An ecosystem approach to Web3.0: a systematic review and research agenda

Chong Guan
Singapore University of Social Sciences, Singapore, Singapore
Ding Ding
School of Business, Singapore University of Social Sciences, Singapore, Singapore
Jiancang Guo
Netvirta Singapore Pte. Ltd., Singapore, Singapore, and
Yun Teng
Centre for Continuing and Professional Education, Singapore University of Social Sciences, Singapore, Singapore

Received 15 October 2022
Revised 24 March 2023
23 May 2023
Accepted 29 May 2023

Abstract

Purpose – This paper reviews the extant research on Web3.0 published between 2003 and 2022.
Design/methodology/approach – This study uses a topic modeling procedure latent Dirichlet allocation to uncover the research themes and the key phrases associated with each theme.
Findings – This study uncovers seven research themes that have been featured in the existing research. In particular, the study highlights the interaction among the research themes that contribute to the understanding of a number of solutions, applications and use cases, such as metaverse and non-fungible tokens.
Research limitations/implications – Despite the relatively small data size of the study, the results remain significant as they contribute to a more profound comprehension of the relevant field and offer guidance for future research directions. The previous analysis revealed that the current Web3.0 technology is still encountering several challenges. Building upon the pioneering research in the field of blockchain, decentralized networks, smart contracts and algorithms, the study proposes an exploratory agenda for future research from an ecosystem approach, targeting to enhance the current state of affairs.
Originality/value – Although topics around Web3.0 have been discussed intensively among the crypto community and technological enthusiasts, there is limited research that provides a comprehensive description of all the related issues and an in-depth analysis of their real-world implications from an ecosystem perspective.
Keywords Web3.0, Systematic review, Ecosystem, Blockchain, Decentralized network, DApp, Smart contract, Metaverse, NFT
Paper type Research paper

1. Introduction

Web3.0, also known as Web3, is the next generation of the internet. It incorporates the concepts such as decentralization, blockchain technology and token-based economies (Bambacht & Pouwelse, 2022; Belk, Humayun, & Brouard, 2022; Cheng *et al.*, 2022). In April 2014, Gavin Wood first systematically conceptualize Web3.0 as a "decentralized online ecosystem based on blockchain," which provides developers with the building blocks to create applications in

Journal of Electronic Business & Digital Economics
Vol. 2 No. 1, 2023
pp. 139-156
Emerald Publishing Limited
e-ISSN: 2754-4222
p-ISSN: 2754-4214
DOI 10.1108/JEBDE-10-2022-0039

a whole new way (Wood, 2022). Wood argues that in the post-Snowden era, internet users no longer trust enterprises and believe that businesses only manage and use user data for profit. Therefore, there is a need to create internet infrastructure and applications based on the concept of "trustlessness," meaning that one need not rely on or trust a third party. Web3.0 can be seen as the enforceable Magna Carta of the internet and the cornerstone of individual freedom against authority (Belk *et al.*, 2022). The concept piqued the interest of venture capital firms, cryptocurrency investors and major technology companies. In particular, starting in late 2021, the number of searches on the internet for the keyword "Web3" grew rapidly (as shown in Figure 1). People began to talk enthusiastically about Web3 and companies are starting to prepare for a new business model built on the Web3 platforms.

Web3 is not a new phenomenon but rather a continuation of the cyberpunk and cryptopunk spirit that emerged in the 1980s and 1990s. The current Web3.0 revolution is more like a renaissance after injecting cyberspace with native economic inflows. Cryptocurrencies, non-fungible tokens (NFTs), decentralized autonomous organizations (DAOs), decentralized finance (DeFi) and other concepts are part of the vision for this future blockchain-based web (Sheridan *et al.*, 2022). The idea that Web3.0, a decentralized, blockchain-based internet ecosystem owned and run by its users, aims to achieve a better and fairer internet, is one of the most persuasive narratives surrounding it (Bambacht & Pouwelse, 2022; Wang *et al.*, 2022). Web3.0 proponents specifically envision an internet where users can reclaim control from a few extractive, centralized institutions and where everyone with an internet connection can compete on equal footing.

The concept of Web3.0 has significant implications for the current economic landscape (Guan, Ding, & Guo, 2022). Some of its key implications include but are not limited to:

(1) Disrupting traditional business models and creating new opportunities: The rise of decentralized applications (DApps) built on blockchain technology is a good example, which has enabled the creation of new marketplaces and platforms for users to exchange value directly with each other without involving centralized authorities.

(2) The creation and use of digital assets and currencies: Web3.0 introduces new types of digital assets and currencies, such as cryptocurrencies and digit tokens. The assets can be used for value transfer, governance, access control and other purposes, and create new economic incentives for users to participate in the ecosystem.

(3) Enabling new forms of peer-to-peer collaboration and value creation: take DAOs as an example, they emerge as a new model for decision-making and resource allocation without involving centralized authorities.

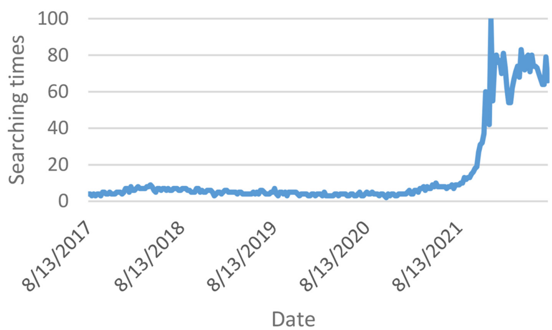


Figure 1.
Google search trends on "Web3.0" (worldwide)

Source(s): Figure by the authors

(4) Incubating new business models: Web3.0 is fostering new business models built on decentralized networks and blockchain technology. Companies leveraging the technology can create new products and services and enable users to interact with each other in a decentralized and secure manner.

It is important to note that Web3.0 based on a blockchain decentralized network is distinct from what was described by Tim Berners-Lee's concept for a Semantic Web (Berners-Lee, Hendler, & Lassila, 2001). The Semantic Web aims to make data machine-readable. Innovative technologies such as resource description framework and web ontology language are the key enablers for encoding semantics with the data (Blei, 2012; Blei, Ng, & Jordan, 2003; Mimno, Wallach, Talley, & McCallum, 2011). These tools are used to formalize metadata representation. The significant benefits of this integrated semantics include the ability to reason over data and work with a variety of data sources (Monteiro, 2013). However, after a few years of development, the Semantic Web did not materialize in the end due to its technical challenges and other constraints.

Unlike the Semantic Web which focuses on technical advancements, "Web3.0" uses blockchains, cryptocurrencies and NFTs to return ownership and authority to the consumers (Potts & Rennie, 2019). Web3.0 aims to replace the exploitative and unfair web owned and profited by centralized repositories with a decentralized internet where people own their time and data and are fairly reimbursed for it.

Although topics around Web3.0 have been discussed intensively among the crypto community and technological enthusiasts, there is limited research that provides a comprehensive description of all the related issues and an in-depth analysis of their real-world implications. To fill this gap, this study reviews the extant research on Web3.0 published between 2003 and 2022 to obtain a holistic understanding of the current development of Web3.0 and all the related sub-topics. Using a topic modeling procedure, latent Dirichlet allocation (LDA), we uncover seven research themes that have been featured in the existing research and the key phrases associated with each theme. In particular, we highlight the interaction among the research themes that contribute to the understanding of a number of solutions, applications and use cases, such as metaverse and NFT. Building upon the pioneering research in the field of blockchain, decentralized networks, smart contracts and algorithms, we conclude by proposing an exploratory agenda for future research from an ecosystem approach.

2. Evolution of the internet: from Web1.0, Web2.0 to Web3.0

We first review the brief history of the web into two broad periods – Web 1.0 and Web 2.0 – focusing on the key differences between them.

2.1 Web1.0: read-only (1990–2004)

Tim Berners-Lee created the decentralized protocols for the World Wide Web in 1989 at CERN in Geneva, enabling the sharing of knowledge from any location (Berners-Lee *et al.*, 2001). From 1990 until 2004, the initial development of Web1.0 took place, which primarily consisted of static HTML websites controlled by businesses, and user involvement or interaction was minimal. At this stage, there are few content creators, and most users are simply content consumers. Although there were portals such as America Online and forums such as private chat rooms and bulletin boards (BBs), the internet had little interaction or payment transaction capabilities at the time (Bevacqua, Carnuccio, Ortale, & Ritacco, 2011). Web1.0 was not completely devoid of interaction or payment functions, but these functions were severely limited by the transfer infrastructure's inability to guarantee security.

2.2 Web2.0: read–write (2004 onwards)

The introduction of social media platforms in 2004 marked the beginning of the Web2.0 era. The web evolved from a read-only medium to a read–write two-way platform. Instead of providing users with materials, businesses began to provide platforms through which users could exchange user-generated content and communicate with one another. As more individuals went online, a small number of leading businesses started to hold a disproportionate percentage of the traffic and value produced on the internet. Web2.0 also created the advertising-based business model (Monteiro, 2013). However, while users may generate content, they did not own it or get paid when it was created. In the Web2.0 era, ordinary web users could exchange information and collaborate on various internet platforms at a very low cost, and the core concept of internet products was interaction, sharing and association (Bevacqua *et al.*, 2011). The state of the internet service is deteriorating, with users trusting the platforms and giving up their privacy in exchange for better service. At the same time, the platform service providers' valuation has increased as a result. However, as the business model matures and the platforms' growth hit a bottleneck, they need to extract more data from users to maintain growth, causing users to lose trust and former partners becoming competitors. Through years of status accumulation, insurmountable entry barriers for new entrepreneurs have been created, impeding the emergence of competition and innovation. This began to erode the interests of various stakeholders and internet users, and the internet is in dire need of a paradigm shift (Belk *et al.*, 2022).

2.3 Web3.0: read–write–own (2021 onwards)

The decentralization and blockchain technology in Web3.0 provides an improved data ownership and payment model over Web1.0 and 2.0 (Wang *et al.*, 2019). Centralization, monitoring and exploitative advertising are replaced by transparent and secure decentralized infrastructure and application platforms. In this way, people will be able to legally control their data (Potts & Rennie, 2019). The following are a few fundamental features that serve as its guiding principles:

(1) Decentralized: With Web3.0, ownership is divided among its creators and users rather than being controlled and owned by sizable portions of the internet.

(2) Permissionless: Everyone has equal access to engage in Web3.0 and no one is barred from participating because it is permissionless.

(3) Native payments: Web3.0 replaces banks' and payment processors' antiquated infrastructure with cryptocurrency for online purchases and payments.

(4) Trustless: Web3.0 operates without the use of reliable third parties, instead relying on incentives and economic principles.

(5) Interoperability: Web3.0 aims to allow different DApps and platforms to work seamlessly with each other, regardless of the blockchain technology behind them.

(6) Tokenization: Web3.0 enables the creation and management of digital assets which can be used for different purposes.

Users become proprietors in Web3.0's decentralized network, participating in the development, management and governance of the protocols themselves. Overall, Web3.0 offers improved data ownership, transparency and user control on top of the previous web phases, and the key concepts and elements will be introduced in the following section. The key differences between Web1.0, Web2.0 and Web3.0 are summarized in Table 1 below.

2.4 The core elements of Web3.0

The decentralized technology stack of the Web3.0 model continues to evolve and grow, covering a variety of technologies such as blockchain, smart contracts, prophecy machines, crypto wallets and storage networks. The following section details the key components of the Web3.0 technology stack.

2.4.1 Blockchain. Blockchains are networks with extremely high levels of security and decentralization that allow people to store data, exchange value and record transaction activity in a shared ledger that is not controlled by any centralized entity (Wang *et al.*, 2022; Yang *et al.*, 2019; Zarrin, Wen Phang, Babu Saheer, & Zarrin, 2021). The blockchain network is the backbone of Web3.0, providing a secure execution layer in which cryptographic assets can be created, issued and traded, and programmable smart contracts can be developed. Essentially, the blockchain is the settlement layer of Web3.0, ensuring that all transactions are secure and transparent.

2.4.2 Cryptographic assets. The use of cryptographic assets in Web3.0 is made possible by the secure and decentralized blockchain network, which provides a tamper-proof, environment for transactions (Belk *et al.*, 2022). Cryptographic assets are the native currency of Web3.0 DApps, which can also be used to pay for Web3.0 services and participate in Web3.0 governance. In Web3.0, a token can represent an investment in a protocol, project or blockchain, and can be used to pay for or secure them. In addition, a token allows the holder to participate in the governance of the protocol or project. For instance, a participant would be able to influence how a network is run or governed if he/she owns a sufficient number of digital tokens for that network. To better understand the concept, potential benefits and applications of token financing models, researchers have extensively studied them (Chod, Trichakis, & Yang, 2022). In addition to token financing, blockchain has also enabled new possibilities in economic activity, such as allowing firms to raise capital via initial coin offerings.

2.4.3 Smart contracts and decentralized applications (DApps). Smart contracts are computer programs built on blockchain platforms that are tamper-proof and can be executed automatically using code logic that says "if x is true, then execute y." Programmable smart contracts can create decentralized applications or "DApps," which are protocols based on the cryptographic economy that laid the groundwork for the development of Web3.0 and put it into the hands of users (Dannen, 2017).

Unlike Web1.0 and Web2.0 applications, DApps are not run by a single entity, but by a decentralized blockchain network. DApps may seem simple, but they are capable of creating very complex automated systems such as peer-to-peer (P2P) financial services in DeFi, data-driven insurance products and play-to-earn (P2E) games.

2.4.4 Prophecy machine. For smart contracts to realize their full potential, they must be able to interact with data and systems outside of the blockchain network. The prophecy machine can connect the blockchain to real-world data and systems and provide the critical infrastructure to create an interoperable and unified Web3.0 ecosystem.

Web1.0 (1990–2004)
- Open protocols that were decentralized and community-governed
- Most of the value accrued to the edges of the network-users and builders

Web2.0 (2004 onwards)
- Siloed, centralized services run by corporations
- Most of the value accrued to a handful of companies like Google, Apple, Amazon and Facebook

Web3.0 (2021 onwards)
- Open-source protocols, but collectively owned through cryptoeconomics
- Independent of traditional organizations, code executed as written
- Values open source software, user ownership of data and permissionless access

Source(s): Table by the authors

Table 1. Evolution from Web1.0, Web2.0 to Web3.0

The prophecy machine expands the Web3.0 technology stack to transport off-chain data and services to drive smart contract innovation, enabling cross-chain interoperability to ensure seamless connectivity across blockchains. The prophecy machine infrastructure also provides an entry point for Web2.0 backend systems into the Web3.0 world, enabling legacy systems to easily access any public and private chain seamlessly. Ultimately, the prophecy machine will bring decentralized computing and cryptographic security to legacy systems and build a bridge between Web2.0 and Web3.0 (Bhutta *et al.*, 2021; Nasir *et al.*, 2022; Renu & Banik, 2021).

2.4.5 Identity system. In the Web3.0 model, the front-end of a website or application remains the same, but the backend data structures undergo significant changes. Anyone can participate in verifying transactions and be compensated for their contribution with a network token. From a traditional perspective, Web3.0's identity system is all about accounts. In professional terms, it is everything that a string of private key hashes can correspond to one by one in a distributed ledger. In a Web3.0 world where accounts (addresses) are generated irreversibly by passwords (private keys), private keys are the lowest level of identity. All of Web3.0's participants revolve around the private key. In a Web3.0 portal, the identity system is arguably the most important infrastructure besides the blockchain or public chain itself (Renu & Banik, 2021; Shawon, Ahammad, Shetu, Rahman, & Hossain, 2021).

3. Web3.0: a systematic review of fundamental approaches and implementations

We operationalized Web3.0 as an umbrella term for online systems that center around decentralization. Because of the exponential growth of blockchain technologies, the chosen scope would be more thoroughly discussed in recent publications. As a result, we focused our research on Web3.0 from 2003 to 2022.

We investigate previous research themes and trending topics in the field of Web3.0 through a comprehensive analysis of the literature. We use an automated technique (web-scraping) to retrieve and compile journal papers, conference proceedings and book chapters from major publisher databases in related fields, such as IEEE, Association for Computing Machinery (ACM), Springer, IGI and Wiley. Considering the rapidly evolving landscape of Web3.0, we have carefully curated papers from repositories of electronic preprints such as arXiv and SSRN. Industry/trade publications, policy briefs and government white papers were excluded to maintain a focus on the scholarly research result. A total of 73 research papers were selected based on the inclusion criteria.

3.1 Topic modeling using latent Dirichlet allocation (LDA)

The abstracts of selected articles were quantitatively analyzed using a probabilistic topic modeling procedure, the LDA approach (Blei, 2012; Blei *et al.*, 2003). This technique can reveal the hidden (latent) structure of the articles determining which articles address similar topics. LDA enables us to determine three components of the hidden structure: (1) a relatively small number of topics as research themes; (2) each article can be considered as a compilation of the topics discovered by the model, with the exact mix determined by how heavily each abstract is weighted toward each topic; (3) Specific words from each featured topic are assigned to the article by the model. This strategy is rooted in the notion that each article is made up of a variety of different topics, each with its own collection of words.

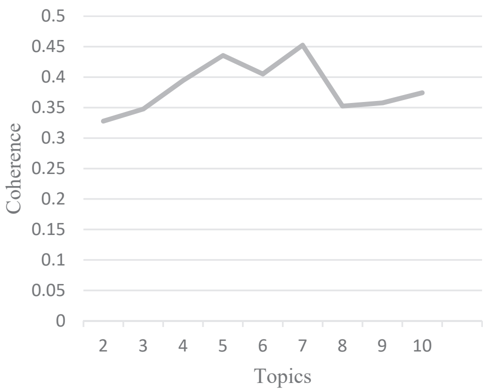
3.2 Results

The optimal number of topics requires quantitative and conceptual evaluation. Topic coherence (C_v), a summary measure that captures "the tendency of a topic's high probability words to co-occur in the same document," or simply put, the degree of semantic similarity between top keywords in a topic, is one way to evaluate topic extraction (Mimno *et al.*, 2011). This metric is based on a sliding window, one-set segmentation of high-scoring words and an indirect confirmation measure that uses a normalized version of the pointwise mutual information criterion and the cosine similarity, which is the metric used in this study to compare model performance.

The coherence score distribution for a variable number of dimensions was sampled to determine the optimal number of dimensions. The coherence scores, C_v, as a function of the number of topics (1 to 10 topics), with $\alpha = 0.91$ and $\beta = 0.91$, are shown in Figure 2. Seven-topic model was extracted to yield the highest coherence scores, which is chosen for subsequent modeling.

The seven topics shown in Table 2 were identified by the LDA model utilizing their most representative terms and the names we assigned to each of them. These are terms that have a substantially higher chance of occurring in articles concerning that topic than their average chance of appearing across the corpus.

As shown in Table 2, seven research themes and corresponding keywords have emerged in the area of Web3.0 research throughout the last two decades (2003–2022). We also performed manual content analysis to corroborate the findings with qualitative illustrations of emergent topics. Appendix contains a list of representative text excerpts from the abstracts for each topic, demonstrating how the concepts in the article are related to the Web3.0 ecosystem. The overall findings indicate that research efforts in this field have primarily focused on technology, organizational structure and application practices.



Source(s): Figure by the authors

Figure 2. Topic coherence: Determining the optimal number of topics

	Top terms in topic	Name assigned to topic
1	Blockchain, chain and platform	Blockchain platform
2	Metaverse, services and user need	Metaverse
3	System, user and data	User-centricity
4	Blockchain, information and application	DApp
5	Data, smart contracts and algorithm	Smart contracts
6	Decentralized, distributed and network	Decentralization
7	Ethereum, price and transactions	Transactions

Source(s): Table by the authors

Table 2. Web3.0 research topics 2003–2022

The key research thrusts provide an ecosystem to Web3.0: (1) underlying logic of decentralization, (2) technologies being deployed (e.g., blockchain and smart contracts), (3) governance framework/structure (e.g., peer networks and DAOs), (4) application use cases such as metaverse and (5) targeted outcomes (e.g. user-centric solutions). These prominent research thrusts that have emerged throughout the Web3.0 literature will be discussed in the following section. A conceptual framework that delineated the relationships between the research issues and technical opportunities of Web3.0 is then introduced.

3.3 Discussion

3.3.1 Decentralization. The first stream of research has focused on decentralization, as the key differentiator and defining trait that distinguishes Web3.0 from its previous era (Liu *et al.*, 2022). This is captured in Topic 6 of our LDA model results. Current research in decentralization is mainly on developing and exploring the application of the decentralized infrastructure. For instance, Bambacht and Pouwelse (2022) conducted the first study on integrating government-issued travel documents into a decentralized societal infrastructure and proved its efficiency, effectiveness and resistance. They highlighted the importance of the decentralized infrastructure for the future of technology and finance. Another study by Panda *et al.*, in 2021, focused on the consensus algorithms of proof-of-work and proof-of-stake under the concept of decentralization and implemented smart contracts using the Ethereum blockchain platform. Their work was the first step toward the revolution of the current centralized economy to a decentralized one. Decentralization is the backbone of almost all the research studies on Web3.0, and the current exploration in this area is more on the development and application of all the techniques based on the idea of decentralization.

3.3.2 Blockchain technology and interoperable platforms – critical infrastructure enablers for Web3.0.

(1) Blockchain technology: Blockchain technology and interoperable platforms provide a digital infrastructure for Web3.0 (Liu *et al.*, 2022). This stream of research is reflected in **Topic 1** under our LDA model results.

By decoupling authentication, organization, computation, communication and mediation from central or intermediary entities, blockchains and interoperable platforms enable decentralized and scalable operations, authentication, communication and collaborations among loosely connected individuals and local nodes to physically, virtually, intellectually or jointly form decentralized ecosystems, resulting in Web3.0 movements. One of the most commonly cited public blockchain platforms is Ethereum, which is also reflected in the keywords in **Topic 7**.

Previous research investigates the capabilities of blockchain to deliver a stable, robust and secure decentralized platform for Web3.0 (Wang *et al.*, 2022). The consensus algorithms are critical components for the decentralization of the blockchain (Zarrin *et al.*, 2021). Blockchain-enabled architecture is able to enforce equitable roles among peers, in which cryptographically hashed blocks (digital records) are chained one after the other, and each node replicates and stores its previous blockchain (Bhutta *et al.*, 2021). The network maintains and updates an identical ledger database (called a distributed ledger), which records, validates, manages and distributes the chained digital consensus across the entire blockchain ecosystem (Nasir *et al.*, 2022).

(1) *Proof-of-work and proof-of-stake:* Past research compares and analyses the difference between proof-of-work and proof-of-stake as consensus algorithms that are deployed to govern and regulate blocks on distributed platforms (Panda & Satapathy, 2021). Both methods work toward the same objectives, which are to ensure users are being honest in their transactions and to minimize double spending in the system. Mining is

used in proof-of-work to verify bitcoin transactions. According to a set of rules in proof-of-stake, validators are selected based on the "stake" they have in the blockchain, or how much of that token they agree to lock up in order to be considered as a validator. In either scenario, cryptocurrencies are built to be decentralized and distributed, meaning that all computers in the world can see and validate transactions. (Cao, 2022). According to Halaburda, Haeringer, Gans, and Gandal (2022), the major challenge involved in the process is to handle the absence of trust, as any players can tamper with the blockchain and it would be difficult to identify the "bad" miners.

(2) Interoperation: Blockchains allow assets to be transferred and record transactions through blockchain interoperation. The decentralized identities of individuals, devices and other "things," with no involvement from centralized entities, are the basic ingredient for blockchain interoperation (Viriyasitavat, Bi, & Hoonsopon, 2022).

(3) Smart contracts: Smart contracts enable digital asset transactions between entities to be conducted on blockchains without human intervention. That is, there is no centralized administrator, server, or trusted authority for authentication, governance, communication, management and mediation in blockchain ecosystems. This stream of research is captured in **Topic 5** under our LDA model results.

3.3.3 DAOs – new organizational paradigms to create, engage, govern and implement Web3.0. The Web3.0 protocol enables users to exchange value directly, eliminating the need for trusted service intermediaries (Potts & Rennie, 2019), like Google, Apple or Facebook.

In a massively scaled and interoperable network of decentralized crypto-state, citizens have governance rights. Key research efforts in this field focus on DAOs. DAOs are structured through smart contracts and do not rely on central authorities for governance. Researchers have covered how web3.0 innovation is being organized through DAO frameworks to enable efficient operational and strategic decision-making in the context of distributed information (Filipčić, 2022). Machine-based automation enforces DAO member agreements, in which a set of tamper-resistant rules is predefined and distributed as smart contracts on blockchains. (Wang *et al.*, 2019). Furthermore, members gain governance rights through tokens issued by DAOs, and on-chain voting is used to arrive at a decentralized consensus on organizational decisions. These outcomes are determined specifically based on the DAO voting mechanisms, which are calculated using tokens via smart contracts (Zhao, Ai, Lai, Luo, & Benitez, n.d).

3.3.4 Use cases. The research themes reflect the diverse applications of Web3.0 in various use cases. The two main streams that are captured in our LDA model are **Topic 2** – Metaverse and **Topic 4** – DApps.

(1) Metaverse: The metaverse coined by Neal Stephenson in the 1992 science-fiction novel "Snow Crash" has evolved significantly in terms of vision, conceptualization, execution and applications during the last 30 years. It has progressed from the early stages of the digital twin represented by the online virtual world Second Life to a shared vision among technology entrepreneurs to close the perceived gaps between digital and physical realities with embodied virtual and augmented reality. Technically, the metaverse is thought to broaden the sphere of human action by overcoming natural spatial, time and other resource restrictions (Cheng *et al.*, 2022).

The metaverse seeks to provide (1) an online or cloud-to-device real-time generated 3D interactive world that provides a comprehensive virtualized or virtually physically integrated immersive experience; (2) human-device interfacing and user-to-user communication and team; and (3) a diverse ecosystem with trading and financial services, economic activities and social interactions (Cao, 2022). Identity management and authentication standards are key to metaverse services.

The metaverse's virtual economy is backed by the Web3.0 ecosystem, which comprises blockchain technology, smart contracts and **NFTs**. These decentralized consensus procedures minimize transaction and agency costs and thus enable trustless social and economic interactions.

Given the nature of entrepreneurship in the metaverse, new and innovative products and services, job profiles and business strategies may emerge as a result. Players can engage in social and economic interactions, such as **P2E** gaming and **GameFi**. GameFi is a blockchain game that allows players to earn by playing. Completing tasks, combating other players and progressing through the levels earn the player cryptocurrency and NFT incentives. Combining immersive virtual–physical interaction, teamwork and cooperation while providing trading capabilities and services, this P2E genre, popularized by games like Axie Infinity, signaled that GameFi has become of the prominent use cases of Web 3.0 (Kshetri, 2022).

(2) *DApp – Value-based economics'*

Another topic that emerge*s* from our LDA model results is the DApp – **Topic 4**. A DApp is a web application with critical components dispersed across a peer-to-peer network (Zheng, Gao, Huang, & Guan, 2021), which is made up of smart contracts that are performed by all nodes on the network at roughly the same time (Dannen, 2017). Past research on DApp deployments encompasses a wide range of solutions: voting (Pramulia & Anggorojati, 2020), crowdfunding (Dianovics & Majd, 2021), tenant management (Nayak, Narendra, Shukla, & Kempf, 2018), ridesharing (Renu & Banik, 2021), certificates verification (Shawon *et al.*, 2021), among others. In the creative and entertainment industries, one of the experimental use cases of Web3.0 aims to develop artist-centric business solutions, displacing agency-centric business models that facilitate connections between artists and their fans. Blockchain technology enables DApp-based new "value-based economics" in which artists set the terms and conditions of their market involvement through the automation of value components such as payments, licensing and intellectual property (IP) management, contracts, and governance, digital content access and storage (Potts & Rennie, 2019). Such solutions improve supply chain transparency, lower distribution costs and improve the handling of IP and royalties.

3.3.5 User autonomy and user-centricity. Past research has reviewed the challenges faced by the current model of the internet as a result of the influence of centralization. One of the most pressing issues highlighted by (Zarrin *et al.*, 2021) is trustability. Large Internet firms and service providers can collect, maintain, control, and regulate user data, access and activities. While hosting personalized services and applications in centralized entities can enhance the end-users' experience, such data monopolies may go beyond monetizing the users' personal information. Some service providers can use such a centralized model to implement monitoring or censorship, leading to abuse of trust (Chowdhury, Jahan, Sara, & Nandi, 2020). By having users dependent on a centralized service provider, they are exposed to various types of vulnerabilities that could jeopardize the network.

The notion of Web3.0 revolves around user independence and autonomy from centralized services, and the real shift is toward user ownership of digital assets and making people accountable for their data (Zarrin *et al.*, 2021). Zarrin *et al.* (2021) examined the potential and capabilities of blockchain-based solutions that can be effectively applied to achieve user autonomy and user-centricity. It can also provide resilience for data protection, offering incentives for users to collaborate (Yang *et al.*, 2019). DApp reduces the danger of a single point of failure while still ensuring the user experience (Zheng *et al.*, 2021).

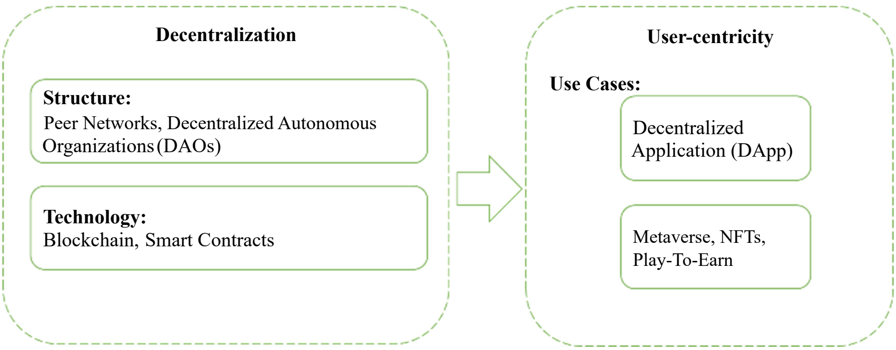
The seven topics generated from LDA have been discussed in detail in the preceding sections. The 73 papers analyzed in this study have been categorized into seven topics based on the keywords summarized from their abstract. The coherence score has been used as an indicator of the model's performance. Other than the individual topics, the visualizations generated by LDA provide valuable insights into the correlations between different topics and their interrelationships. Topic 1 (blockchain platform) exhibited the highest frequency among all the keywords extracted. Topics 2 to 5 (metaverse, user-centricity, decentralized apps and smart contracts) displayed relatively similar frequencies. Conversely, topics 6 (decentralization) and 7 (transactions) were less common or prominent compared to others. The visualizations not only highlight the relative prevalence of topics but also indicate the interrelationships among them. Notably, topics 3, 5 and 7 were found to be closer, showing a higher degree of similarity and will be discussed together in the following sections, while the rest exhibited greater distinctiveness. The results provided a more comprehensive understanding of the main research topics on Web3.0 and their relationships.

While each of the papers has been assigned to a specific topic, the interlinkage between different topics and the overlapping between the keywords have resulted in many papers describing multiple topics, thus constructing a network of Web3.0 concepts. Figure 3 delineated the relationships between the research issues and technical opportunities of Web3.0 as discussed in the previous section.

By utilizing LDA to analyze pre-sorted literature on Web3.0, the most commonly discussed topics have been identified and the study has provided insights into the current research status in this field. With a better understanding of the current progress and the expected outcomes, potential gaps can be identified and thus prioritized areas for further investigation. The future research direction will be summarized and described in the following section.

4. Toward a research agenda on the ecosystem of Web3.0

As Web3.0 is a relatively new concept that only started to attract attention from researchers in the past decade, the current research on the topics around Web3.0 is still at a very early stage. The LDA analysis provided valuable insights into Web3.0, regarding the main themes and topics that are most frequently studied in the literature. Although we have identified seven distinct themes from the past studies, the width and depth of research coverage in each of the themes vary, and there are still many gaps that need further investigation. In addition, there are also important areas that are not covered by the existing studies but may have significant implications in the future development of Web3.0 and therefore they require more in-depth investigations and urgent attention.



Source(s): Figure by the authors

Figure 3. An ecosystem approach to Web3.0 research topics

Based on the review and discussion from the previous sections, we identify and propose the following five research areas and relevant issues to be addressed which can serve as a guide for future research agenda.

4.1 The decentralized structure, organization and governance

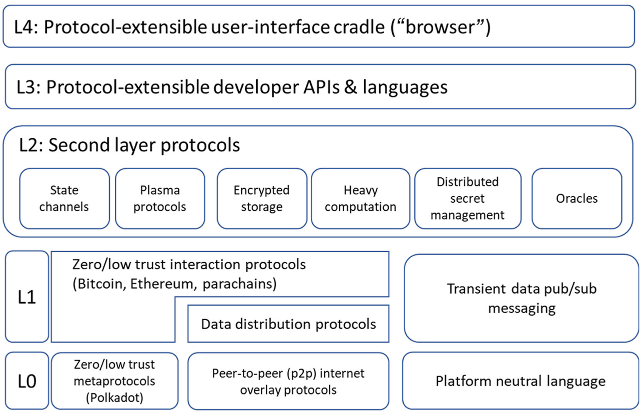
There has been considerable research and practice development in the area of decentralization; however, research on the organization and governance of decentralized structures is relatively scarce and there remain several issues to be explored further to better understand this new structure of organizations. For instance, in contrast to typical top-down organizations which almost all corporations and nonprofits are, DAOs operate with a flat hierarchical structure, giving all members a voice in important decisions that affect the entire group rather than just the major stakeholders (Yu, Wang, Bi, Chen, & Xu, 2022). While the literature on the DAO has much to offer on the benefit of this entirely new economic organization, there is still work to do on the governance of such new structures, and lessons to be transferred from the DAO literature into other contexts.

4.2 Web3.0 technologies and infrastructure

Blockchain technology and other protocols significantly alter how data are stored, disseminated and retrieved in the decentralized Web3.0 environment while also offering a native transaction layer. Similar to Web2.0 apps, decentralized apps in Web3.0, or "DApps," are made up of a front-end user interface that communicates with a "smart contract" that is installed on the blockchain. When processing transactions or adding data to the blockchain, the front-end can also communicate with a user's wallet. The primary distinction between a Web3.0 and a Web2.0 app is that the smart contract and blockchain replace the functions of a standard server and database that are owned and maintained by one person or business.

In 2017, the Web3 Foundation published the 5-level (L0 to L4) Web3.0 Technology Stack (Figure 4). This serves as an important guide to understanding the infrastructure building of Web3.0.

With the technology stack, we can see the important role of blockchain, in particular, the public chain plays in all different layers. The history of the public chain reflects different community groups' understandings of the world and solutions to the problems. However, like all solutions in the world, old solutions can become new problems. One thing is certain about the future of Web3, the public chain will be the underlying core for a long time, and it will



Source(s): Web3.0 Technology Stack ©2022 Web3 Foundation

Figure 4. Web3.0 technology stack

continue to iterate. In terms of blockchain as a whole, public chains are still only MVP (minimum viable product). After we enter the smart contract era started with Ethereum, there are still a lot of "parts" that need to be connected to extend the functionality of public chains to direct applications and make them more accessible to developers, researchers and general users.

Ethereum is the dominant player in the public chain circuit, but its high interaction fees are overwhelming for most users. New public chains with lower transaction fees and faster operation take up the value spillover. With the support of major institutions, developers and users, the new public chain ecosystem has gained tremendous growth in the past year. However, due to technology constraints and competition, most public chains are not directly interoperable with each other, which leaves users, assets, data and DApps sealed off within their ecosystems, creating a silo effect. This is contrary to the spirit of interoperability and scalability of blockchain. The current multi-chain pattern is like a single computer that is not connected to the internet, and there is still a lot of potentials to be released.

Under this circumstance, the cross-chain demand of blockchain natives has started to awaken, and various cross-chain solutions have been launched in the market in time (Haugum, Hoff, Alsadi, & Li, 2022). However, cross-chain technology is still imperfect and security incidents are frequent. This is an area that requires continuous research and investments and may take a long time to bring us to the full development of Web3.0.

4.3 Distributed storage: mechanisms, tracks and issues

As one of the infrastructures of Web3.0, distributed storage is a necessary choice for the decentralization of large-scale on-chain data, especially since it has a unique advantage in solving single points of server failure and data loss. Compared with centralized storage, distributed storage has very competitive advantages in terms of privacy protection, data security and corresponding speed.

At present, the role of distributed storage for the Web3 era has not yet been reflected, and the data stored are mainly reflected in NFT images, on-chain contracts, on-chain graphics and other data with a relatively small memory footprint and low interaction frequency (Chen *et al.*, 2022). However, the rapid development of the metaverse concept will bring the demand for large-volume data storage such as video, audio and digital model, creating new development opportunities for distributed storage.

Like on-chain finance, distributed storage also faces many practical problems.

First, there is the problem of illegal content regulation. The tamper-evident nature of blockchain also makes the spread of illegal content uncontrollable. Therefore, for distributed storage, how to build a chain-wide regulatory model from the input side to the output side is a problem necessary for it to face mainstream society.

Second, how to improve the storage space utilization of distributed storage. The current distributed data storage has a large portion of junk data and redundancy of stored data. Once it goes to large-scale applications, it remains to be verified whether the current distributed storage projects can quickly adapt to the extremely rapid changes in the market.

4.4 Web3.0 use cases and user experience

In the Web3.0 world, communication and information sharing are being redefined by decentralized technologies. However, the majority of DApps still have user experiences that resemble early web prototypes, and not many of them have a usable front-end. Most people are unaware of the potential of DApps or the blockchain technology that underpins them. The few who have used them have frequently found them challenging and complex. It can be difficult for both developers and designers to communicate the differences between Web2.0 and Web3.0 due to the language, dynamism and visual design of the latter. Solutions need to be user-friendly if the Web3.0 vision is to be widely adopted. Designers may help with this by working closely with engineering teams to make sure these structures are open to and usable by all users.

Currently, a user has several options for interacting with a Smart Contract that has been created on the blockchain: (1) directly through the command line, (2) through the form-like interfaces of their digital wallet or DApp browser or (3) through the richer front-end that the Smart Contract developer already has or will create. The last option, which offers a sophisticated user interface integrated with the experience of working with a blockchain-based distributed application, is undoubtedly the key to the widespread acceptance of DApps.

Currently, the research on Web3.0 user experience mainly focuses on the technical aspects and functionality of DApps, the benefits of the technology and the control of data ownership. However, there is not much discussion on the experiences from the user's perspective, how users interact with others in the community, and how the user experiences differ from those with Web2.0 applications (Ali *et al.*, 2023). There is much research that can be done to fill the gap from the perspective of users to help improve the Web3.0 user experience for widespread adoption of Web3.0.

4.5 Regulations and future of Web3.0

With the growing acceptance of crypto tokens globally, there are various financial institutions and services available for the crypto transactions and token economy, providing the financial system necessary for the development of the Web3.0 world.

However, the realities that arise from the virtual finance world, such as the risk of speculation, money laundering and other financial crimes, are receiving increasing attention from regulators in various countries. At the current stage of Web3.0 development, security incidents are frequent and financial losses are huge (Sheridan *et al.*, 2022).

For instance, in the world of DeFi, most users cannot check the code and rely on the protocol for the security of their funds. If there is a vulnerability in the protocol contract, it may be hacked and cause huge losses. Once the stolen funds enter the coin mixer, the possibility of recovering them is very low. Cross-chain bridges and aggregators are the high-incidence areas. In addition, if the project owner supervises the theft or the private key is lost, it is difficult to check whether it is done intentionally. In the case of anonymous projects, the likelihood of problems occurring is even greater, and it is more difficult to trace the responsibility. This reveals that not only is there a problem with DeFi at the protocol level, but the infrastructure is also not perfect.

At the same time, governments are focusing on promoting innovation and industrial development in the emerging field of Web3, hoping to seize the bonus of the next round of the Internet revolution. How to find a balance between preventing risks and encouraging innovation may be a challenge for regulators in various countries.

In terms of future trends, we need to see the urgent need to promote regulations for cryptocurrency finance to address criminal activity globally. On the other hand, with the revolutionary innovation that cryptocurrency finance and Web3.0 could bring to the economy, it is time to end regulatory fragmentation and act in a unified manner to regulate and promote the development of this sector. The existing regulatory framework was not created with the digital world in mind, and new rules, laws and frameworks must be developed to address it. This is where researchers need to come in and play their role to help us achieve a smooth transition from a Web2.0 world to a Web3.0 world.

In conclusion, this study has highlighted the immense potential of Web3.0 to revolutionize the internet and related applications. Decentralized technologies and the blockchain protocol are the key concepts involved in this new web paradigm. The basic concepts and structures of

Web3.0 have been summarized in this study. Topic modeling has been utilized to categorize the filtered corpus into different topics. Seven topics were identified from the results. The topic details have also been discussed. Decentralization serves as the fundamental differentiator of Web3.0 from the current web, with blockchain and smart contracts serving as the underlying technical infrastructure. Metaverse, DApp, and transactions are important components of user-centric use cases within this framework. These topics are interconnected, forming an ecosystem that embodies the essence of Web3.0. Despite the exponential development of the technology, there are still challenges to be addressed and the collaboration of researchers and practitioners in different areas will play a critical role in shaping the Web3.0 landscape and fully utilizing its potential. The new structure still requires further developments, particularly in refining cross-chain technology. Additionally, the data storage needs to adapt to evolving demands, and gaining a deeper understanding of the user perspective is crucial. Lastly, regulations remain a significant challenge that hinders the advancement of Web3.0. Addressing these areas necessitates ongoing effort and input to drive the implementation of this innovative concept. Overall speaking, the literature on Web3.0 provides valuable insights and directions for future research and development.

References

Ali, O., Momin, M., Shrestha, A., Das, R., Alhajj, F., & Dwivedi, Y. K. (2023). A review of the key challenges of non-fungible tokens. *Technological Forecasting and Social Change*, *187*, 122248. doi: 10.1016/j.techfore.2022.122248.

Bambacht, J. and Pouwelse, J. A. (2022), "Web3: A decentralized societal infrastructure for identity, trust, money, and data", *ArXiv - Computer Science - Distributed, Parallel, and Cluster Computing*, abs/2203.00398.

Belk, R., Humayun, M., & Brouard, M. (2022). Money, possessions, and ownership in the metaverse: NFTs, cryptocurrencies, Web3 and wild markets. *Journal of Business Research*, *153*, 198–205. doi: 10.1016/j.jbusres.2022.08.031.

Berners-Lee, T., Hendler, J., & Lassila, O. (2001), "The semantic web: a new form of web content that is meaningful to computers will unleash a revolution of new possibilities", *Scientific American*, Vol. 284 No. 5, pp. 34-43.

Bevacqua, A., Carnuccio, M., Ortale, R., & Ritacco, E. (2011). *A new architectural paradigm for content-based web applications: Borè. Proceedings of the 15th Symposium on International Database Engineering & Applications*, Lisboa, Portugal. doi: 10.1145/2076623.2076648.

Bhutta, M. N. M., Khwaja, A. A., Nadeem, A., Ahmad, H. F., Khan, M. K., Hanif, M. A., . . . Cao, Y. (2021). A survey on blockchain technology: Evolution, architecture and security. *IEEE Access*, *9*, 61048–61073. doi: 10.1109/ACCESS.2021.3072849.

Blei, D. M. (2012). Probabilistic topic models. *Communications of the ACM*, *55*(4), 77–84. doi: 10.1145/2133806.2133826.

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent dirichlet allocation. *Journal of Machine Learning Research*, *3*, 993–1022.

Bogner, A., Chanson, M., & Meeuw, A. (2016). *A decentralised sharing App running a smart Contract on the Ethereum blockchain. Proceedings of the 6th International Conference on the Internet of Things*, Stuttgart, Germany. doi: 10.1145/2991561.2998465.

Cao, L. (2022). Decentralized AI: Edge intelligence and smart blockchain, metaverse, Web3, and DeSci. *IEEE Intelligent Systems*, *37*(3), 6–19. doi: 10.1109/MIS.2022.3181504.

Chen, C., Zhang, L., Li, Y., Liao, T., Zhao, S., Zheng, Z., . . . Wu, J. (2022). When digital economy meets Web3.0: Applications and challenges, arXiv:2210.08993 arXiv. Available from: http://arxiv.org/abs/2210.08993

Cheng, X., Zhang, S., Fu, S., Liu, W., Guan, C., Mou, J., Ye, Q. and Huang, C. (2022), "Exploring the metaverse in the digital economy: an overview and research framework", *Journal of Electronic Business & Digital Economics*, Vol. 1 Nos 1/2, pp. 206-224, doi: 10.1108/JEBDE-09-2022-0036.

Chod, J., Trichakis, N., & Yang, S. A. (2022). Platform tokenization: Financing, governance, and moral hazard. *Management Science*, *68*(9), 6411–6433.

Choi, S. S., Burm, J. W., Sung, W., Jang, J. W., & Reo, Y. J. (2018). A blockchain-based secure IoT control scheme. 2018. In *International Conference on Advances in Computing and Communication Engineering (ICACCE)*.

Chowdhury, S. M. H. M., Jahan, F., Sara, S. M., & Nandi, D. (2020). *Secured blockchain based decentralised internet: A proposed new internet. Proceedings of the International Conference on Computing Advancements*, Dhaka, Bangladesh. doi: 10.1145/3377049.3377083.

Dannen, C. (2017). Dapp deployment. In Dannen, C. (Ed.), *Introducing Ethereum and Solidity: Foundations of Cryptocurrency and Blockchain Programming for Beginners* (pp. 149–157), Apress. doi: 10.1007/978-1-4842-2535-6_8.

Dianovics, Z. and Majd, N. E. (2021), "CoinCrowder: An accountable Blockchain Decentralized Application (DApp) with tamper-proof evidence of purchase and analyses", *2021 Computer Science Conference for CSU Undergraduates*. Available from: https://scholarworks.calstate.edu/concern/theses/nv935801h?locale=zh.

Filipčić, S. (2022). Web3 & DAOs: An overview of the development and possibilities for the implementation in research and education. *2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO)*.

Gracia, S. V. J. B., Raghav, D., Santhoshkumar, R., & Velprakash, B. (2019). Blockchain based aadhaar. 2019 3rd. In *International Conference on Computing and Communications Technologies (ICCCT)*.

Guan, C., Ding, D., & Guo, J. (2022). *Web3.0: A review and research agenda, 2022 RIVF international conference on computing and communication technologies (RIVF)* (pp. 653–658). Vietnam: Ho Chi Minh City. doi: 10.1109/RIVF55975.2022.10013794.

Gupta, Y. P., Chawla, A., Pal, T., Reddy, M. P., & Yadav, D. S. (2022). 3D networking and collaborative environment for online education. *2022 10th International Conference on Emerging Trends in Engineering and Technology - Signal and Information Processing (ICETET-SIP-22)*.

Halaburda, H., Haeringer, G., Gans, J., & Gandal, N. (2022). The microeconomics of cryptocurrencies. *Journal of Economic Literature*, *60*(3), 971–1013.

Haugum, T., Hoff, B., Alsadi, M., & Li, J. (2022). Security and privacy challenges in blockchain interoperability—a multivocal literature review. *The International Conference on Evaluation and Assessment in Software Engineering*, *2022*, 347–356. doi: 10.1145/3530019.3531345.

Herasymenko, O., & Bachynska, V. (2021). Blockchain technology for accounting and distribution of contributions from a charitable foundation. *Technology Audit and Production Reserves*, *5*(2), (61), 9–14. doi: 10.15587/2706-5448.2021.239019.

Kshetri, N. (2022). Policy, ethical, social, and environmental considerations of Web3 and the metaverse. *IT Professional*, *24*(3), 4–8. doi: 10.1109/MITP.2022.3178509.

Liu, Z., Xiang, Y., Shi, J., Gao, P., Wang, H., Xiao, X., Wen, B., Li, Q. and Hu, Y. C. (2022), "Make Web3.0 connected", *IEEE Transactions on Dependable and Secure Computing*, Vol. 19 No. 5, pp. 2965-2981, doi: 10.1109/TDSC.2021.3079315.

Mimno, D., Wallach, H. M., Talley, E., & McCallum, A. (2011). Optimizing semantic coherence in topic models. In *Proceedings of the 2011 Conference on Empirical Methods in Natural Language Processing*, Edinburgh, Scotland, UK.

Monteiro, F. A. A. J. D. S. A. J. A. (2013). E-commerce business models in the context of web 3.0 paradigm. *International Journal of Advanced Information Technology*, *3*(6), 1–12. doi: 10.48550/arXiv.1401.6102.

Nasir, M. H., Arshad, J., Khan, M. M., Fatima, M., Salah, K., & Jayaraman, R. (2022). Scalable blockchains — a systematic review. *Future Generation Computer Systems*, *126*, 136–162. doi: 10.1016/j.future.2021.07.035.

Nayak, S., Narendra, N. C., Shukla, A., & Kempf, J. (2018). Saranyu: Using smart contracts and blockchain for cloud tenant management. 2018. *IEEE 11th International Conference on Cloud Computing (CLOUD)*.

Panda, S. K., & Satapathy, S. C. (2021). *An investigation into smart contract deployment on Ethereum platform using Web3.js and solidity using blockchain*. Singapore: Data Engineering and Intelligent Computing.

Potts, J., & Rennie, E. (2019). Web3 and the creative industries: How blockchains are reshaping business models. *A Research Agenda for Creative Industries* (pp. 93–111). Edward Elgar Publishing.

Pramulia, D., & Anggorojati, B. (2020). Implementation and evaluation of blockchain based e-voting system with Ethereum and Metamask. *2020 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)*.

Renu, S. A., & Banik, B. G. (2021). Implementation of a secure ridesharing DApp using smart contracts on Ethereum blockchain. *International Journal of Safety and Security Engineering*, *11*(2), 167–173.

Schaufelbühl, A., Niya, S. R., Pelloni, L., Wullschleger, S., Bocek, T., Rajendran, L., & Stiller, B. (2019). EUREKA – a minimal operational prototype of a blockchain-based rating and publishing system. *2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*.

Shawon, S. K., Ahammad, H., Shetu, S. Z., Rahman, M., & Hossain, S. A. (2021). *DIUcerts DApp: A blockchain-based solution for verification of educational certificates*. *2021 12th International Conference on Computing Communication and Networking Technologies (ICCCNT)*.

Sheridan, D. A. H., James, Wear, F., Cowell, J., Wong, E., & Yazdinejad, A. (2022). Web3 challenges and opportunities for the market. doi: 10.48550/arXiv.2209.02446.

Viriyasitavat, W., Bi, Z., & Hoonsopon, D. (2022). Blockchain technologies for interoperation of business processes in smart supply chains. *Journal of Industrial Information Integration*, *26*, 100326. doi: 10.1016/j.jii.2022.100326.

Wang, S., Ding, W., Li, J., Yuan, Y., Ouyang, L., & Wang, F. Y. (2019). Decentralized autonomous organizations: Concept, model, and applications. *IEEE Transactions on Computational Social Systems*, *6*(5), 870–878. doi: 10.1109/TCSS.2019.2938190.

Wang, Q., Li, R., Wang, Q., Chen, S., Ryan, M. D. and Hardjono, T. (2022), "Exploring Web3 from the view of blockchain", *ArXiv - Computer Science- Cryptography and Security*, arXiv:2206.08821.

Wood, G. (2022), "What is web 3? Here's how future polkadot founder Gavin Wood explained it in 2014", *CoinDesk Opinion*. Available from: https://www.coindesk.com/layer2/2022/01/04/what-is-web-3-heres-how-future-polkadot-founder-gavin-wood-explained-it-in-2014/.

Xu, Q., Song, Z., Goh, R. S. M., & Li, Y. (2018). Building an Ethereum and IPFS-based decentralized social network system. *2018 IEEE 24th International Conference on Parallel and Distributed Systems (ICPADS)*.

Yang, W., Aghasian, E., Garg, S., Herbert, D., Disiuta, L., & Kang, B. (2019). A survey on blockchain-based internet service architecture: Requirements, challenges, trends, and future. *IEEE Access*, *7*, 75845–75872.

Yu, G., Wang, Q., Bi, T., Chen, S., & Xu, S. (2022). Leveraging architectural approaches in Web3 applications—a DAO perspective focused, arXiv:2212.05314 arXiv. Available from: http://arxiv.org/abs/2212.05314

Zarrin, J., Wen Phang, H., Babu Saheer, L., & Zarrin, B. (2021). Blockchain for decentralization of internet: Prospects, trends, and challenges. *Cluster Computing*, *24*(4), 2841–2866. doi: 10.1007/s10586-021-03301-8.

Zhao, X., Ai, P., Lai, F., Luo, X., & Benitez, J. (n.d.). Task management in decentralized autonomous organization. *Journal of Operations Management*, *n/a* (n/a). doi: 10.1002/joom.1179.

Zheng, G., Gao, L., Huang, L., & Guan, J. (2021). Decentralized application (DApp). In Zheng, G., Gao, L., Huang, L., & Guan, J. (Eds.), *Ethereum Smart Contract Development in Solidity*. Springer Singapore, 253–280. doi: 10.1007/978-981-15-6218-1_9.

Appendix

Table A1. Exemplary text excerpts from abstract

Research themes	Exemplary text excerpts from abstracts
Blockchain platform	"an open-source Blockchain platform that provides a runtime environment" (Xu, Song, Goh, & Li, 2018)
	"EUREKA is a Blockchain-based scientific publishing platform" (Schaufelbühl *et al.*, 2019)
Metaverse	"Internet of Value and Metaverse" (Wang *et al.*, 2022)
	"3D meeting application on the concept of the metaverse" (Gupta, Chawla, Pal, Reddy, & Yadav, 2022)
User-centricity	"privacy-aware of their online identities and data" (Bambacht & Pouwelse, 2022)
	"adapt to the needs of users" (Bevacqua *et al.*, 2011)
DApp	"content-based web applications based on cooperative interaction" (Bevacqua *et al.*, 2011)
	"a Decentralised App (DAPP) for the sharing of everyday objects" (Bogner, Chanson, & Meeuw, 2016)
Smart Contracts	"Smart Contracts to ensure. . . only the authenticated data is accessed" (Gracia, Raghav, Santhoshkumar, & Velprakash, 2019)
	"a smart contract . . . to prevent any tempering from possible intruders" (Choi, Burm, Sung, Jang, & Reo, 2018)
Decentralization	"Web3 commits to user-centricity using decentralization" (Bambacht & Pouwelse, 2022)
	"implement decentralized application over the Internet using a contract" (Panda & Satapathy, 2021)
Transactions	"a justified price to pay for the transparency of transactions" (Herasymenko & Bachynska, 2021)
	"uses distributed databases (decentralized databases) math and cryptography to record transactions" (Gracia *et al.*, 2019)

Source(s): Appendix by the authors

Corresponding author
Ding Ding can be contacted at: dingding@suss.edu.sg