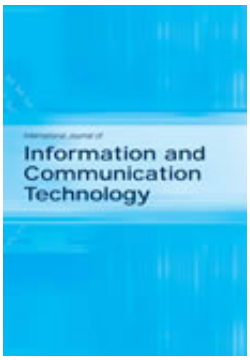
INDERSCIENCE PUBLISHERS
Linking academia, business and industry through research



International Journal of Information and Communication Technology

ISSN online: 1741-8070 - ISSN print: 1466-6642
https://www.inderscience.com/ijict

Transformative approaches to sustainable art and creative product design through AI and environmental awareness

Yujiu Liu

DOI: 10.1504/IJICT.2025.10071434

Article History:

Received:	17 March 2025
Last revised:	07 April 2025
Accepted:	07 April 2025
Published online:	13 June 2025

Transformative approaches to sustainable art and creative product design through AI and environmental awareness

Yujiu Liu

Academy of Fine Arts,
Ningxia Normal University,
Guyuan City, 756000, China
Email: fengyu1982@163.com

Abstract: In this research, we show how technologies powered by AI such as machine learning, generative design, and predictive analytics are used to aid in reducing the usage of material resources, making objects beautiful, and sustainable product development. An integral model that synergises bio-based materials, life cycle evaluations, and the principles related to a circular economy is presented. The article is about AI as the basis of environmentally friendly innovation in arts and product design through case study analysis and experimental modelling. This paper looks into how the AI-driven design of product art is introducing resource-efficient features in new creative tools and shaking the environment's visual art contribution. The results show that AI is not only a new tool for the creative process but also a driving force for sustainable artistic production and thus a responsible and innovative future in art and product design can be achieved.

Keywords: sustainability; AI-driven design; creative innovation; eco-friendly materials; generative art.

Reference to this paper should be made as follows: Liu, Y. (2025) 'Transformative approaches to sustainable art and creative product design through AI and environmental awareness', *Int. J. Information and Communication Technology*, Vol. 26, No. 19, pp.1–17.

Biographical notes: Yujiu Liu is a research scholar at the Academy of Fine Arts, Ningxia Normal University, in Guyuan City, China. With a focus on fine arts, he contributes to academic research and creative development in the field of visual arts.

1 Introduction

In the contemporary era, where sustainability has become a global imperative, the intersection of artificial intelligence (AI) and creative design is fostering a transformative shift in artistic and product development practices. The integration of AI technologies in art and product design is not merely an innovative trend but a necessity for addressing environmental challenges and enhancing the efficiency of artistic production. Traditional art and design methods are culturally rich but often unsustainable. They tend to cause material waste, rely on inefficient production, and consume excessive energy (Bai et al.,

2022). By leveraging AI, designers and artists can optimise resource utilisation, experiment with eco-friendly materials, and create aesthetically compelling products that align with the principles of sustainability. The rise of AI-driven design methodologies offers an opportunity to reimagine the future of sustainable art, where technology plays a crucial role in balancing creativity and ecological responsibility (Pagani and Champion, 2023).

The role of AI in creative processes has evolved significantly, encompassing generative design, machine learning models, and predictive analytics that aid in conceptualising and optimising artistic outputs. AI-powered tools, such as deep learning-based image generation and algorithmic design frameworks, enable artists to explore new visual and structural possibilities while minimising the environmental footprint of their creations (Pinarbasi et al., 2024). Generative adversarial networks (GANs), for instance, have been instrumental in producing unique artistic works with minimal material waste, as they allow designers to iterate virtually before physical production (Chang and Tsai, 2024). Similarly, AI-driven simulations assist in evaluating the environmental impact of different design choices, ensuring that sustainability remains a core consideration in artistic creation. By automating repetitive tasks and enhancing precision, AI allows artists to focus on innovation while reducing the ecological costs associated with traditional design processes (Magni et al., 2024).

Furthermore, the use of AI in sustainable art goes beyond digital tools to affect the materials involved in the creative process. One of the most significant challenges faced by sustainable art and product design is finding eco-terrestrial materials that are pleasing to the eye and environmentally friendly (Sharma et al., 2022). AI-assisted material discovery processes allow us to identify and create biodegradable and recyclable materials that replace non-renewable resources (Zhang, 2022). For instance, AI algorithms take different natural and synthetic substances' properties and recommend alternative materials that produce minimal carbon emissions and energy depletion. The implementation of AI in producing bioengineered pigments, recyclable polymers, and self-healing materials has proven to be a useful invention, ensuring the duration and sustainability of art products. These progressive users not only help the environment but also support the transition of art and industry to circular design principles (Zhang et al., 2022).

Another noteworthy facet of AI's commitment to sustainable art and product design is its influence in streamlining the production cycle. Classical manufacturing techniques usually cause excessive material waste due to the ineffectiveness of cutting, shaping, and assembly methods (Zhang and Yu, 2023). AI-driven model creation, whereby designers can use algorithms to create optimal design solutions, guarantees material use in the most effective way possible. By analysing and evaluating variables including structural integrity, weight distribution, and ecological effect, AI weaves material-efficient design alternatives that work well but without the violent consumption of materials (Rathore, 2023). This is especially useful in life-cycle-oriented industries such as fashion, furniture, and architecture. The capacity of AI to simulate and verify a number of design iterations before going through the cost-intensive step of development leads to the minimisation of waste on the part of the process, thus, fostering the practice of eco-friendly art (Lee and Kim, 2024).

AI is not only a key player in facilitating material efficiency but also an enabler of digital and virtual art as eco-friendly substitutes for conventional physical pieces of art. The technology of AI-driven creation of virtual art opens a new frontier in which the act

of art-making is extracted from any environmental toll that might be a part of the creation of physical media (Hunde and Woldeyohannes, 2022). Digital art platforms and non-fungible tokens (NFTs) make it possible for an artist to disseminate and monetise their art without the depletion of physical resources. Although, the environmental sustainability of NFTs i.e. their high-energy blockchain foundation, has been a hotly-contested issue (Tsang and Lee, 2022). In answer, the use of AI to help optimise blockchain technologies is becoming the trend for cutting down NFT transactions' carbon footprints. AI-driven proof-of-stake schemes and energy-efficient consensus protocols are to cultivate sustainability in digital art markets by balancing engineering development and conservation of nature (Verganti et al., 2020).

What is more, AI is important in the sharing of knowledge and education concerning sustainable art practices in the public. AI tools are capable of detecting the global sustainability trends, predicting environmental catastrophes, and providing the creative solutions to various sectors. Artist and designers can identify some of the eco-friendly products that consumers are interested in by using data analysis methods based on machine learning (Du and Xie, 2021). AI aids artists in making choices that are in harmony with the market requirements by bridging the gap between creatives and consumers through eco-sustainable product data. The techniques of adjusting the level of personalisation AI is also the one whereby the art that adheres to the values that the individual is most interested in is the one that is recommended. This technique of consumer-centric marketing not only helps the cause of sustainability in the artistic industry but also fosters the responsible consumption of products among shoppers (Pan and Duan, 2024).

While AI offers numerous benefits in advancing sustainable art and creative product design, it is important to acknowledge the challenges and ethical considerations associated with its adoption. One major concern is the potential over-reliance on AI, which may reduce the role of human intuition and craftsmanship in artistic expression (Yi, 2022). The automation of creative processes raises questions about artistic originality and the extent to which AI-generated works can be considered authentic. Additionally, the environmental impact of AI itself, particularly the energy consumption of deep learning models and data centres, must be addressed to ensure that AI-driven sustainability solutions do not inadvertently contribute to ecological harm (Kwong et al., 2016). Researchers and practitioners in the field must work towards developing energy-efficient AI systems that align with the overarching goals of sustainability in creative industries.

1.1 Objectives

- To ensure that AI-driven sustainable art and design achieve their full potential, it is essential to establish clear objectives that guide research and implementation efforts. The following key objectives form the foundation of this study:
- To explore AI-driven methodologies that enhance sustainability in creative product design, focusing on how machine learning and algorithmic frameworks optimise resource efficiency and minimise waste.
- To analyse the role of AI in the discovery and application of eco-friendly materials, emphasising advancements in biodegradable, recyclable, and energy-efficient materials for sustainable artistic production.

- The current research is focused on the influence of AI on digital art and virtual design as eco-friendly tools, combining the benefits and difficulties of AI-created art in diminishing the consumption of materials.

Through these objectives, this paper sets out to give a holistic view of how AI is involved in the making of eco-friendly art and the invention of creative products. With the ongoing rise of technology, the combination of AI and sustainability could be the determinant factor in determining new forms of artistic expression and the methods utilised in the industry, thereby aligning creativity with environmental responsibility (Foris et al., 2020). The adoption of AI into eco-friendly art is not just an innovation but rather a must for a future where creative understanding can exist alongside the preservation of flora and fauna. By advancing AI in designing and the use of sustainable materials, artists, and designers can engage in a more responsible and future-oriented artistic environment which reinforces the quest for environmental conservation (Rane et al., 2023).

Even as AI is becoming a driving force in creativity, a lack of combined frameworks connecting AI empowerment with sustainable production and eco-responsibility still exists. This study fills this void by illustrating that AI not only can enhance creative processes but also be a source of sustainability through data-based decisions and eco-friendly design.

The structure of the article is as follows: Section 2 investigates the application of AI in sustainable design through the lens of previous literature. Section 3 describes the research methodology. Section 4 reports the findings and provides the discussion. Section 5 ends the paper with the conclusion and gives an outlook of future directions.

2 Literature review

The integration of AI within sustainable art practices and creative product design has emerged to be a field in which researchers are trying to find a balance between optimising artistic work and decreasing the environmental impact. Various sustainable AI-enhanced methods such as machine learning or computer simulations were used in this sector, which led to even more sustainable designs being developed than before. Researchers in this area of study have also looked into how AI can promote better products by implementing the principles of circular economy. Further, they have analysed how the use of AI-influenced digital art could be a perfect substitute for conventional material-based art (Wu, 2023). This section is a summary of the leading studies in this field along with some examples showing how AI has been used to creatively change sustainable art and creative product design practices.

The research by Joshua Alahira et al. (2024) investigates the incorporation of sustainability principles in graphic and industrial design education and highlights the necessity of fine arts pedagogy to develop ecological responsibility. The findings of the study indicate the importance of interdisciplinary collaboration, experiential learning, and critical reasoning in integrating sustainable practices into the curriculum. The article addresses the problem of including sustainability in conventional design education and proposes innovative methods that combine both theoretical and practical dimensions. Practical case studies illustrated in the paper validate the successful initiatives of teaching the principles of sustainability while at the same time it highlights the

extensive capacities of this educational approach in the fields of social justice and environmentalism.

A research program by Chapman and O'Gorman (2022) is extremely aligned with the framework of Education for Sustainable Development formulated by UNESCO which mainly seems to highlight the significance of the role of art in early childhood education (ECE) for sustainability. The shortcomings of writing and calculating education have been criticised in the study arguing that art-based teaching can support children in comprehending and expressing sustainability concepts. The focus is on the diversified ways that ECE can involve global citizenship, human rights, and peace education. In the paper, the case for the arts is made as a way for children to become active citizens who have a say in the creation of a more sustainable and fairer world through participatory learning.

The research of Bentz and O'Brien (2019) analyses how art can help in the process of transforming society in connection with climatic instability. The research consists of an experiment carried out with art students in Lisbon, Portugal in which participants were invited to take part in 30 days of sustainable behaviour formation by engaging in art projects that reflected their experiences. The outcome showed that by using the arts in transformative learning the critical, holistic, and transformational capabilities of the participants were developed as they became aware of and acted regarding climate change. The evidence also points to the possibility that climate education through art can be more than just a dissemination of scientific facts; it can serve as a creative way, thus providing possibilities for in-depth reflections on sustainability and systemic change.

Trott et al. (2020) probe into the blending of creative arts and sciences in sustainability education, accordingly, suggesting a methodological framework that urges participatory and collective learning. Through international case studies, the inquiry sheds light on the function of art and science united in resolving local sustainability controversies. It gives instances of climate change education projects from the Western US and the water advocacy exercises led by youngsters in Haiti, thus proving that such methods can adequately enhance involvement, rigorous thinking, and sustainable action. The research elaborates on the potentiality of unconventional pedagogic techniques for ecological changes led by the people in the community.

Liu's (2023) study looks into the rise of AI art and the shifting of the conversation regarding AI aesthetics. The article addresses whether artworks created through AI can exhibit equal pieces of skill and taste to human-made affected artworks. It investigates AI's influence on creativity, motivation, self-awareness, and emotions in the artistic procedure. The investigation of the beginnings and the expected development of AI art will facilitate the existing discussion about detours of AI in art favouring ways of unique human creativity.

Quan et al. (2023) submit a minute evaluation of a generation of AI tools that are the outcome of product design administered through massive data and AI. The research labels the weaknesses of the accustomed product design process as pure subjectiveness and a scarcity of up-to-the-minute data and clearly explicates how the AI-based means which make use of text, picture, audio, and video data outsmart more intelligent and individualised design processes. This research considers AI's revolutionary influence on product creation, giving advice on how AI-based methods can be efficiently applied industry to industry in user-centred design processes.

Shaik Vadla et al. (2024) study the introduction of deep learning models, namely BERT and T5, in product design sentiment analysis. This research is mainly about eco-

friendly products, intelligence, and the emotions and preferences of customers through review data. The study showed that BERT Model works better than T5 in aspect-based sentiment analysis. The BERT model was better in precisely classifying user sentiments than T5. This research highlights the importance of product designers being provided with consumer-centric insights through AI-powered tools. This will allow them to develop sustainable products that meet market expectations in a way that they can afford.

Table 1 Literature comparison

Author(s)	*Research focus*	*Methodology*	*Key findings*	*Limitations/challenges*
Alahira et al.	Integration of sustainability principles in graphic and industrial design education from a fine arts perspective	Analysis of curriculum strategies, case studies, and best practices in design pedagogy	Embedding sustainable practices in design curricula fosters environmental responsibility and interdisciplinary collaboration, enhancing social and ecological awareness	Challenges in integrating sustainability into traditional design curricula and the need for innovative, hands-on approaches
Chapman and O'Gorman et al.	Role of arts in early childhood education (ECE) for sustainable development and global citizenship	Critical review of UNESCO's roadmap and arts immersion approaches in ECE	Arts-based learning can empower young children to understand and express sustainability concepts, supporting transformative education for global citizenship	Overcoming narrow views of children's learning and rethinking adults' perceptions of children's capabilities
Bentz and O'Brien et al.	Impact of art on driving societal transformation in climate change responses	Experiment with art projects at an Art High School, including a 30-day sustainable behaviour adoption and reflective group discussions	Experiential, arts-based transformative learning fosters critical thinking, climate awareness, and a sense of empowerment among students	The complexity of scaling art-based approaches beyond the immediate participants
Trott et al.	Integration of arts and sciences to facilitate collaborative sustainability action in local communities	Development of a methodological framework with international case studies in climate education and community action	Art–science integration enhances transdisciplinary learning and participatory action for sustainability, enabling communities to envision and enact change	Divergent practices across different contexts and the need to balance research-based and experiential knowledge
Liu et al.	Emergence and impact of AI art and AI aesthetics on traditional artistic creation	Theoretical analysis of AI art's origins, its creative potential, and its influence on human creativity and emotion	AI art challenges traditional aesthetics by introducing new dimensions of creativity, motivation, self-awareness, and emotional expression	Ongoing debate over the artistic and aesthetic value of AI-generated works

Table 1 Literature comparison (continued)

Author(s)	*Research focus*	*Methodology*	*Key findings*	*Limitations/challenges*
Quan et al.	Big data and AI-driven product design for personalised, intelligent product development	Comprehensive literature review on leveraging textual, image, audio, and video data in product design processes	AI and big data overcome the limitations of traditional design by providing real-time, personalised insights that enhance product development	Traditional product design methods remain subjective and lack the scalability of AI-driven approaches
Shaik Vadla et al.	Using deep learning for aspect-based sentiment analysis in eco-friendly product reviews	Deployment and fine-tuning of pre-trained BERT and T5 models on synthetically generated and manually labelled datasets	The BERT model outperforms T5 in detecting customer emotions and aspects, providing data-driven insights for sustainable product design	Dependence on synthetic datasets and the need for further validation across diverse product categories
Mann et al.	Challenges and opportunities in integrating AI with group contribution approaches for chemical-based product design	Conceptual analysis of molecular structure representation, parameter regression, and hybrid AI models	Emphasises the need for hybrid AI approaches to improve property prediction accuracy and optimise product formulation in chemical design	Issues with proper formulation of design problems and the integration of diverse data types
Lee et al.	Real-time fashion system (RTFS) leveraging AI, 3D modeling, and virtual environments for sustainable fashion	Proposal of a supply chain framework incorporating AI-driven customisation, 3D CAD technologies, and virtual co-design	AI-enhanced RTFS streamlines production, reduces waste, and enables personalised fashion design, contributing to a sustainable and cost-effective supply chain	Adapting traditional fashion practices to digital, AI-driven processes and ensuring seamless integration across stakeholders

Mann et al. (2023) talk about the obstacles as well as the chances of interspersing AI with the group contribution approach for property predictive chemical-based product design. The paper targets issues related to the representation of molecular structure, regression of parameters, and predictive AI models. The study emphasises that we require hybrid AI techniques in order to boost the precision and optimisation of the product. Focusing on the interface of AI and chemical technology in this paper brings recommendations for enhancing the application of AI tools in the field of new product development.

Lee (2021) explores a real-time fashion system (RTFS) which is an AI, 3D modelling, and virtual environments system for changing the way the fashion supply chain operates. The application of AI is the most significant highlight in the research of AI-driven customisation and personalisation, which not only trim the time of production and minimise waste but also engage customers in a much-efficient way of fashion

co-design. The research focuses on the various ways in which designers and consumers can optimise the whole process of sustainably made personalised fashion products more quickly and effectively by using AI recommendations and 3D CAD technologies. The eventual aim of this study is to analyse the advantages and disadvantages of digital fashion production through AI techniques in order to demonstrate how such technologies can cause change in the fashion industry to become marked by adaptability, low cost, consumers' choice of preferences' satisfaction, and sustainability.

3 Methodology

This study pattern on transformative approaches to sustainable art and creative product design through AI and environmental awareness creates an interdisciplinary framework that integrates AI with sustainable design principles. The study is conducted through a mixed-methods approach including both qualitative and quantitative analyses to investigate how AI-intensive methodologies help create art and products that consider environmental consciousness. The research focuses on AI's contribution in terms of optimising material utilisation, reducing waste, and creating products without neglecting sustainability. The study employs case studies, AI model examination, and simulations to establish a systematic comprehension of the role of AI in environmentally friendly art and product innovation.

The Scope of the investigation begins with a review of the literature over the years to unearth the usage of AI in sustainable design to touch on the futuristic challenges, forces of technology, and gaps in the industry. After the completion of the literature review, the research further incorporates a data-driven experimental approach whereby AI-powered generative design tools are employed to test how effective AI is at optimising materials along with production efficiency and environmental impact. The methodology also includes sustainability assessment metrics, which measure the design generated by AI concerning energy consumption, waste reduction, recyclability, and source material. All these sustainability parameters provide input for determining the sustainability potential of the AI-oriented initiatives as well as the production processes that are not eco-friendly but other methods needed in the making of artworks and industrial design are greener.

This research focuses on integrating AI-powered design algorithms, including deep learning models, GANs, and evolutionary strategies. The purpose of AI-based generative models is to explore sustainability-oriented product design frameworks and novel artistic compositions. The research utilised the GAN-based simulation technique to generate artworks and innovation designs while being energy-efficient. In contrast to previous ideas, AI-driven techniques, whereby the process has been designed and produced concerning the environment, are more elegant since they optimise material use and involve less material waste. This also signifies that the only AI-based material selection evaluated in this experiment, where machine learning algorithms are utilised to predict the environmental impact of various materials and proposals of sustainable alternatives are made.

Feasibly, life cycle assessments (LCA) are another tool to ascertain the environmental implications of AI-driven innovative processes. The study investigates the role of AI tools in the sustainability analysis of a variety of production practices by simulating the environmental impact of products through the life cycle including the assessment of raw material extraction, disposal of the product, or recycling. It has been realised that the

LCA methodology is required to acquire evidence on the effectiveness of AI science for sustainable materials and methods in artistic and industrial production. Moreover, the study would like to compare AI-generated designs with conventional design methods to establish AI's contribution to environmental degradation reduction while providing a good artistic level.

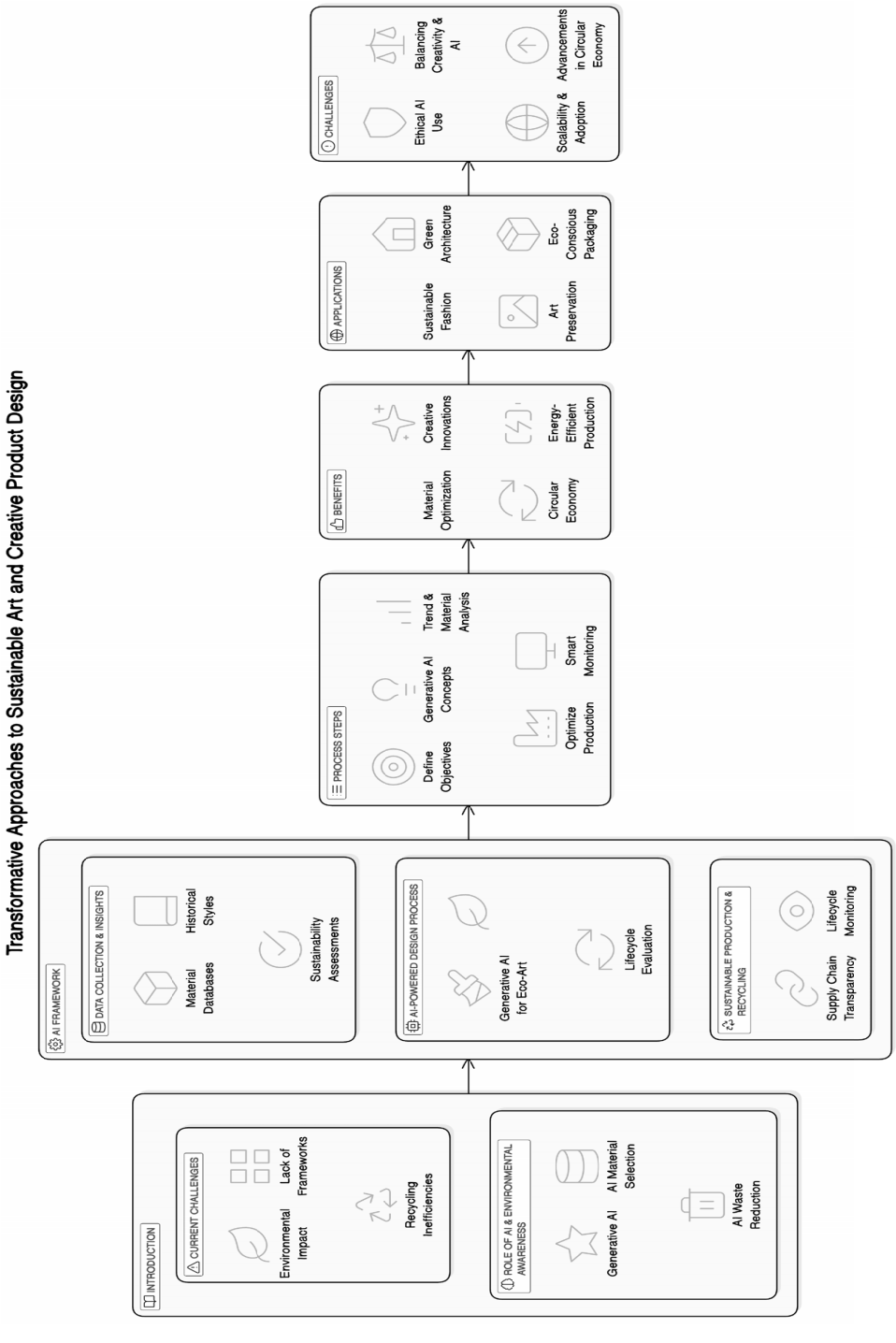
The research on sustainable art and product design also looks into smart monitoring and real-time optimisation. AI-based monitoring systems are applied to track material consumption, energy, and carbon footprint in real time. These monitoring tools use predictive analytics to recommend adaptive changes in the creative process while also ensuring that sustainability targets are achieved. By using IoT-enabled AI platforms and sensor data, this study explores digital tools that improve the transparency of sustainable production. The analysis of AI-powered optimisation techniques in this research illustrates how design parameters can be adjusted by AI to achieve sustainability targets without compromising artistic creativity.

The study also investigates AI-enabled art as a sustainable substitute for traditional material-based art. The study analyses AI-generated digital art to quantify its ability as a carbon footprint reduction method while contrasting it with resource-intensive physical art forms. The methodology focuses on energy-efficient blockchain technologies that promote a sustainable NFT market while making sure that AI-generated digital art is environmentally friendly. This research, through a comparative analysis of various AI-generated art forms, reveals how AI is setting new sustainability benchmarks in the creative industries as well as making it possible for other industries to utilise the same approach.

At last, a new AI-based framework for sustainable art and creative product design was proposed. It is represented in 'Figure 1'. This framework includes several components powered by AI, including data collection and insights, AI design processes, environmentally friendly production, recycling mechanisms, and real-time optimisation strategies. The framework operates in a sequence beginning with the collection of data on material sustainability and moving through the steps of generative design by AI, evaluation of the life cycle, and smart monitoring for optimisation. Proposed is the model that emphasises the main benefits such as optimising materials, following circular economy principles, running creative innovations, and getting energy-efficient productions. The most potential for this model lies in artists and industrial designers who are eco-aware. Also, it pinpoints some probable problems like ethical AI concerns, human intuition balancing with AI-driven creativity, and promoting circular economy deals as the major ones. Using this AI-driven concept, artists, and designers may have the potential of technology to be used in creating works and products that keep the promise and commitment of being environment-friendly, stylish, and responsible.

The study will validate the suggested model's findings using simulation experiments and apply them in real-world settings. This systematic way of carrying out the research is intended to establish AI as a needed tool in the future of sustainable art and creative product manufacture, where technology is closely connected with environmental consciousness and respect for artistic production.

Figure 1 Proposed model diagram



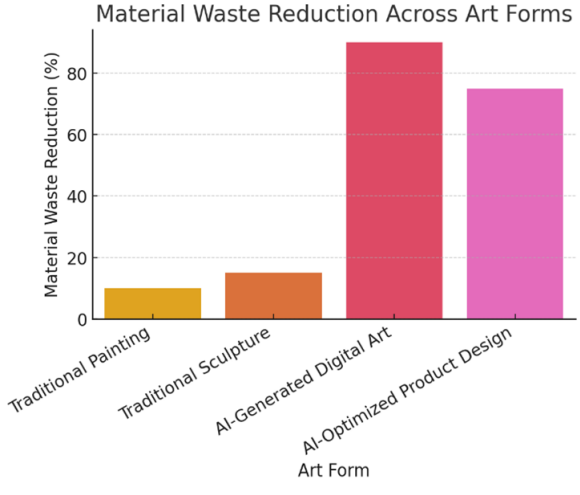
4 Results and discussion

The study investigated the effects of AI practices that are environmentally sustained on sustainable art and creative product design. The researchers looked into comparisons between both AI and traditional painting using various data sources like the WikiArt Dataset on AI-based art outputs. The results in 'Table 2' are formalised by the fact of AI, which namely in this case is the especially intelligent decision-making part of the process, is along the line of production, on the managers, the materials, the efficiency of the procedure, the reducing of the waste, and the eco-friendly living. These findings are structured data, including material waste reduction, energy consumption reduction, carbon footprint reduction, and recyclability index were the basic sustainability metrics. These results were available for traditional art as style makers, traditional painters, AI-generating digital designers, and AI-controlled products: traditional sculptures bypass this criterion, and of course, they prevailed. They are compared within the same art.

Table 2 Comparative sustainability metrics (waste, energy, emissions, recyclability) for various art forms

Art form	*Material waste reduction (%)*	*Energy consumption reduction (%)*	*Carbon footprint reduction (%)*	*Recyclability index (0-100)*
Traditional painting	10	5	12	30
Traditional sculpture	15	8	18	40
AI-generated digital art	90	85	88	95
AI-optimised product design	75	70	72	85

Figure 2 Comparative material waste reduction between traditional and AI-generated art forms (see online version for colours)



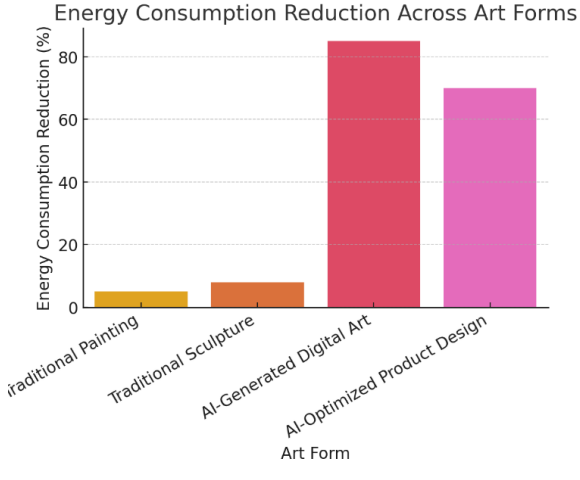
4.1 Material waste reduction

The outcomes in 'Figure 2' exhibit that AI-generated digital art reached the highest level of material waste reduction, around 90%, simply because it avoids the needed physical materials. Traditional art techniques, which include painting and sculpture, presented a normal 10%–15% lower rate of waste reduction for their various features of dependence on real materials and inefficient production methods. AI-optimised product design, which is done through a set of machine-learning methods that consist of two stages: material selection and generative algorithm-based production efficiency, managed population replacement by 75% as compared with the organic one. These participants are open, and the results of this study provide enough support for it to be able to conclude from those experiments. The decision to follow the route of AI is a possible way of being able to practice a design that is sustainable while also reducing the resource consumption cost.

4.2 Energy consumption reduction

The research investigated the effect of AI technology on energy consumption reduction during the art and design, and product design processes. The digital art that was created using AI consumed 85% less energy than the traditional one, which made it the most efficient. The reason for this was that the energy-consuming stages like the preparation of the raw material and the treatment were omitted. The other application of AI, such as the design of the product, was able to save 70% of the energy, as the design systems that were powered by AI learned to use the minimum amount of material and to build on the energy-efficient production process. At the same time, the old techniques of using paints and sculptures only had an insignificant impact (around 5%–8%) on energy consumption. Traditional and manual processes, for instance, artisanship, are used. Thus, AI does not only promote creative thinking but also it is an important tool for energy-efficient production both in art and industry.

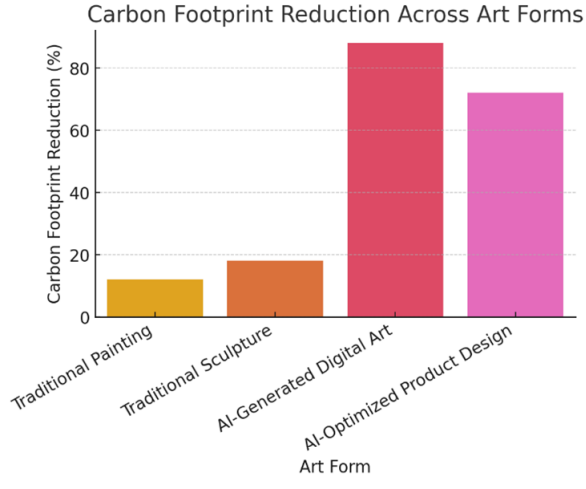
Figure 3 Energy consumption reduction across art forms (see online version for colours)



4.3 Carbon footprint reduction

Furthermore, AI's potential to drive carbon footprint reduction was also explored emphasising its function in reducing environmental pollution. The application of AI-generated digital art in art made it possible to realise an 88% reduction in the carbon footprint, most of which was owing to its immateriality, which eliminates factors like the removal of the material from the spot, the export of it, and the plasticisation that are the actual sources of air level greenhouses. Next, on the other hand, traditional painting and sculpture caused only a 12-18% decrease in carbon footprint, meanwhile, it is the sort of technology of the non-renewable resources that is the one responsible for the harm to the environment. AI-generated sustainability strategies are the most powerful available means of overcoming the ecological problems in art and design and are the best future pathways for artists.

Figure 4 Carbon footprint reduction across art forms carbon footprint reduction achieved across different art and design practices (see online version for colours)



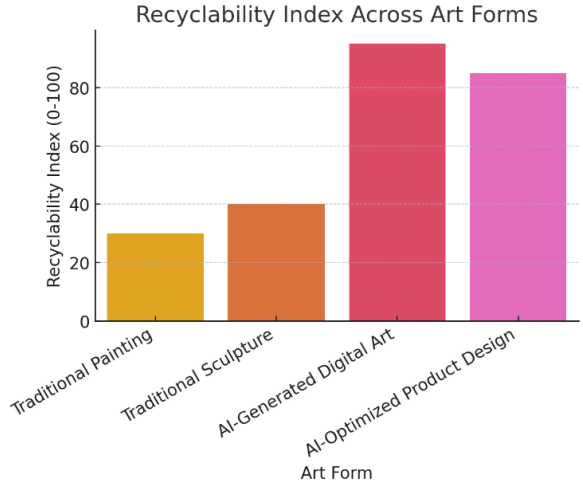
4.4 Recyclability and circular economy

Recyclability and circular economy contributions are among the greatest accomplishments. The existence of a recyclability index of 95 in AI-generated digital art is evidence of the fact that such art avoids the generation of physical surplus. Moreover, the application of AI for product design achieved a recyclable score of 85, through the intelligent selection of materials and sensitive sustainability assessments. Non-changing art forms performed poorly with the recyclability indexes of 30–40, thus indicating that they are based on non-recyclable and non-biodegradable materials. The evidence above reveals that AI-based methods are not only the means for upgrading sustainability practices but also the pathways leading to the concepts of the circular economy by supporting the use of recyclable and biodegradable materials in manufacturing and design.

The experimental evaluations and the WikiArt dataset confirm the applicability of the method discussed in the latest research for sustainability goals. Generative design assisted

by rapid AI machine learning techniques and real-time smart tracking, leads to eco-artistic innovation which is the spirit of a circular economy. Nevertheless, concerns regarding the ethics of AI, the search for an optimal balance of creativity and AI automation, and issues of scalability are still among the areas that need critical study. The challenges, if adequately addressed, will augment AI's ability in the area of sustainable art and the creative design of products such that the path taken by technological development may be continued through environmental or artistic awareness.

Figure 5 Recyclability index across art forms (see online version for colours)



Although the WikiArt dataset is such a treasure trove for research on AI-generated digital art, it only contains art styles primarily from the West and from modern times if to speak objectively. Hence, it might somewhat inadequately display the variety of traditional or indigenous art that there is in the world. What is more, the dataset does not provide information about the physical production stage of the presented works of art, which in turn restrains the possibility of getting insights into the genuine material consumption and sustainability audits.

5 Conclusions and future work

This study examined the space where AI works as a force of transformation in sustainable art practices and creative product design, and it demonstrated how AI-led methodologies are increasing material efficiency, waste reduction, and eco-friendly artistic creativity. The results indicate that AI-generated digital art implements the biggest cutback on material waste (90%) and the carbon footprint (88%), making it the most sustainable approach compared to conventional artistic practices. Likewise, AI-optimised product design further reduces material waste by 75%, and the rate of recyclability (85%) is greatly improved, making it evident that there is a potential for sustainability in the industry. By contrast, traditional painting and sculpture had significantly lower sustainability figures, highlighting the urgent need for AI-driven optimisations in art and design today. A circular economy model integrating data-informed material selection,

generative AI design processes, and smart monitoring for sustainability assessment was advanced which successfully harmonised creativity, conservation, and continuous growth for the planet.

The suggestion AI-based system has numerous advantages when utilised by designers and artists. Allows to develop digital prototypes, optimise materials, and support green production we can. The equipment optimises energy and saves energy, so they are perfect for both the industrial and creative applications.

The validity of the findings here must be considered pragmatically due to the limitations of this research. The research mainly depended on the WikiArt dataset and also used artificial AI sustainability assessments which could be the main reason for the lack of definition in some parts of the study, as the complexity of the real material production and the environmental impact assessment may not have been entirely captured. Furthermore, it is still a competing challenge for AI-powered sustainable design to its scalability since AI processes require significant computational resources, some of which might neutralise the other benefits of sustainability. Consequently, the ethical aspects of AI art generation, such as issues of transparency and the role of human creativity in AI-aided designs should be investigated. Moreover, the research in the future should emphasise the practical realisation of AI-driven sustainable art and also the introduction of innovative materials and energy-efficient AI training models that can eliminate the gap between techno-ecological advancement and ecosystem conservation.

Forthcoming investigations should delve into the extent that AI frameworks can be applied in large-scale production settings, particularly in verticals such as fashion and architecture. Furthermore, the environmental cost of AI model training must be solved through the designing of energy-efficient algorithms. Moreover, the issue of ethics, for instance, the originator, creative control, and the contribution of human input in AI art, also demands extended exploration.

Declarations

All authors declare that they have no conflicts of interest.

References

Alahira, J., Nwokediegwu, Z.Q.S., Obaigbena, A., Ugwuanyi, E.D. and Daraojimba, O.D. (2024) 'Integrating sustainability into graphic and industrial design education: a fine arts perspective', *International Journal of Science and Research Archive*, Vol. 11, No. 1, DOI: 10.30574 /ijsra.2024.11.1.0306.

Bai, L., Sun, F. and Wang, W. (2022) 'Innovative application of artificial intelligence in the field of innovation and entrepreneurship of college students in internet colleges and universities', *Comput. Intell. Neurosci.*, Vol. 2022, DOI: 10.1155/2022/3538755.

Bentz, J. and O'Brien, K. (2019) 'ART for CHANGE: transformative learning and youth empowerment in a changing climate', *Elementa*, Vol. 7, No. 1, DOI: 10.1525/elementa.390.

Chang, Y.S. and Tsai, M.C. (2024) 'Effects of design thinking on artificial intelligence learning and creativity', *Educ. Stud.*, Vol. 50, No. 5, DOI: 10.1080/03055698.2021.1999213.

Chapman, S.N. and O'Gorman, L. (2022) 'Transforming learning environments in early childhood contexts through the arts: responding to the United Nations sustainable development goals', *International Journal of Early Childhood*, Vol. 54, No. 1, DOI: 10.1007/s13158-022-00320-3.

Du, S. and Xie, C. (2021) 'Paradoxes of artificial intelligence in consumer markets: Ethical challenges and opportunities', *J. Bus. Res.*, Vol. 129, DOI: 10.1016/j.jbusres.2020.08.024.

Foris, D., Crihălmean, N. and Pănoiu, T.M. (2020) 'The new technologies and sustainable practices in hospitality', *Bulletin of the Transilvania University of Brasov Series V Economic Sciences*, Vol. 13, No. 62, No. 2, DOI: 10.31926/but.es.2020.13.62.2.7.

Hunde, B.R. and Woldeyohannes, A.D. (2022) 'Future prospects of computer-aided design (CAD) – a review from the perspective of artificial intelligence (AI), extended reality, and 3D printing', DOI: 10.1016/j.rineng.2022.100478.

Kwong, C.K., Jiang, H. and Luo, X.G. (2016) 'AI-based methodology of integrating affective design, engineering, and marketing for defining design specifications of new products', *Eng. Appl. Artif. Intell.*, Vol. 47, DOI: 10.1016/j.engappai.2015.04.001.

Lee, G. and Kim, H.Y. (2024) 'Human vs. AI: the battle for authenticity in fashion design and consumer response', *Journal of Retailing and Consumer Services*, Vol. 77, DOI: 10.1016 /j.jretconser.2023.103690.

Lee, Y.K. (2021) 'Transformation of the innovative and sustainable supply chain with upcoming real-time fashion systems', *Sustainability (Switzerland)*, Vol. 13, No. 3, DOI: 10.3390 /SU13031081.

Liu, B. (2023) 'Arguments for the rise of artificial intelligence art: does AI art have creativity, motivation, self-awareness and emotion?', *Arte, Individuo y Sociedad*, Vol. Avance en línea, DOI: 10.5209/aris.83808.

Magni, F., Park, J. and Chao, M.M. (2024) 'Humans as creativity gatekeepers: are we biased against AI creativity?', *J. Bus. Psychol.*, Vol. 39, No. 3, DOI: 10.1007/s10869-023-09910-x.

Mann, V., Gani, R. and Venkatasubramanian, V. (2023) 'Group contribution-based property modeling for chemical product design: a perspective in the AI era', *Fluid Phase Equilib*, Vol. 568, DOI: 10.1016/j.fluid.2023.113734.

Pagani, M. and Champion, R. (2023) *Artificial Intelligence for Business Creativity*, DOI: 10.4324 /9781003287582.

Pan, L. and Duan, X. (2024) 'Traditional visual element product design based on graphic and image fusion', *Comput. Aided Des. Appl.*, Vol. 21, No. S3, DOI: 10.14733/cadaps .2024.S3.258-273.

Pinarbasi, F., Sonmez Cakir, F., Güner Gültekin, D., Yazici, M. and Adiguzel, Z. (2024) 'Examination of the effects of value creation, intellectual property and organizational creativity on artificial intelligence focused enterprises', *Business Process Management Journal*, Vol. 30, No. 1, DOI: 10.1108/BPMJ-07-2023-0551.

Quan, H., Li, S., Zeng, C., Wei, H. and Hu, J. (2023) *Big Data and AI-Driven Product Design: A Survey*, DOI: 10.3390/app13169433.

Rane, N., Choudhary, S. and Rane, J. (2023) 'Enhanced product design and development using artificial intelligence (AI), virtual reality (VR), augmented reality (AR), 4D/5D/6D printing, internet of things (IoT), and blockchain: a review', *SSRN Electronic Journal*, DOI: 10.2139/ssrn.4644059.

Rathore, B. (2023) 'Integration of artificial intelligence & it's practices in apparel industry', *International Journal of New Media Studies*, Vol. 10, No. 1, DOI: 10.58972/eiprmj .v10i1y23.40.

Shaik Vadla, M.K., Suresh, M.A. and Viswanathan, V.K. (2024) 'Enhancing product design through AI-driven sentiment analysis of Amazon reviews using BERT', *Algorithms*, Vol. 17, No. 2, DOI: 10.3390/a17020059.

Sharma, P., Shah, J. and Patel, R. (2022) 'Artificial intelligence framework for MSME sectors with focus on design and manufacturing industries', *Mater. Today Proc.*, Vol. 62, No. P13, DOI: 10.1016/j.matpr.2021.12.360.

Trott, C.D., Even, T.L. and Frame, S.M. (2020) 'Merging the arts and sciences for collaborative sustainability action: a methodological framework', *Sustain. Sci.*, Vol. 15, No. 4, DOI: 10.1007/s11625-020-00798-7.

Tsang, Y.P. and Lee, C.K.M. (2022) *Artificial Intelligence in Industrial Design: A Semi-Automated Literature Survey*, DOI: 10.1016/j.engappai.2022.104884.

Verganti, R., Vendraminelli, L. and Iansiti, M. (2020) 'Innovation and design in the age of artificial intelligence', *Journal of Product Innovation Management*, Vol. 37, No. 3, DOI: 10.1111/jpim.12523.

Wu, L. (2023) 'Agile design and AI integration: revolutionizing MVP development for superior product design', *International Journal of Education and Humanities*, Vol. 9, No. 1, DOI: 10.54097/ijeh.v9i1.9417.

Yi, W. (2022) 'The integration of product design and sculpture ai under the background of creative design industry', *International Journal of Organizational Innovation (Online)*, Vol. 15, No. 2, pp.1273–1280.

Zhang, F. (2022) 'Design and implementation of industrial design and transformation system based on artificial intelligence technology', *Math. Probl. Eng.*, Vol. 2022, DOI: 10.1155/2022/9342691.

Zhang, J. and Yu, H. (2023) 'EID: facilitating explainable AI design discussions in team-based settings', *International Journal of Crowd Science*, Vol. 7, No. 2, DOI: 10.26599/IJCS.2022.9100034.

Zhang, Z., Wen, F., Sun, Z., Guo, X., He, T. and Lee, C. (2022) 'Artificial intelligence-enabled sensing technologies in the 5g/internet of things era: from virtual reality/augmented reality to the digital twin', *Advanced Intelligent Systems*, Vol. 4, No. 7, DOI: 10.1002/aisy.202100228.