Minting the future of art: a comprehensive overview of non-fungible tokens in the art metaverse

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Abstract

Purpose – Non-fungible tokens (NFTs) are reshaping art markets and gaining strong stakeholder interest. While research has examined their applications in art ecosystems, their role in advancing Web3D markets remains unclear.
Design/methodology/approach – A systematic literature review was conducted to investigate the impact of NFTs on the Web3D market and its impact on stakeholders, analysing 89 systematically selected articles.
Findings – The results of the study show that NFTs in the Web3D context can enhance privacy and trust through blockchain technology and protect intellectual property and ownership rights while influencing market dynamics, behaviour and investment strategies.
Originality/value – As the Web3D ecosystem grows, ongoing research and collaboration are critical to developing strategies that ensure sustainability, transparency and innovation in digital arts. This study is the first step in exploring these dynamics.

Highlights

(1) NFTs utilise robust blockchain technology, enhancing privacy and trust by safeguarding intellectual property within digital art ecosystems in Web3D spaces.
(2) Tokenised art significantly impacts market dynamics, behaviours of market actors and investment strategies in Web3D spaces.
(3) Exclusive NFT communities offer significant social returns.
(4) Continuous research is vital to developing robust policy frameworks and standards, ensuring environmental and social sustainability, transparency and innovation in digital art ecosystems.

Keywords Non-fungible tokens (NFTs), Digital art, Blockchain, Metaverse, Artificial intelligence

Paper type Literature review

1. Introduction

The art ecosystem has undergone a disruptive transformation process with the emergence of Non-Fungible Tokens (NFTs) (Colella, 2022; Damodaran, 2023). This is mainly because NFTs, defined as blockchain technology-based tokenised digital assets, have (re-)shaped the way users perceive and interact with digital collectables, such as physical art, music or 3-D assets (Fernandes and Morais, 2022; Hurst *et al.*, 2023; Messina *et al.*, 2024; Peters and Cartwright, 2023). NFTs introduce a unique value, representing a digital entity (certificates, smart contracts, cryptocurrencies) or a piece of art (fine art, digital art, music), which distinguishes them from interchangeable conventional cryptocurrencies (Notaro, 2022; Peters and Cartwright, 2023). The introduction of NFTs has also actively shaped ownership

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authentication, value generation and artwork trading in the digital space (Ante, 2023). Although NFTs have often been considered as speculative objects, it is becoming increasingly clear that NFTs are not just a short-term trend but represent the conceptualisation of value exchange in digital markets that can be disruptive in nature (Colella, 2022; Flick, 2022).

More precisely, NFTs are empowering artists, creators and industry experts to monetize their (digital) artwork by leveraging the power of blockchain technologies in ways that were unimaginable in the past (Banaeian Far and Hosseini Bamakan, 2023; Macdonald-Korth *et al.*, 2018). This is because blockchain technology allows authenticity proof, challenging traditional notions of ownership and generating value in and above traditional (art) markets (Aksoy and Üner, 2021).

The introduction of NFT initiatives to formalise the integration of NFTs, such as CryptoPunks and the ERC-721 standard, have paved the way for mass adoption (Wang *et al.*, 2023a, b). While Mike Winkelmann's NFT sale at Christie's for 69.3 million dollars showcased the actual and future market potential of NFTs, making them stand out within the art community. With these initiatives, NFTs in the digital art market have become a trend, which is still evolving, as they are transformed into a more interactive and immersive art experience. This transition also relies on extended reality (XR), multisensory experiences and interactive installations that provide active user engagement. For example, Theodoropoulos and Antoniou (2022) discuss that there is an increasing interest in the use of immersion in museum experiences, and Chung *et al*. (2024) highlight the role of virtual reality specifically for visitor experiences. Platforms including SuperRare (https://superrare.com/) and OpenSea (https://opensea.io/) have furthered the digital ownership and value of digitised art, fostering greater creativity and collectability.

As mentioned before, the parallel development of immersive technologies, such as augmented reality (AR), virtual reality (VR) and mixed reality (MR), offer immersive futuristic and interactive tokenised art experiences (Wang *et al.*, 2023a, b; Belk, 2024). The tokenisation of these innovative technologies enhances, thus, the experience of artworks via NFTs within immersive environments, which can serve as authenticity proof of all kinds of digital assets in the 3D generation of the Internet (Web3D) spaces. Moreover, XR technologies also allow artists to reach greater audiences in a digital Web3D context, audiences that could not be reached with traditional art expositions (Bucur and Miclea, 2023).

Yet, while the potential role of NFTs in the art domain has been extensively discussed and the impact of XR on art has been addressed from various academic perspectives, currently the scatter literature does not provide clear answers in understanding the role of NFTs within the emerging art ecosystem of Web3D applications. Therefore, the overarching goal of the structured literature review is to explore how the tokenisation of art through NFTs can further transit the art sector and the Web3D generation of the Internet. This is particularly significant as the literature has reached a critical mass but remains scattered, failing to provide structured answers to the stated research question.

Our research, thus, provides an understanding of the evolving landscape of digital transformation processes within the art domain via disruptive, immersive technologies. The remainder of this article is as follows. Section 2 provides an overview of the search methodology underlying the systematic literature review, the research questions and the applied data collection processes. The results are provided in Section 3, while the findings are discussed in Section 4. The article is concluded in Section 5.

2. Methodology

2.1 Research questions

A set of research questions and sub-questions was formulated to explore recent and future developments and challenges of NFTs within the modern art Web3D ecosystem and their impact on the art ecosystem, provided in Table 1. The formulated research questions were inspired by the identification of existing research work addressing the application of NFTs in

Table 1. Research questions

RQ 1	How can the integration of NFTs ensure privacy and trust for users and customers within the emerging Web3D art ecosystem
RQ 2	What are the behavioural and financial repercussions of NFTs on customers and (end-)users in art ecosystems and Web3D applications (e.g. the consumption and investment strategies of collectors in immersive art markets)?
RQ 3	How can NFTs leverage the development and growth of the Web3D domain and virtual immersive (XR,VR,AR) worlds?

Source(s): Authors' own work

the art domain, and insights were drawn from related work in similar conducted research studies. Research question one explores how NFTs can ensure privacy and trust in the emerging Web3D domain, reflecting the concerns of digital ownership and authenticity in virtual environments. Research question two investigates the behavioural impacts of tokenised art on consumption and investment strategies in Web3D markets. Research question three examines how NFTs can foster the growth of the Web3D art ecosystem, recognising their transformative potential via leveraging disruptive, immersive technologies.

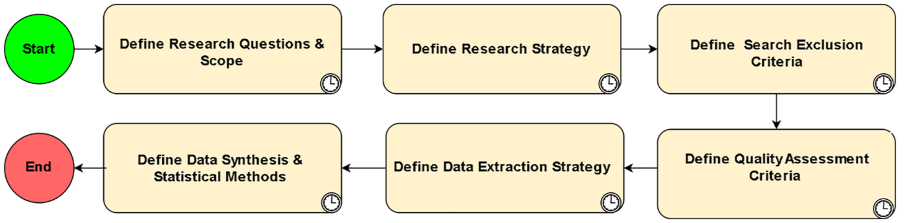
2.2 Search strategy

A systematic literature review (SLR) methodology was adopted to explore the concept of NFTs, focusing on the roles and effects NFTs may play in digital art markets (fine, digital, music, fashion, etc.) within the broader Web3D landscape. Nine databases and search engines to retrieve and analyse a large dataset of available information were used, namely IEEE Xplore, MDPI, Scopus, Taylor and Francis, Web of Science, Science Direct, ERIC, ACM Digital Library and Google Scholar. This extensive search within information sources was crucial in ensuring a qualitative format and a wide-ranging collection of scientific literature relevant to answering the predefined research questions. Figure 1 displays the schematic representation of the adopted methodology that was followed to complete the study.

The initial step was to extract published articles related to the predefined research questions, followed by the definition of the exclusion criteria. The next step was the definition of the quality assessment criteria, which was followed by the formalisation of the data extraction strategy and lastly, the definition of data analysis and synthesis.

2.3 Data collection and assessment

The data collection, cleaning and analysis of all relevant studies for this review followed the design approach by Kitchenham *et al*. (2010). By utilizing all the available information in the aforementioned databases, an initial keyword search was conducted with the predefined search query involving keywords related to Web3D technologies (1):



Source(s): Adopted from Kitchenham *et al*. (2010)

Figure 1. Review protocol

(net OR fungible OR tokens* OR crypto OR blockchain) AND (art* OR artist OR virtual OR gallery OR exhibition OR artificial OR intelligence) AND (metaverse OR virtual AND world)

Titles and abstracts of the available literature were assessed based on their relevance to the domain under study. This process involved excluding studies that were not related to the research scope. Subsequently, the full text of the articles that passed the initial control screening was reviewed in detail with a focus on content, methodology, research findings and conclusions. The predefined inclusion and exclusion criteria (EC) questions EQ1-EQ2 presented in Table 2 were applied. Each selected study that fulfilled the previous validation steps was then subjected to the quality control criteria (QAC) based on predefined criteria presented in Table 3. With emphasis placed on the relevance of the studies covering the subject of Blockchain, NFTs, Art, Metaverse, AI, the future of these technologies and their contribution to the overall focus of this research. A grading scale was used, ranging from 0 (no-pass) to 1 (pass), with each relevant study assessed based on multiple criteria receiving either a 0, 0.5 or 1 for each criterion. The scores from all criteria were then summed to provide a total score for each study. For the determination of pass or no pass, a minimum threshold of three points five was required to be considered to have passed the assessment, with a maximum score of eight.

The studies that met the EC and QAC were included in the intermediate step in the research methodology for the systematic analysis. The research was focused on publications in the defined timeframe from 2021 to 2024, with February being the last month of research, capturing the recent up-to-date advancements in the field since the development of NFTs and their application in the modern art and Web3D domain.

This oriented methodology to data processing and selection was used to grant high-quality and relevant studies, providing a rich knowledge database for understanding the domain understudy. Additionally, the grading bias was avoided by performing an independent blind

Table 2. Inclusion and exclusion criteria

EQ1	Studies not available in English
EQ2	Exclude non-peer-reviewed sources
EQ3	Exclude unpublished works, conference papers etc. Without full-text availability
EQ4	Exclude Studies that are literature reviews
EQ5	Exclude studies that do not explicitly address the intersection of Net Fungible Tokens, Art, Artificial Intelligence and the Metaverse
EQ6	Exclude studies with missing complete research framework, such as methodology, results or conclusions
EQ7	Exclude studies with a narrow focus that did not contribute to a broader understanding of the topic
EQ8	Exclude duplicate studies

Table 3. Quality assessment criteria

Q1	Does the study address the intersection of net fungible tokens, art, artificial intelligence and the metaverse?
Q2	Is the research data clearly defined?
Q3	Is the methodology appropriately described and justified?
Q4	Is the data collection process well-documented?
Q5	Is the source considered reliable in the domain under study?
Q6	Are any ethical concerns discussed herein?
Q7	Is the presentation of results clear and well-organized?
Q8	Does the study make a meaningful contribution to the understanding of the topic?

Source(s): Authors' own work

Table 4. Cohen's Kappa

Cohen's kappa
Main Author and Assessor 1: 1.0 *(Perfect agreement)*
Main Author and Assessor 2: 0.4 *(Fair agreement)*
Assessor 1 and Assessor`2: 0.4 *(Fair agreement)*
Average kappa across all pairs: 0.6 *(Moderate agreement)*

Source(s): Authors' own work

assessment of 3 random articles, in which the criteria were applied without the assessors knowing the predefined grading of the articles. The validity and reliability of the predefined criteria are calculated from Cohen's Kappa (Sun, 2011). The perfect kappa score (1.0) between the author and assessor 1 indicates that their assessments are in complete agreement. The fair kappa scores (0.4) between the main author and Assessor 2 and between Assessor 1 and Assessor 2 suggest that the level of agreement is sufficient. The overall moderate average kappa score (0.6) across all pairs suggests a reasonable level of consistency among the authors, which is crucial for reducing grading bias Table 4.

2.4 Data extraction, analysis and synthesis

A data extraction template was created for logging the extracted data, containing authors' names, titles, year, source type, document type, repository, keywords, external link, quality scores, abstract, umbrella terms and personal comments. Next, the pilot data extraction process was performed, in which all fields related to the research questions were defined. For the data-collection process, MS Excel spreadsheets were employed, containing the extracted information before the data synthesis.

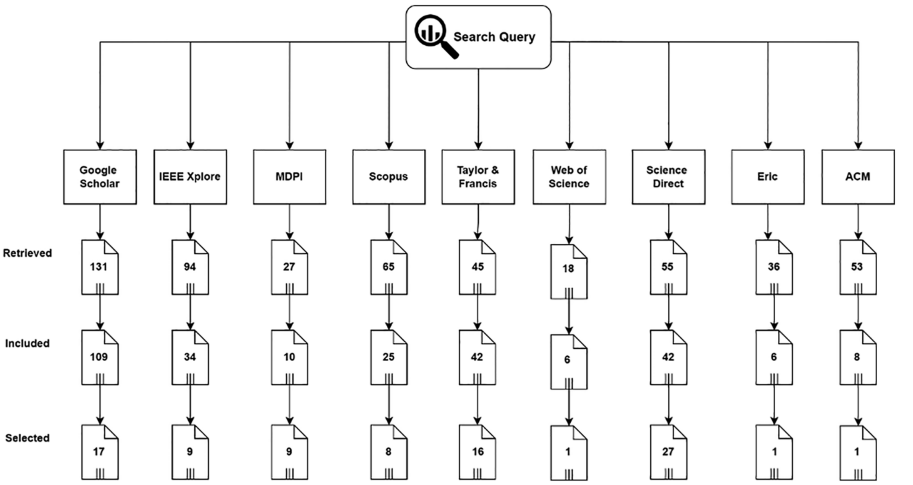
A qualitative research methodology approach was adopted for the needs of this study, presenting the extracted information in a descriptive format. The next step was the data synthesis, in which results are summarised and presented in a meaningful manner to answer the research questions. Similar themes across various sources of information, even if related to similar concepts, were identified and categorised by the use of umbrella terms, as in Table 5.

Figure 2 schematically presents the methodical approach used for the systematic research by sourcing all relevant studies of the aforementioned academic sources and compiling them in a central data repository for detailed analysis.

Table 5. Umbrella terms of RQs

Research question	Umbrella terms
RQ1	• Digitized Authentication and Safety of Assets • Blockchain Privacy and Trust • Digital Art Legal Framework
RQ2	• Art Market Dynamics and User Behaviour • Speculative Behaviours and Value Perception • Digital Innovation
RQ3	• NFT-Driven Meta Economy • Innovation in XR through NFTs • Metaverse and GLAM • Web3D

Source(s): Authors' own work



Source(s): Authors' own work

Figure 2. Data selection and extraction process

3. Results

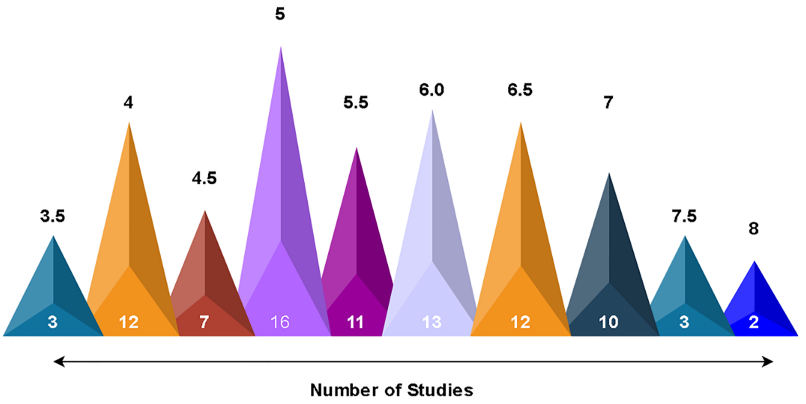
The conducted literature review considers reviewed research articles in the predefined timeframe starting from 2021 to 2024, with February being the last month of paper extraction. The starting point was chosen due to the increased popularity and technological maturity of the NFT domain during the defined timeframe. The number of publications per year shows that the topic is of great interest in the current debate: $n = 3$ publications for 2021, $n = 20$ for 2022, $n = 50$ for 2023 and $n = 16$ for 2024 (until February). The results of the purification process, after the application of the predefined search and quality queries, are provided in Table 6.

The diversity in various publication streams (IEEE Xplore, MDPI, Scopus, Taylor and Francis, Web of Science, Science Direct, ERIC, ACM Digital Library and Google Scholar) underscores the broad interest of the academic community in the field of NFTs in general. The quality scores of the selected 89 studies are presented schematically in Figure 3. As it can be seen from the schematic representation of studies, 15 selected studies scored greater or

Table 6. SLR results overview

Source	Retrieved	Included	Selected	Method
IEEE xplore	94	34	9	Automated
MDPI	27	10	9	Automated
Scopus	65	25	8	Automated
Taylor and Francis	45	42	16	Automated
Web of Science	18	6	1	Automated
Science Direct	55	42	27	Automated
ERIC	31	6	1	Manual
ACM	53	8	1	Manual
Google Scholar	131	109	17	Manual
Total	*519*	*290*	*89*	Manual

Source(s): Authors' own work



Source(s): Authors' own work

Figure 3. Quality score distribution

equal to 7, which can be categorised as *high-quality contributions*, while the remaining 36 studies scored 5.5 to 6.5, indicating a *medium quality score*; and 38 studies score between 3.5 and 5, being considered as a *sufficient quality score*.

3.1 How can the integration of NFTs ensure privacy and trust for users and customers within the emerging Web3D art ecosystem?

A core advantage of NFTs is the empowerment given to artists. With NFTs, artist have control over the ownership of their creations, while they can offer them to end-users in a digital context, making their work available for sale to a wide audience. This results in retaining a greater share of the profits if they decide to mint and sell their art creations (Macdonald-Korth *et al.*, 2018). This is an important feature of NFTs because it leads to the democratisation of art markets, allowing emerging artists and actors from diverse backgrounds to expand their reach and network without the interference of galleries or auction houses, which hold enormous power in the art value chain (e.g. Sotheby's, Christys, Phillips) (Sidorova and Bourron, 2023), while in parallel providing them with a tool to increase the legitimacy within the art market (Mitchell *et al.*, 1997) and engaging users within virtual, immersive environments. Review of the articles indicates that the use of NFTs and the underlying blockchain technology can legitimise and validate works of art. This notion was previously only possible with the aforementioned institutions and has a lasting impact on power dynamics between actors operating in the art ecosystem.

Additionally, the tokenisation and distribution of digital art collectables, as NFTs, challenge the elements of liability and authenticity, reshaping the evaluation of artworks (Liddell, 2023). This repercussion that is extended beyond the limits of art introduce various challenges related to intellectual property (IP), copyrights and the sustainability of blockchain technologies (Xie *et al.*, 2023a, b; Aksoy and Üner, 2021). The variety in views and risk assessments of these new technologies underpins the complexity of their application within the art domain and the broader cultural and digital economic ecosystem (Chen *et al.*, 2022). Aspects that show the importance of education and adaptation of artists, as well as the involved actors, to inform about the ongoing changes of the digital ecosystem. As the integration of NFTs raises questions regarding privacy and trust within the emerging Web3D art ecosystem, having an impact on user behaviour and investment strategies in immersive markets, it remains crucial to understand actors' needs in the digital transition of art ecosystems.

The results of the SLR further indicate that the integration of NFTs within the emerging Web3D art domain imply a potential deviation in art creation, distribution, value estimation and copyright protection in comparison to existing established art markets (Dong and Wang, 2023; Ante, 2023; Vermeir and Heiremans, 2023). For example, NFTs provide artists with new platforms and tools for tokenised art creation, allowing for unique and verifiable ownership, as discussed by Dong and Wang (2023). Additionally, NTFs facilitate global distribution streams without intermediaries, democratizing access to art via platforms, OpenSea (https://opensea.io/category/art) and Nifty Gateway (https://www.niftygateway.com/) are just two examples, allowing artists to directly reach a wider audience by bypassing traditional curating processes and evaluation activities (Ante, 2023).

Hence, the transparency of blockchain technology ensures provenance and ownership and in parallel, makes artwork easily accessible, allowing a more objective and accurate value assessment that is, finally, conducted by artwork end-users (Vermeir and Heiremans, 2023). Additionally, NFTs offer robust mechanisms ensuring copyright production by embedding usage rights and ownership elements into the tokenised asset, securing the asset from unauthorized use and reproduction (Dong and Wang, 2023). These factors evidence the transformative potential of NFTs in the current art ecosystem because they disrupt existing market dynamics and processes.

While several benefits of NFTs in digital art ecosystems have been identified, the reviewed articles also display some remaining challenges (systematic legal control, demand uncertainty, oversupply, fierce competition) (Radermecker and Ginsburgh, 2023) that should be addressed.

One challenge is the (perceived) relationship of NFTs with the speculative market dynamics of cryptocurrencies (Chalmers *et al*., 2022; Uddin *et al*., 2023; Radermecker and Ginsburgh, 2023). Guo *et al*. (2023a, b) indicate that tokenised art is significantly influenced by the price movements of cryptocurrencies. Hence, *NFT bubbles* have a strong correlation with cryptocurrency fluctuations and prices. In this way, broader financial market dynamics and sentiments measured by indices such as the VIX (Volatility Index) have a significant impact on end-user perceptions and the associated value generated by tokenised art compared to traditional art market dynamics, which could directly impact perceived end-user confidence. According to Chalmers *et al*. (2022), the volatility associated with the speculative nature of cryptocurrency markets can undermine users' trust in Web3D-based artworks and exhibitions, while Uddin *et al*. (2023) simultaneously emphasise the need for robust data protection measures that require disruptive technological advances. As emphasised in the research articles reviewed, addressing these issues involves developing secure, transparent systems. Radermecker and Ginsburgh (2023) also note that educating actors about the complexities and risks associated with NFTs is crucial for full integration into the art market, especially to address the challenges mentioned above. This finding again shows the complexity of NFT integration in evolving digital art ecosystems.

The boundaries between digital tokenised art, speculation and the notion of authenticity are also examined and criticised in the work by Botz-Bornstein *et al*. (2021) (titled "Bullshit Art"). The gesture of destroying the physical artwork for digital value enhancement (for example, Banksy's, "Morons White") showcases the complex interconnection between physical art and its digital versions. This act reveals the authenticity pursuit in the process of art dematerialisation, raising more discussions regarding the future of art in the digital era. In that way, the tokenised artefact serves a new form of authenticity and ownership detached from the physical form, questioning blockchain as an art preservation strategy (Rivero-Moreno, 2024; Lee *et al*., 2023). By establishing a secure blockchain immutable record of ownership and provenance, NFTs can, thus, enhance trust among end users. However, as highlighted by Lee *et al*. (2023) and Rivero-Moreno (2024), there are also challenges related to the long-term preservation and stability of digitised assets on the blockchain.

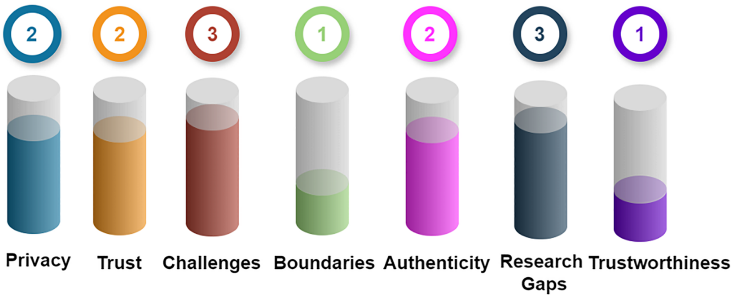
Another challenge identified in the SLR is that the current NFT art ecosystem lacks research initiatives that focus on trust characteristics, digital intellectual property rights and how actors can best protect users from threats and vulnerabilities (Jia and Yao, 2023;

Mackenzie and Bērziņa, 2022; Wang *et al*., 2024) – aspects that are of crucial importance for artwork end-users. In research conducted by Hasan *et al*. (2022), a publicly available, robust blockchain-based framework was presented which increases the trustworthiness of the NFT ecosystem by preventing fraud and security threats. Furthermore, Dong and Wang (2023) discuss how NFTs maintain the protection of creators' intellectual property, thus ensuring trust in digital transactions. Furthermore, Aksoy and Üner (2021) emphasise the role of NFTs in securing artists' rights, especially when integrated with blockchain technologies to mitigate fraud risks. Banaeian Far and Hosseini Bamakan (2023) emphasise that privacy in the metaverse can be enhanced through the integration of NFT-based identity management systems that enable control over individual users' data. As transparency in NFT transactions can promote high brand loyalty standards and high purchase intent among millennials and Gen-Zs (Xie *et al*., 2023a, b), these aspects remain essential for the successful integration of NFTs. Feld (2024) and Kalbermatten (2024) show the potential of NFTs and how they can change the authenticity and ownership of art by offering new forms of engagement and trusted ownership in the digital art space. Table 7 presents the number of behavioural consequences of NFT integration as well as the repercussions found in the corresponding literature. Figure 4 presents schematically the number of publications addressing these aspects.

Table 7. Privacy, trust, challenges and boundaries of NFTs in the Web3D and art domain

Aspect	Behavioural consequence	Repercussion	Publication
Privacy	Integration of NFTs ensures secure and transparent verification of ownership and transactions	Enhanced user privacy and protection against fraud	Abilkaiyrkyzy *et al*. (2023), Hasan *et al*. (2022)
Trust	Public and traceable transaction records increase consumer trust and confidence in digital art markets	Increased consumer trust and confidence	Ante (2023), Alkhudary *et al*. (2023)
Challenges	Speculative market dynamics of cryptocurrencies affect the value and stability of tokenized art	Potential volatility and instability in tokenised art value	Chalmers *et al*. (2022), Uddin *et al*. (2023) Radermecker and Ginsburgh (2023)
Boundaries	The uncertain nature of tokenised art is significantly influenced by cryptocurrency price movements and financial market sentiments	Value and perception of tokenized art affected by broader financial market dynamics	Guo *et al*. (2023a, b)
Authenticity	Digital value enhancement through physical art destruction raises questions about authenticity and art preservation in the digital era	Challenges in maintaining authenticity and preservation of digital art	Botz-Bornstein (2021), Rivero-Moreno (2024)
Research Gaps	Lack of research focusing on trust features, digital IP law and protection from threats and vulnerabilities in the NFT ecosystem	Need for further research and development in trust features and digital IP law	Jia and Yao (2023), Mackenzie and Bērziņa (2022), Wang *et al*. (2024)
Trustworthiness	Blockchain-based frameworks introduced to enhance the trustworthiness of the NFT ecosystem by preventing fraud and security threats	Improved trustworthiness and security in the NFT ecosystem	Hasan *et al*. (2022)

Source(s): Authors' own work



Source(s): Authors' own work

Figure 4. Publications addressing the aspects of privacy, trust, challenges and boundaries of NFTs in the Web3D and art domain

3.2 What are the behavioural and financial repercussions of NFTs on customers and (end-) users in art ecosystems and Web3D applications?

In various NFTs, early and latest marketplaces (Open Sea, Nifty, etc.), the trading volumes of high-value collectables (e.g. Crypto Punks, Bored Ape) have shown high correlation with higher returns, indicating their significant investment potential (Tang *et al.*, 2023). This underscores the potential profitability of investing in NFTs that can drive user interest and confidence in the tokenised art market. Whereas, as mentioned above, the high volatility could discourage users from engaging with and trusting NFTs.

It was found that trading volumes before a purchase of a tokenised collectable NFT negatively relate to the return volume, proposing that investors should make a sellout when market activity is quite high (Xie *et al.*, 2023a, b). It is indicated that the mimic behaviour of investors with the crowd consumer behaviour potentially leads to speculative behaviours, market bubbles and crashes (Boido and Aliano, 2023; Mosna and Soana, 2023; Sifat *et al.*, 2024).

NFT appreciation in the art domain is not only connected with collective belief in their growth but also with the individual willingness to invest. Indicators, such as the reputation and global reach of the artist, uniqueness of tokenised art, storytelling and innovation labour are critical in value determination (Alkhudary *et al.*, 2023; Li and Chen, 2023; Wu *et al.*, 2023; Yilmaz *et al.*, 2023). Additionally, the utility (IP rights, exclusive access to events) of tokenised assets is formed by their applicability within the digital ecosystem, shaping the valuation processes (Xie *et al.*, 2023a, b).

Particular tokenised items (e.g. bored Ape Yacht Club) provide not only ownership rights but also a societal status and access to particular communities and events (e.g. Paris NFT week). This exclusivity element can increase the perceived value of NFTs, having a high influence on investor strategies where the social return of investment becomes more important than the financial one (Deventer *et al.*, 2024).

In the emerging market of digitised tokenised assets, visual features (AR elements, animations, robotics) and the societal impact of traders can also influence the price Guo *et al.*, 2023a, b). Various studies but also market trends have shown that these elements, accompanied by the historical sale prices of the related NFTs, can have a substantial influence on price spillovers (Aharon and Demir, 2022; Ho *et al.*, 2024; Wang, 2022). As a result, speculative investment strategies in NFTs and the broader Web3D domain can be significantly influenced by social utility and trending aesthetic themes (Hwang and Koo, 2023). In Table 8, the behavioural consequences and repercussions found in the available literature are presented, providing an overview of the current NFT business ecosystem.

Table 8. Behavioural consequences in NFT market studies

Publication	Behavioural consequence	Repercussion
Chen and Friedmann (2023)	Increased trading volumes of high-value collectibles	Potential market bubbles and speculative behaviours
Horky *et al.* (2023)	Negative relationship between pre-purchase trading volumes and return volumes	Investors may sell during high market activity, affecting market stability
Zhang (2023)	Crowd consumer behaviour	Increased risk of market crashes and speculative bubbles
Wang *et al.* (2023a, b)	Speculative behaviour during high market activity	Potential for rapid market corrections or crashes
Tang *et al.* (2023)	Trading volumes influencing returns on NFT investments	Investors may prioritize financial returns over long-term value
Xie *et al.* (2023a, b)	Mimic behaviour of investors	Speculative behaviours and potential for market bubbles
Boido and Aliano (2023)	Speculative market behaviours leading to bubbles	Market crashes or utopian artistic revolutions
Mosna and Soana (2023)	Speculative behaviours/money laundering in the digital era	Low liability due to illegal
Sifat *et al.* (2024)	Collective belief in NFT growth vs. individual willingness to invest	Volatility in NFT markets due to varying investor strategies
Alkhudary *et al.* (2023)	Reputation and global reach of artists affecting NFT appreciation	High value placed on unique, innovative and well-known artists
Li and Chen (2023)	Importance of storytelling and innovation in value determination	Higher value and appreciation for NFTs with compelling stories and innovative features
Wu *et al.* (2023)	Usability, security, privacy and governance challenges in NFT applications	Need for improved platform usability, enhanced security measures and better governance frameworks
Yilmaz *et al.* (2023)	Utility of tokenized assets (e.g. IP rights, exclusive access) shaping valuation	Increased perceived value of NFTs with practical and exclusive benefits
Xie *et al.* (2023a, b)	Applicability within digital ecosystem influencing valuation processes	NFTs with greater utility and integration in digital ecosystems may command higher prices
Deventer *et al.* (2024)	Social return on investment becoming more important than financial return	Investors prioritizing social status and community access over financial gains
Guo *et al.* (2023a, b)	Visual features (AR elements, animations, robotics) influencing price	Higher prices for NFTs with advanced visual features
Aharon and Demir (2022)	Historical sale prices and societal impact of traders affecting price spillovers	Market prices influenced by past sales and the perceived societal impact of influential traders
Ho *et al.* (2024)	Aesthetic value of performances on a metaverse platform had a major influence on performance viewing	Limited impact of educational components on audience engagement and platform adoption for performances
Wang (2022)	Speculative investment strategies shaped by social proof and trending aesthetic themes	Investors may follow trends, leading to increased market volatility
Hwang and Koo (2023)	Aesthetic appearance themes driving speculative investment	Trends and social proof may lead to price fluctuations and speculative investment behaviours

Source(s): Authors' own work

3.3 How can NFTs leverage the development and growth of the Web3D domain and virtual immersive (XR, VR, AR) worlds?

With the recent developments in the human-centric Web3D art ecosystem, there is promise for leveraging the full potential of the emerging technologies combined with NFTs (Mourtzis *et al.*, 2022; Qin *et al.*, 2023; Ray, 2023). For example, in various immersive worlds related to

gaming, education, musical in which users can develop or create via means of prompt engineering, buy and sell digital tokenised items or even whole worlds and proof of concepts, digital ownership can be tied and tracked back to the creator or current owner (Bao *et al*., 2024; Kalhoro *et al*., 2023; Lee *et al*., 2023; Sutikno and Aisyahrani, 2023; Truong *et al*., 2023; Turchet, 2023; Vidal-Tomás, 2022; Vital *et al*., 2023). In that way, intellectual property rights are secured, and digital creations are valued while being embedded with their corresponding information in immersive or mixed-reality environments (Hwang, 2023; Truong *et al*., 2023).

NFTs have the potential for various interoperability enhancement efforts within different XR platforms and devices, as discussed by Chen *et al*. (2023). The interoperability may lead to a more cross-platform collaborative approach of actors and an interconnected expansive digital ecosystem shaping the future of the next generation of the Internet (Sylaiou *et al*., 2024). The democratisation and monetisation of such experiences, as well as the economic returns derived from various creative initiatives, might potentially attract more talented artists and investment into the Web3D art ecosystem.

Banaeian Far and Hosseini Bamakan (2023) discussed that the virtual real estate domain is now also expanding in the Web3D, for example, material testing, digital twins and monument digital enhancement (e.g. AR Utrecht). Thus, NFTs can be applicable in representing the ownership of virtual real estate, representing the physical ones within immersive worlds (Casale-Brunet *et al*., 2023). Banaeian Far and Hosseini Bamakan (2023) also project that this can lead to the development of meta-economies where users buy, sell or lease properties (real estate 3D printing, smart houses, etc.). The development of such a Web3D estate landscape and infrastructure can, therefore, be enhanced with the innovative uses of virtual cultural spaces such as galleries, social clubs and social events (or even individual artworks) created for Web3D real-estate landscapes and infrastructures (Far *et al*., 2023).

With the addition of various AI-enabled assistants (e.g. meta-humans), NFTs can represent the unique tokenised identity of each of them (Spyrou *et al*., 2025). This enables end-users to have a distinct presence on multiple platforms at the same time. The emerging domain of XR gaming can encourage the secondary market creation of unique AI copilots, further enriching the digital art ecosystem. Figure 5 displays the pipeline of the generation and tokenisation processes and general various processes and activities in the creation of AI-generated meta-human agents (Banaeian Far and Hosseini Bamakan, 2023; Bao *et al*., 2024).

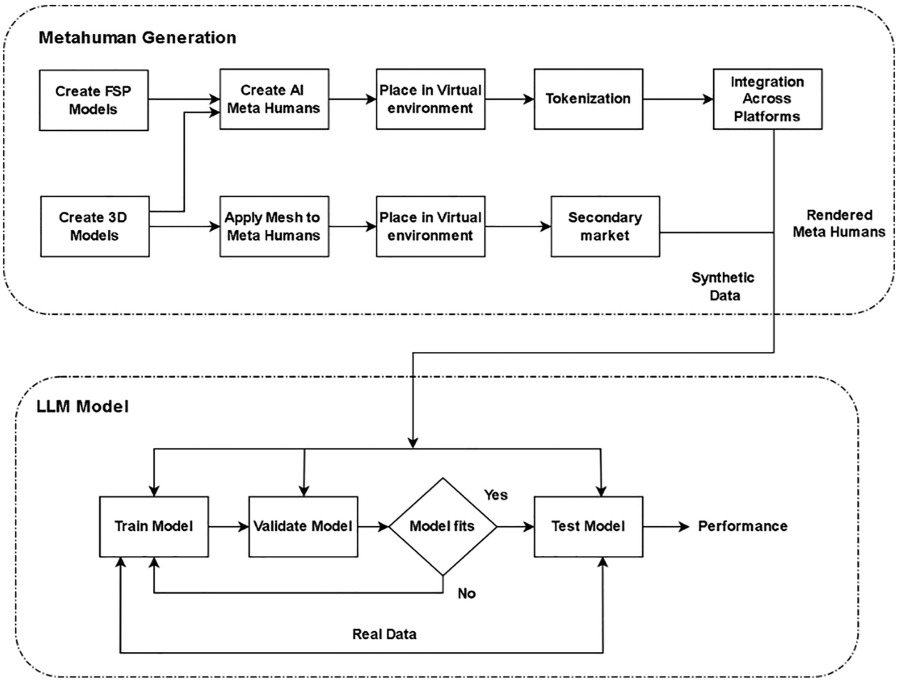
NFTs embedded in the GLAM (Galleries, Libraries, Archives, Museums) sector can embrace the concepts of scarcity and authenticity to digitised assets translated to high impact in immersive art experiences within enhanced worlds (Feld, 2024; Jung, 2023; Sidorova and Bourron, 2023). This enhances the status of digital art and storytelling and, at the same time, strengthens the (partial) ownership of the digital shadow of the physical object (Damodaran, 2023; Kalbermatten, 2024; Santalo *et al*., 2023).

4. Discussion

The field of blockchain technologies is developing rapidly and is redefining the world of tokenised art ecosystems (Belk *et al*., 2022). This transition is impacting the way users interact with artwork, their notions of ownership and how the art is consumed.

There are growing examples of artists incorporating XR technologies into their novel creations, leveraging the power towards higher audience engagement (Vital *et al*., 2023). Immersive technologies that lie under the umbrella term of XR have the potential to transform the domain of NFTs by providing engaging experiences compared to traditional art viewing. Tokenised artworks in virtually enhanced immersive worlds can protect verifiable ownership of these Web3D experiences via blockchain technologies (Hurst *et al*., 2023).

With the constant growth of the NFT market, the need for implementing regulatory frameworks and standards becomes increasingly crucial. Due to the complexity and rigorous evolvement of art-based blockchain systems, more challenges arise in applying existing legal frameworks in such a digital ecosystem (Cho *et al*., 2023). Issues like trust, intellectual



Source(s): Authors' own work

Figure 5. Pipeline diagram for metahuman tokenization process and activities

property rights, copyright and consumer protection in the context of these types of transactions need to be addressed and tailored responsibly towards societal progress as well as end-users acceptance (Vidal-Tomás, 2023). Only when the digital infrastructure has a solid, legal basis end-users will be able to experience the full potential of immersive artworks and all the associated benefits in Web3D worlds. A predefined set of regulatory standards could, therefore, lead to a higher stability of such tokenised immersive and non-immersive economic systems, providing the foundation and guidance to all stakeholders involved in the field (creators, collectors, developers, web3d marketers). The design, implementation and validation of regulatory approaches will lead to more innovative initiatives with an impact on the overall market growth (Huang *et al*., 2023; Yang *et al*., 2022).

The future directions of tokenised art hold significant potential for equity beyond high return on investments, extending into education and marketing. By leveraging the power of the aforementioned disruptive technologies, artists can create and donate tokenised artworks that can serve also as tools contributing to greater inclusivity and awareness. Therefore, the application can lead to more social sustainability improvements that are not only beneficial for the artist or their associated value chain actors but are also crucial for sustainability system transitions. An example might be the help that artists could provide for vulnerable groups that are unable to express themselves in traditional settings and with traditional tools (e.g. smallholder farmers in developing countries or other marginalised communities through donations), given the complex global business dynamics in current economies. In addition, incorporating sustainability elements into tokenised artworks can raise awareness of environmental issues and encourage more sustainable practices in various sectors. By combining creativity and technology, artists can contribute to greater social justice,

environmental sustainability and community empowerment, ultimately bringing about positive change and societal progress.

5. Conclusion

As the reviewed articles show, NFTs present a significant number of opportunities but there remain also challenges related to the sustainability, ownership and value generation of digitalised artworks with clear signs of valourisation in the wider cultural and economic landscape.

Future developments regarding the impact of the integration of disruptive technologies on this evolving landscape may vary. Interdisciplinary research involving different actors from multidisciplinary, interconnected fields (art historians, legislators, developers, marketers, etc.) remains crucial for the sustainable growth of the Web3D art ecosystem. Although some aspects of the sustainable implementation of NFTs in the art market are displayed, future studies should also address topics such as intellectual property rights, digital property and the environmental and ethical impact of blockchain technologies. In addition, future research needs to be conducted at the intersection of AI and the Web3D to enhance interactive digital art experiences that enable greater immersion and audience engagement. Investigating the long-term sustainability as well as the environmental sustainability of NFTs, including market trends, demand and risks affecting the value of tokenised art, is crucial. There is also a need to focus on the development of more energy-efficient blockchain technologies to promote sustainable, low environmental footprint practices within the digital art community.

The promotion of education, awareness and the simplification of NFT initiatives and the tokenization efforts of art among the actors (artists, collectors, public, etc.) are of significance for broader participation, leading to the creation of more inclusive art communities. As the Web3D ecosystem continues to grow, ongoing research, active dialogues and collaboration between various value chain actors (for example, policymakers, artists and collectors) are crucial for the design and application of sustainable frameworks and standards.

The integration of NFTs into the future fusion of the digital and physical worlds represents an interesting development that raises critical questions about the future of art and its value in the new digital age. The Web3D art domain reveals its complexity in terms of digital ownership issues, artistic innovation and the overall policy regulatory framework and associated standards that ensure the transparency of all interconnected entities within the overall domain ecosystem.

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