RESEARCH ARTICLE

What Users Tweet on NFTs: Mining Twitter to Understand NFT-Related Concerns Using a Topic Modeling Approach

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ABSTRACT Non-fungible token (NFT) trade has grown drastically over recent years. While scholarship on the technical aspects and potential applications of NFTs has been steadily increasing, less attention has been directed to the human perception of or attitudes toward this new type of digital asset. The aim of this research is to investigate what concerns are expressed in relation to non-fungible tokens by those who engage with NFTs on the social media platform Twitter. In this study, data was gathered through online social media data mining of NFT-related posts on Twitter. Two datasets (with 18,373 and 36,354 individual tweet records, respectively) were obtained. Topic modeling was used as a method of data analysis. Our results reveal 19 overall themes of concerns around NFTs as expressed on Twitter, which broadly fall into two categories: concerns about attacks and threats by third parties; and concerns about trading and the role of marketplaces. Overall, this study offers a better understanding of the expressions of concern, uncertainty, and the perception of possible barriers related to NFT trading. These findings contribute to theoretical insight and can, moreover, function as a basis for developing practical design and policy interventions.

INDEX TERMS Concerns, digital asset, non-fungible tokens (NFTs), social media, topic modeling, Twitter.

I. INTRODUCTION

Non-fungible tokens (NFTs) have recently attracted considerable media coverage and increased public interest. NFTs are currently one of the key decentralized technologies and assets traded on blockchain that are popular across a wide range of industry sectors [1]. An NFT is a digital representation of an asset that can be traded using digital currencies and is encoded in a 'smart contract' (i.e., a series of codes kept in a decentralized ledger on the blockchain). As a unique kind of crypto asset, NFTs are commonly used in areas like collectibles, art, gaming, digital image files, video, audio, as well as other non-digital, offline assets. In contrast to fungible cryptocurrencies or conventional fiat currencies, NFTs are understood to be distinctive as blockchain-based assets because their unique identifier makes any unit precisely non-interchangeable with any other unit, i.e., they are

'non-fungible' [2]. Any activities or transactions involving NFTs, such as creating, 'minting', purchasing, or selling, are equally recorded on-chain, and NFT marketplaces serve as platforms to facilitate NFT transactions. NFTs were originally part of the Ethereum blockchain, but more and more blockchains have added their own versions of NFTs [3].

While some have praised the emergence and growth of NFTs as a significant advancement that brings unicity and scarcity to the digital sphere [4], others have expressed serious concerns, naming NFT trading hazardous, a pyramid scheme, or even a fraud [5]. Also, research has revealed that concepts of trust [6], risk [7] and concerns around blockchain-based assets or the use of tokens [8] are to some extent inherently characterizing NFTs.

However, little is known about the type and scope of concerns, or perceptions of risks or danger, that users express in relation to this relatively new phenomenon of NFT trade. The studies that explore concerns around NFTs are either not considering the perspective of human use of NFTs at

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all, or they mention the possible perceived risks or dangers of NFT trade as a side note. Thus, apart from incidental exceptions [9], the state-of-the-art literature lacks a focused, in-depth investigation of the scope and character of concerns about NFTs, as well as the meaning, importance, or context of these concerns for users. Therefore, research that outlines and provides a deeper understanding of the concerns or perceived dangers and risks that individuals express regarding NFTs would make a significant contribution to the literature. The research question that this study seeks to answer to fulfill its research aim is:

- What types of concerns are expressed in relation to non-fungible tokens (NFTs) by those who engage with NFTs on the social media platform Twitter?

Nowadays, social media platforms play an indispensable role in understanding users' opinions, ideas, and perceptions about various phenomena. In this study, we focused on exploring user-generated content from the microblogging platform Twitter, where the concentration was on users' statements of perceptions and beliefs regarding NFTs, as well as users' conversations around NFTs on this platform. More recently, Twitter has become such an attractive platform for NFT-based content conversations that it has introduced official support for using NFTs as Twitter profile pictures [10].

Our work contributes to the literature in the following ways: First, we enrich the literature on NFT perceptions and opinions by identifying concerns around non-fungible tokens expressed on social media. Second, we provide a better grasp of patterns of topics expressed on social media in relation to NFTs through a text mining approach. Although several studies have discussed and investigated NFTs from different perspectives [11], this is the first study to analyze the opinions and perceptions of users on NFTs using big data capabilities. Lastly, we believe these findings may contribute to theoretical insight and can, moreover, serve as a basis for developing practical (design or policy) interventions.

The rest of the article is organized as follows. In the next section, we detail the state of the art of related work in NFT research. Here we identify three main clusters of concerns about NFTs and NFT trading that have thus far been identified: concerns about the general status and impact of NFTs; about the use and usability of NFTs; and about security risks. In the next section, we detail our methodology, which involves data gathering through social media web data mining of Twitter posts, and data analysis through topic modeling. In our results section, we specify the results of the two studies we conducted: one focusing on NFT marketplace-directed tweets (study 1), and the other on tweets with NFT-related keywords (study 2). Next, we delineate the theoretical and practical contributions that this study makes: our findings strengthen observations about concerns relating to safety and security in NFT trade, and in addition, identify a fresh range of concerns related to the role of NFT marketplaces, which—to those engaging with NFTs—can function both as a facilitator and an arbiter of who can engage in NFT trade. These findings can form the basis for identifying practical steps that marketplaces, individuals, and policymakers may take in relation to NFT trading in order to respond to existing concerns.

II. RELATED WORK

In recent years, the emerging disciplines of sentiment analysis and affective computing—dealing with capturing public opinion regarding political movements, commercial efforts, and a variety of other social events using social media data—have become very popular [12], [13]. Affect theory is the systematic investigation and evaluation of the role of affect (sometimes used interchangeably with 'difference making', 'emotion', or 'sentiment') in people's experiences, behaviors, and social-communicative interactions [14]. Besides affect theory, our work also leans on media theory. Media theory is a systematic study of 'media', that is, avenues of communication (or information transmission), including how the form and technology utilized in such communication affect information transfer [15, p. 1]. As techno-social systems, media can both facilitate and constrain social and communication activity [16, p. 37]. There has been discussion in media theory about how access to media that promote social networks or peer-to-peer interaction, such as (micro)blogging, might be understood to have liberating, empowering, or democratizing possibilities. Concerns about risk or danger inside a (social) media platform might come to the forefront in delineating boundaries between an in-group and an out-group; between those who are and are not regarded to be part of the 'community'. This may be accomplished by distinguishing behavior, 'styles of speech', or other 'enactments of belonging' [17, pp. 164, 167]. According to Macdonald [18], media discourses may have a considerable influence on what is viewed as dangerous. Or, alternatively, opinions may be expressed, as Moores [17, pp. 150–151] indicates (for the context of broadcasting), to erase worries about risk in order to convey reassurance or exude confidence.

There is a considerable amount of research on people's reactions, opinions, or attitudes towards the phenomenon of NFTs and trust toward various events expressed on social media, which can typically be categorized by the type of event and the purpose of the study [19]. Natural disasters, health-related events, criminal and terrorist actions, and protests are all examples of such event types. Since research on the comparatively new phenomenon of NFTs has only been conducted for a relatively short period of time, studies analyzing people's behavior and attitudes towards NFTs are scarce. While the adoption of NFTs now still remains a niche phenomenon, as the industry grows, blockchain-based transactions are expected to pervade ever-larger areas of an ever-growing number of lives. Understanding the perceptions and meanings that people attach to the NFT technology—how it is viewed as well as people's attitudes and expressed beliefs—is a critical step in building a firm comprehension of this phenomenon under these circumstances.

From the perspective of technical aspects, NFT research is focusing primarily on copyright regulations [20];

components, protocols, standards, and desired properties [21]; new blockchain-based protocols to trace physical goods [22]; and the implications of NFTs on the art world [23], [24], particularly because they allow for the sharing of secondary sale royalties with the artist.

When it comes to questions of perceived dangers or risk of NFT trading, the existing body of knowledge related to NFT is centered around three main concern clusters. First, concern about the general status and impact of NFTs, such as the legal status [25], [26], privacy issues [27], [28] as well as the significant use of energy and resources needed to facilitate blockchain-based assets [29], [30].

The second cluster revolves around the use and usability of NFTs, including the perceived lack of practical utility [31], [32], including the risk of losing access to one's assets e.g. [33], [34]; the process of creating NFTs being inefficient and costly [35], [36]; and the financial concerns about high market volatility [2], [37].

The third and last group of concerns is focused on the possibility that NFT trade can involve security risks [38], [39] and can facilitate crime or fraud [40], [41]. Whereas these studies primarily concentrate on other, technical NFT-related themes, the fact that they address possible concerns about NFT trade might assist in identifying the appropriate terrain for expressions of attitudes about perceived risks, challenges, and opportunities in trading NFTs.

The above analysis indicates that the reviewed and presented research currently has shortcomings, as none of the existing studies has a direct focus on human usage, perception, and experience with NFTs in social media settings. These elements are frequently addressed only in passing in otherwise more technically oriented investigations. More crucially, when studies explore perceived hazards or possible difficulties associated with the use of NFTs, the risks are typically emphasized by researchers rather than conveyed by participants themselves [42], [43]. To address these limitations, this work investigates what concerns are expressed by users in relation to non-fungible tokens by those who engage with NFTs on the social media platform Twitter, with special attention to possible concerns about crime, using NFT marketplaces, and market dynamics.

III. METHODOLOGY
A. PROCEDURE
The methodological workflow used in this research aligns with what Martinez-Plumed et al. [44] have identified as the 'Data Science Trajectories' (DST) framework, which allows for more open-ended, flexible trajectories of working with data, compared to standardized data mining methodologies such as CRISP-DM, KDD or SEMMA. As such, it starts (1) with exploring the data source, namely posts on Twitter, and with identifying the most relevant data to be extracted in order to answer the main research question (data source exploration). Next follows the phase of (2) data acquisition, during which the required data are extracted from the external
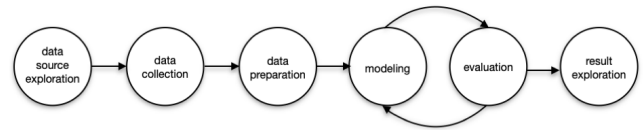

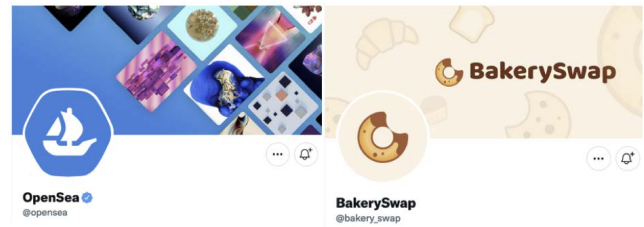**FIGURE 1.** Schematic representation of the steps taken in this research.

FIGURE 2. A hexagonal-shaped NFT Twitter profile with the OpenSea marketplace account (on the left), and a regular, round-shaped Twitter profile image with the BakerySwap marketplace account (on the right).

data source, namely Twitter through web data mining; and (3) data preparation (or preprocessing), which included steps to integrate, clean and transform the data and handle missing values or inconsistencies, to enable processing. In the next phases, (4) modeling and (5) evaluation, topic modeling techniques are selected and applied to the data, and these models are (iteratively) evaluated on how well they help answer the research question. In the final phase of (6) result exploration, results are analyzed and explored to determine the most fitting interpretation to be drawn from the models to gain valuable insights from the research. The entire workflow is illustrated in Figure 1 below.

As a data source, the Twitter platform is characterized by short messaging (with a strict 280-character limit on posts), and a users' timeline consisting of posts either from accounts that a user follows, or that are promoted, or that have been engaged with by accounts that the user follows. By default, posts on a Twitter user's timeline are sorted non-chronologically, in a way that prioritizes 'engagement' cf. [16, p. 179], [45]. As Poynter [46, p. 253] already pointed out, Twitter is used for "[a]lerting contacts to your thoughts and activities", and in that light, Twitter contains a significant volume of NFT-related posts and discussion. Scholarship indicates there to be a significant connection between blockchain-based activities and operations on social media e.g. [47], [48], particularly Twitter cf. [49]. More strongly, in March 2022, the Twitter platform strengthened its association with NFT trading; it rolled out official support for using NFTs as Twitter profile pictures, which are differentiated from regular user profiles by having a hexagonally shaped, rather than the standard round, profile picture frame [10] (see: Figure 2).

Twitter has in fact become such a prominent platform for NFT-based statements and conversations, that certain developers have built plugins to block users with NFT profiles, for those Twitter users who do not wish to engage with NFT-related posts or accounts [50], [51].

B. DATA COLLECTION

The method for data collection used in this study consisted of social media web data mining of posts relating to NFTs on the social media platform Twitter (using English language settings). Such web data mining from Twitter captures perceptions and statements as they are expressed by user posts in a natural online setting, unprompted by researcher intervention. The Twitter platform was accessed using the Twitter API (application programming interface) for academic research [52], which responds to http queries with tweets records containing natural language textual data and metadata in a JSON file format. Based on the research question, it was decided to retrieve the fields for: `text` (which is the body text of a tweet), `created_at` (the UTC time stamp for when a tweet was posted), `id` (the unique identifier of a tweet), `author_id` (the unique identifier of the author of a tweet), and `conversation_id` (the unique identifier of a conversation, or tweet thread, that an individual tweet is part of). The following shows a sample tweet record received in response to a call to the Twitter API:

```
{
"text":"@opensea @opensea 1/1s collection of NFTs
waiting for collectors make me go viral
#opensea #NFTCommunity
\nhttps://t.co/T2So4623TK https://t.co/1nZdLJdEKS",
"created_at":"2022-03-15T17:55:37.000Z",
"id":"1503792047718809606",
"author_id":"1491564460011667456",
"conversation_id":"1503783763419009026"
}
```

The size of the population focused on in this research would be found at the intersection of two groups: on the one hand, the set of people who use, engage with, or otherwise trade in NFTs; and on the other hand, the set of people who use Twitter. An indication of the volume of the size of the former is gained from the number of unique monthly wallets that were used to buy or sell an NFT, which is estimated to have been around 363,692 in December 2021 [53]. In terms of the latter, Twitter is reported to have had around 229 million 'monetizable' daily active users' worldwide in the first quarter of 2022 [54]. (Twitter no longer reports 'monthly active users'.) Data collection was carried out in two distinct studies, using complementary data collection processes or sampling strategies.

1) STUDY 1: NFT MARKETPLACE ACCOUNT-CENTERED

In acquiring the data for study 1, the focus was on settings where users engage with official Twitter accounts associated with prominent online NFT marketplaces. The aim of the setup is that it enables capturing posts about NFTs in a manner that is closely linked to a trading platform, yet which at the same time is neutral toward whether a post is positive or negative (and so, whether it might express a concern or not). Hence, study 1 can help identify any concerns about NFTs that may come up within the wider context of engaging with NFT marketplace accounts.

TABLE 1. Overview of NFT marketplaces for which interactions were extracted.

Marketplace	Founded	30-day active user count	Official Twitter account	Follower # (March 2022)
BakerySwap	2020	1 954	@bakery_swap	425.8K
Binance	2017	not known	@TheBinanceNFT	626.8K
Foundation	2020	14 147	@foundation	306.5K
KnownOrigin	2020	315	@KnownOrigin_io	106.9K
MakersPlace	2016	207	@makersplace	108.6K
NiftyGateway	2018	not known	@niftygateway	216.3K
OpenSea	2017	390 313	@OpenSea	1.4M
Rarible	2020	4 818	@rarible	435.7K
SuperRare	2018	235	@SuperRare	294.9K

Table 1 contains findings from a pilot investigation we conducted during January–February 2022 that identified a set of nine core NFT marketplaces that were well-established in terms of the number of people trading on these platforms, or in terms of how long they have been operating [55]. To facilitate cross-comparison, NFT marketplaces that are exclusively tied to an online game or virtual world, such as Decentraland or the Axie Marketplace associated with the Axie Infinity game, were excluded. Multiple marketplaces were selected to strengthen the validity of the findings.

During a seven day period (9–15 March 2022, inclusive), all tweets that were posted to the official Twitter accounts belonging to this selection of nine prominent NFT marketplaces and that contained the term 'NFT' were captured.

2) STUDY 2: NFT KEYWORD-CENTERED

In gathering the data for study 2, our approach was centered on the use of specific keywords or hashtags (which, for certain users, can function as flexible channels of engagement). Specifically, it concentrated on tweets that contained one or more of a set of keywords associated with potential concerns about danger, problems, or risks around NFT trading. A set-up concentrating on keywords in posts can capture any expressions of concern around NFTs that users post either amongst themselves, or when they are not specifically addressing an NFT marketplace—it does not require being tweeted toward a marketplace. A keyword query was deemed to be suited for this.

A pilot study in February 2022 demonstrated that a search exclusively for the broad, generic keywords or hashtags "#NFT", "#NFTs", "non-fungible token∗" (or "non fungible token∗") would include quite a lot of noise, as well as posts that do not directly concern perceived issues or uncertainty around NFTs. Hence, through progressive, iterative search for hashtags and keywords co-occurring with the hashtag "#NFT", "#NFTs", "non-fungible token∗" (or "non fungible token∗") that could signal concern, a preliminary set of core, commonly used keywords was identified that could form a focal point here. These include,

TABLE 2. Overview of keywords for which posts were extracted.

Keywords and keyword combinations	
NFT	AND (crime OR criminal OR cryptoscam OR damage OR damaging OR fake OR fakemint OR fraud OR hack OR harm OR harmful OR illegal OR illicit OR launder OR laundering OR liar OR loss OR losing OR lost OR lying OR MLM OR phished OR phishing OR ponzi OR privacy OR problem OR pyramid OR pyramidscheme OR risk OR risky OR rug OR rugpull OR safe OR safety OR scam OR ScamAlert OR spam OR steal OR stealing OR stole OR stolen OR theft OR toxic OR trust OR volatile OR volatility OR warn OR warning -"a steal" -"trust wallet")
FuckNFTs	—
NFTfraud	—
NFTrug	—
NFTsAreAScam	—
NFTscam	—
NFTscamalert	—

for instance: #NFTscam, #NFTCommunity, #NFTfraud, #NFTscamalert, #NFTartist, #ScamEconomy, #FuckNFTs, #ArtistTheft, #Cryptodicks, #NFTart, #NFTwats, #NFTwack, #Openseafraud #BinanceStopScamming. Based on considerations of the degree of noise and relevance of the results obtained with each of the keyword searches, a longlist was eventually narrowed down to a selection of commonly occurring keywords and keyword combinations to use in the full study, as presented in Table 2.

During a 48 hour-period (11–12 March 2022, inclusive), for each of these selected keywords, keyword combinations, or hashtags, all tweets that contained one or more of them were captured.

C. DATA PREPARATION

In terms of data preparation (or preprocessing), to prepare the data for topic modeling, the data obtained through multiple calls to the Twitter API were integrated into a single file for each study, in which each line represents a single tweet 'record'. To facilitate better processing, data was also transformed: all content in the text field (the body text of the tweet) was converted to lowercase. Emoji (i.e. the small icons used to represent ideas or emotions) were substituted by their Common Locale Data Repository (CLDR) Short Name, based on the Unicode Full Emoji List v14.0 and the Full Emoji Modifier Sequences, v14.0 (e.g. 'smiling-face-with-sunglasses' for the ⬤ emoji) [56], [57]. The decision to substitute, rather than strip out, emoji in this study was taken because emoji have come to constitute an integral part of short message electronic communication, including on Twitter. Hence, omitting this part of the tweets would risk losing a significant dimension of the content being communicated. In addition, at this stage also an extended list with 'stop words' (i.e. words that are common in many documents, but are less revealing of document content, such as 'and', 'the' or

'but') was compiled, to supplement the default stop-words list in the MALLET (MAchine Learning for LanguagE Toolkit) topic modeling software [58].

D. TOPIC MODELING

For the data analysis, this research used topic modeling (and evaluation of such topic models) to identify patterns of topics that characterize posts related to NFTs on Twitter. Topics models can be understood as machine learning algorithms that can be used to identify themes in large volumes of unlabelled data [59, p. 77]. As Blank [60, p. 639] states, the analysis method of topic modeling provides "a (relatively) automated procedure to code the content of a body of text into a (relatively) small set of substantively meaningful categories", or 'topics'. This form of semi-automated data analysis enabled the building and evaluating models to assist the understanding of expressions of concerns about NFTs within larger patterns and NFT-related conversations. Topic modeling is suited for this research as it enables a broad understanding of the main topics present in the data and provides a basis to describe patterns in how or where these topics come up. Topic modeling can be effective to summarize, detect themes, or make relevance judgements concerning a large collection of documents or records.

The current study makes use of the Java-based MALLET software that also facilitates statistical natural language processing, document classification, clustering, and other machine learning applications to text. MALLET supports topic modeling through Latent Dirichlet allocation (LDA) [58], [61, p. 996]. LDA is a generative probabilistic model of a corpus that allows for dimensionality reduction for collections of discrete data, which can include text corpora such as tweet records. With LDA, each tweet record is represented as a random mixture over latent topics, while in turn, topics are characterized by a distribution over words. Apart from the LDA method, other topic modeling methods include Latent Semantic Indexing (LSI) [62] and Probabilistic Latent Semantic Analysis (PLSA) [63]. In view of prior research, LDA performs better in big data mining than the other two approaches because of its three-level Hierarchical Bayesian model with a clearer internal structure, and its word bag model makes it easier to develop models [64].

Based on the research question and an understanding of the data, the variables selected were the text and id values, where the id is the unique tweet ID which functions as an identifier of the tweet records, and the text value contains the content that the modeling was performed on. Within MALLET, several tests were conducted in training the model on the datasets with an output of either 10 (default), 20, 30, 40 or 50 topics. The optimal number of topics was determined based on human judgment cf. [65]. Following considerations of: on the one hand, sufficient breadth, so as to allow specific topics to shine through, and on the other hand, avoiding topics becoming too narrow, the choice of 40 topics was made as one that would strike the right balance, and so would be most useful in helping answer the research question. In addition, use

was made of an optimiser (`-use-symmetric-alpha`) to minimize the occurrence of thinly supported topics. Hence, we used the MALLET topic modeling function set to an output of 40 topics.

A number of diagnostic points can help signal topic quality. These include, among others: document entropy, or the probability (or 'predictability') of a record (or document) given the distribution of a topic over all records (where lower entropy indicates that a topic is contained in only a few records, while higher entropy indicates that the topic occurs across many records); average word length, in characters (where a higher average length—that is, longer words—can indicate a more specific topic, and a lower average length a less specific one); topic coherence, that is, whether words in a topic tend to co-occur (understood as the log probability that a record that contains a 'higher-ranked' word also contains at least one 'lower-ranked' word in a topic) (where smaller values, such as those close to 0, indicate greater coherence, and larger negative values indicate lesser coherence within a topic); and exclusivity, which indicates the probability of top words in a topic equally occurring as top words in another topic (the lower the exclusivity value, the more 'exclusive' words in a topic are) [66].

IV. RESULTS

Two distinct studies of NFT-related communication on Twitter were conducted as part of this research: one concentrating on tweets directed at one or more official NFT-marketplace accounts (study 1), and the other focused on tweets containing one or more of a selected set of keywords emerging as associated with NFT-related concerns (study 2). An overview of the top 10 most frequent terms per topic for each of the studies can be found in the Appendix.

A. STUDY 1: NFT-MARKETPLACE ACCOUNT-DIRECTED TWITTER POSTS

Study 1 contains a dataset consisting of 18,373 unique tweet records (body text and metadata) of Twitter posts that were made directly to one or more of the official Twitter accounts of a selection of the nine major NFT marketplaces on Twitter. Tweet records were stored in a JSON file format.

Performing topic modeling using MALLET with the parameters described in section 3.4 on the data of study 1 resulted in a set of 40 topics with, among others, the topic quality indicators as shown in Table 3.

Some of the basic diagnostics for the 40 topics generated for the dataset of study 1 can give an indication of the overall character of the topics found. The average document entropy in this set of topics is closer to the maximum found in this set, suggesting that on average a topic in this set is less concentrated in just a few records, and occurs more spread-out across many records (which would indicate lower information gain per topic). While there are instances of longer words in the topics (12 characters), the average word length is only medium-length (7 characters), which could indicate only medium specificity of the topics. The topic's

TABLE 3. Selected diagnostics for topics of study 1.

	Min.	Max.	Average
Document entropy	5.7501	7.0556	6.5732
Word length	5	12	7.33
Coherence	-1298.5312	-47.6038	-911.1775
Exclusivity	0.3719	0.7929	0.55333

coherence suggests that there are topics in the set where words do tend to co-occur, yet that there are also quite a number of topics that display less coherence. The values for exclusivity indicate that the top words in a topic do, on average, tend to be slightly more exclusive to that topic.

When turning to the content of each topic, it is possible—based on contextual knowledge of the tweet records and close study of the words that compose each topic—to code each topic and to assign it an interpretation and meaning. Through a process of initial descriptive coding and subsequent abstraction and assigning classification, nine overall categories or themes for the topics were identified in the data of study 1 (Table 4).

From the main themes in these topics, concerns that users tweet to the NFT marketplace accounts can be observed for topics falling within the themes of 'marketing and promotion' (10 topics), opportunity and urgency (8 topics), and finance and trading (7 topics).

Topics associated with the theme of 'marketing and promotion' in many cases include a cluster of collections or brand names, often accompanied by terms such as 'awesome', 'amazing', 'wonderful', 'check' or a heart (♥) or fire (🔥) emoji. These topics may also jump on current affairs, potentially as a promotion tactic. For instance, the occurrence of key terms such as 'women', 'femininity' (topic 25) or 'powerofwomennft' (topic 32) may have to do with International Women's Day, and Russia's invasion of Ukraine shows through with key terms such as "collection ukraine ▪ war peace country support donated" (topic 34) (which, from inspection of the data, relates to Ukraine-themed NFT collections which promise that proceeds will be donated to support Ukrainian defense efforts).

Topics around the theme of 'finance and trading' include key terms that signal the buying, selling, fees or pricing involved in NFT trade (such as 'price', 'floor', 'sale', 'gas', 'buy', 'fees', 'sold', 'minting', or 'whitelist', in topic 17). Further, an equally prominent dimension that is captured under the theme 'opportunity and urgency' identifies topics with key terms that signal future opportunities, time pressure or urgency around the trade in NFTs. For example, top words include 'opportunity', 'future', 'hope', 'miss' (topic 9) and 'special', 'limited', 'exclusive' (topic 37)—suggesting both oncoming options and promise, and a risk of missing out.

While not containing many topics, also noteworthy in light of our research question are the themes of 'security' (4 topics) and 'platform operations' (2 topics). Security is relevant as a

TABLE 4. Themes identified in topics of study 1.

Theme	Description	Topic numbers in theme
marketing and promotion	Topics with prominent words associated with marketing or promoting (e.g. 'collection', 'unique', 'launching')	2, 4, 7, 8, 10, 11, 16, 25, 32, 34
opportunity and urgency	Topics with prominent words associated with opportunity or urgency (e.g. 'check', 'limited', 'exclusive', 'unique', 'miss')	9, 15, 20, 21, 24, 29, 33, 37
finance and trading	Topics with prominent words associated with finance or trading (e.g. 'price', 'selling', 'buying', 'floor', 'auction')	1, 5, 12, 17, 30, 35, 38
security	Topics with prominent words associated with security (e.g. 'security', 'phishing', 'scam', '■' [unicode short name: 'check-mark-button'])	6, 18, 26, 36
community	Topics with prominent words associated with community engagement (e.g. '🙏' [unicode short name: 'folded-hands', used to indicate gratitude], 'community', 'join')	14, 19, 23
platform operations	Topics with prominent words associated with platform operations (e.g. 'platform', 'verified', 'upload')	0, 13
art and creativity	Topics with prominent words associated with art or creativity (e.g. 'creative', 'self-expression', 'artwork')	22, 28
meta	Topics with prominent words about NFTs or using NFTs themselves (e.g. 'nftcommunity', 'nftproject', 'nftdrop')	3, 31
gaming	Topics with prominent words associated with games (e.g. 'play', '🎮' [unicode short name: 'video-game'], 'fun')	27

theme because, with top words such as 'scam' (in topic 36), or 'phishing' and 'scandal' (topic 6), it signals that also when people are tweeting directly at marketplace accounts, issues to do with crime or illegal dealings with NFTs are on users' radars. Further, terms such as 'doxxed' (referring to the action of providing full transparency about the identity of the team behind a specific project) and 'audit' in topic 18 suggest that actors tweeting at marketplace accounts proactively identify salient transparency and security measures. Likewise, topics within the theme of platform operations (2 topics) also show relevant issues that users may encounter, with top terms including 'hope', 'join', 'platform', 'verify' (topic 13) and 'recaptcha' (topic 0), which draws attention to joining or getting verified on a platform, as well as to steps taken during login, such as completing a reCAPTCHA security step used to distinguish bots from humans.

B. STUDY 2: NFT KEYWORD-CENTERED TWITTER POSTS
Study 2 focused on keywords used on Twitter in posts and conversations related to uncertainty and (mis)trust

TABLE 5. Selected diagnostics for topics of study 2.

	Min.	Max.	Average
Document entropy	6.6497	8.1276	7.2712
Word length	5	9	6.84v
Coherence	-1411.6943	-372.8660	-916.6566
Exclusivity	0.2602	0.7588	0.5332

concerning NFTs. This resulted in a collection of 36,354 individual tweet records (body text and metadata), which were stored in a JSON file format.

Performing topic modeling on the data of study 2, which contains tweets posted with a selected set of keywords or hashtags, equally resulted in a set of 40 topics with associated topic quality indicators (see: Table 5).

The average document entropy in this set of topics is higher than that identified for the topics of study 1, meaning that on average a topic in this set is still more spread-out across many records, rather than concentrated in only a few records. The average word length among this set of topics is also slightly lower (6.84 characters), which could signal a reduced specificity of the topics. The coherence of the topics in this set is on average lower than that of study 1, yet the top words in each topic are somewhat more exclusive to that topic in case of study 2.

For study 2, it is also possible to use the content of each topic—based on background knowledge of the dataset and close study of the words composing each topic—to assign an interpretation and meaning. Through descriptive manual coding and subsequent abstraction and classification, ten overall themes were identified for the topics in study 2 (Table 6).

From the main themes of these topics, concerns that individuals tweet when using these keywords can be observed for core topics that fall within the themes of 'crime' (12 topics), 'winning and giveaway' (7 topics), and 'trading' (7 topics).

As this was a keyword-based study, it is entirely expected that the top words in the topics include some of the keywords that had been selected for gathering the data. These show up prominently in topics within the theme of 'crime'. Topics identified as 'crime' contain words such as: 'warning', 'rug' (for 'rug pull', a type of scam in which a project is launched, hyped and abandoned as the founders run off with investors' money), 'scam', 'fake', 'stolen', 'avoid' (topic 18), or 'hacked', 'lost', and 'problem' (topic 10). (Some of which, incidentally, were not in the initial keyword search.) This points to various types of illegality and cautions being noted in tweets within this dataset.

It may equally not be surprising that, as in study 1, here too, top words associated with the basics of NFT trading show up in many topics. Terms such as 'market', 'investors' (topic 1), 'mint', 'purchasing', 'exchange'' (topic 26) or 'liquidity' and 'trade' (topic 38) indicate that across the data from both studies, trade is a recurrent and strong theme that people tweet about.

TABLE 6. Themes identified in topics of study 2.

Theme	Description	Topic numbers in theme
crime	Topics with prominent words associated with illegal activities (e.g. 'fraud', 'scam', 'stolen', fake', 'hacked')	2, 8, 9, 10, 11, 12, 14, 16, 18, 21, 36, 37
winning and giveaway	Topics with prominent words associated with winning or giveaways (e.g. 'giveaway', '🏆' [unicode short name: 'trophy'], 'prize')	5, 6, 13, 17, 19, 30, 32
trading	Topics with prominent words associated with trading (e.g. 'market', 'trade', 'floor', 'liquidity')	1, 3, 26, 33, 34, 35, 38
security and safety	Topics with prominent words associated with security or safety (e.g. 'security', 'safe', 'privacy')	7, 27, 28, 31
community	Topics with prominent words associated with community engagement (e.g. 'join', 'community')	0, 23, 29, 39
gaming	Topics with prominent words associated with games (e.g. 'players', 'game', 'gamefi')	8, 11, 21
warning, spread the word	Topics with prominent words associated with warning others or spreading a message (e.g. '🚨' [unicode short name: 'police-car-light'], 'careful', 'attack')	4, 20
risk and opportunity	Topics with prominent words associated with risk or opportunity (e.g. 'trust', 'loss', 'risk', 'fortune')	15, 24
marketing and promotion	Topics with prominent words associated with marketing or promoting (e.g. 'popular', 'amazing')	22
meta	Topics with prominent words about NFTs or using NFTs themselves (e.g. 'nftcollector', 'nftproject')	25

More surprising, perhaps, is the strong prominence of topics associated with the theme of 'winning and giveaway'. For instance, one finds this with tokens such as '🖤', 'prize', '🏆' 'giveaway', 'win', as well as the associated terms 'tag' and 'follow' often used to encourage participation in prize draws or giveaways (topic 17). Prizes, options to win things, or giveaways, are instruments that can be used to increase engagement or to draw people into a project or collection—which shines through in the co-occurrence of the final two terms ('tag' and 'follow'), which are frequently used to instruct readers to tag others or to follow an account.

Containing a smaller number of topics, but potentially of special interest here given the research question, are the themes 'security and safety' (4 topics), 'warning, spread the word' and 'risk and opportunity' (both 2 topics each). With topics in the theme of security and safety, we found words such as 'privacy', 'security', but also 'fearing' (topic 28) and 'harm' (topic 31). While in topics for the theme 'warning, spread the word', top words include: 'careful', 'attack', and '🚨' (a police car light) (topic 4), signaling caution and potential danger. The theme 'risk and opportunity', then,

contains topics with words including: 'trust', 'hoping', 'fortune' (topic 15) and 'risk' and 'lost' (topic 24), which could identify conversations to do both with future opportunities, as well as potential risk involved.

C. VALIDATION OF RESULTS
Steps have been taken to ensure and strengthen the validity of the results of this study. For one, this study is upfront in that it does not investigate NFT trading behavior itself, but considers specifically perceptions of, and attitudes toward, NFT trade as expressed on Twitter. Second, no attempt was made to determine, for each of the tweets included in the datasets of the two studies, what type of actual NFT-trading the tweet author was engaged in. However, as a proxy, a manual inspection of a random sample of 1000 tweets from study 1, and 999 tweets from study 2, was carried out to determine whether the author associated with a tweet uses the recently rolled-out feature of having an official (hexagonal-shaped) NFT Twitter profile, as shown in Figure 2. Given that any official NFT profile picture is added to Twitter using an API through which a user connects the 'wallet' in which they hold their crypto assets to their Twitter profile [67], having an official NFT Twitter profile confirms that a tweet author has access to a wallet. With the first sample of 1000 randomly selected tweets from study 1, a total of 919 unique tweet author_ids were found, of which (upon inspection) 49 accounts had been deleted or suspended since making their post. Of the 870 remaining accounts, 839 (96,43%) had a regular, round (non-NFT) Twitter profile, while 31 (3,56%) used an official NFT Twitter profile. With the second sample of 999 randomly selected tweets from study 2, a total of 936 unique tweet author_ids were found. Upon inspection, 61 of these accounts had been deleted or suspended since their original postings. Of the 875 remaining accounts, 853 (97,49%) had a regular, round (non-NFT) Twitter profile, while 22 (2,51%) made use of the official NFT Twitter profile feature. Given that each of these samples was selected randomly, these proportions can be inferred to generalize to the whole of the datasets from each of the respective studies.

In addition, to strengthen the reliability of the results of this study, during coding, codes were regularly checked with the data to avoid code drift; discordant information that might not fit with the proposed diagnosis was also presented; and the researchers used peer debriefing to contribute to greater accuracy cf. [68, pp. 190–192].

V. DISCUSSION
This study investigates users' expressed concerns in relation to NFTs on the social media platform Twitter. Drawing on the theoretical framework of affect theory, this study illustrates that NFT can be understood to function as a form of what Ahmed [69] has called a 'happy object'. In other words, NFTs may be understood as (digital) objects that are thought to promise a particular feeling, such as the happiness or fulfillment brought on by financial gain. This allows them to circulate within a community or society as something desired;

as objects, NFTs would be understood to represent (or, 'point towards') a happy, pursuit-worthy condition.

While it is true that, in certain cases, NFTs might serve as happy objects or as indicators of a desired financial situation, that does not indicate that they will always deliver on their perceived promises—in this case, a financial success [70]. Moreover, a plethora of concerns also surfaced during our empirical study of NFT-related Twitter posts.

The adoption of the theoretical approach of affect and media theory [17, pp. 150–51], wherein NFTs are perceived as 'happy objects' and the Twitter platform as a medium on which criticism, complaints, and in-group/out-group divisions around these happy items can be communicated, enables us to direct more attention toward the identified themes with concerns that were distinguished in this study. Based on the empirical findings, we identified nineteen themes for the topics in studies 1 and 2, which can be grouped into two distinct categories: concerns about *attacks and threats by third parties*; and concerns about *trading and the role of marketplaces*.

The first category indicates that concerns related to attacks and threats by third parties have been an integral part of the users' posts. Recently, research conducted in the field of NFT security has also demonstrated that NFTs are vulnerable to cyberattacks, breaches, as well as other forms of scams and fraud [71]. In the topic modeling performed in our study, attacks can be associated with five themes. The theme 'security' was found in study 1, while 'crime', 'security and safety', 'warning, spread the word', and 'risk and opportunity' were found in study 2. In terms of concerns, the 'security' theme and its corresponding topics can be interpreted as a concern from the perspective of the interruption of interaction with NFTs as 'happy objects'. When it comes to themes identified in study 2, these would less directly point to a disruption or termination of the relationship with NFTs. Rather more indirectly, they could indicate the expectation or readiness that, in addition to the opportunities for financial windfall, there is also a risk of loss, as well as the willingness to share information about possible risks or dangers that could threaten a successful, happy outcome. These findings support the study of Das et al. [72] suggesting that various potential security issues revolving around NFTs can lead to significant financial losses.

In relation to the second category of trading and the role of marketplaces, from both studies, we identify the themes 'finance and trading', 'trading', and 'platform operations'. Many terms or keywords related to trading appear in many topics, like 'market', 'investors', 'buying', 'exchange', 'mint', 'liquidity' and 'trade', indicating that trade is a frequent phenomenon that users tweet about. But when we focus on the theme of 'platform operations', concerns begin to surface. Here, elements of the marketplace or (intentional) design and operational decisions taken by the NFT trading platform trigger concerns. For the marketplaces, such as those that request an invitation or do not allow anyone to create an account, the process of simply joining the platform—or,

alternatively, getting the coveted 'verified' status check mark on one's profile—can serve as a barrier that prevents people from fully pursuing their happy objects. Concerns are raised here as well regarding the behavior and operations of NFT marketplaces in their capacity as what Fradkin [73] refers to as an ''aggregator and matchmaker'' between buyers and sellers. A second layer of concern arises even when users are able to function in a marketplace without considerable practical barriers. This is the concern that users will be locked out of their accounts at any time (stuck completing repetitive reCAPTCHA security checks), or that their particular work or whole collections would be removed without warning.

There are three main clusters of concerns in the existing state-of-the-art literature, which were emphasized in section 2, namely: (a) concerns about the general status and impact of NFTs; (b) concerns about the practical use and usability of NFTs; and (c) concerns related to security and fraud. Both clusters (b) and (c) may be instantly recognised as having parallels to the themes discovered in this research, as presented in Figure 3.

Most noticeably, there are similarities between the concerns in cluster (c) regarding crime and security threats and the themes of 'security' (or 'security and safety'), 'crime', and 'warning, spread the word' of this empirical study. Moreover, parallels exist between cluster (b) on the practical use and usability of NFTs and the theme group 'opportunity and urgency', given that tweets that point to NFT opportunities are sometimes marked by a sense of urgency and a need to act right away; tweets referring to NFT opportunities can be seen as a way to make ''happenings'' that have a ''halo of expectation and anticipation'' [17] cf. [74]. In addition, some users' practical use of NFTs will be hampered by the specific concerns that users expressed about the operation of marketplaces and issues with platform operations. This includes needing an invitation to set up an account; having no control over obtaining a 'verified' status; concerns about reCAPTCHA security measures; getting locked out of an account; getting a work or collection taken down [75]. The themes 'warning, spread the word' and 'risk and opportunity' belong to the cluster (b) due to their containing words that can also be linked to the practical use of NFTs [76].

Nevertheless, there is no apparent relationship between the topics and themes revealed in the present empirical research and the cluster of concerns (a), pertaining to the general status and impact of NFTs. The general status in cluster (a) includes the legal status and obligations connected with transactions and contracts utilizing NFTs; possible privacy concerns of blockchain-based transactions; and blockchain's high level of energy consumption and environmental effects. The absence of a relationship might imply that those broader legal and environmental issues are not among the more prevalent concerns of Twitter users who participate in NFT discussions. This cluster of concerns, on the other hand, is more ubiquitous among researchers that explore the technical and practical applications of NFTs [29], [77], [78], [79].
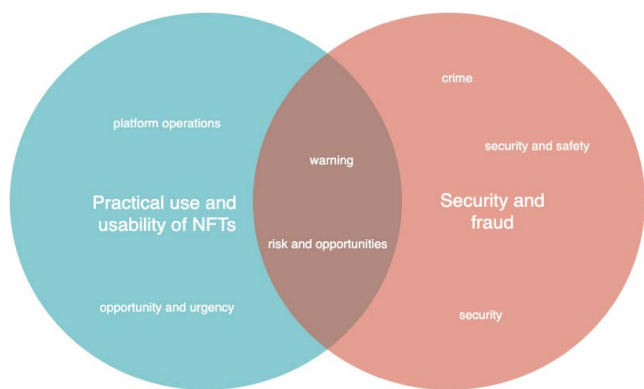
FIGURE 3. A comparison of the findings of this research to the current literature's clusters of concern.

A. THEORETICAL AND PRACTICAL CONTRIBUTIONS

The aim of this research was to understand what types of concerns are expressed in relation to NFTs by those who engage with this digital asset type on the social media platform Twitter. As such, the present study makes a theoretical contribution to scholarship on NFTs by analyzing people's perceptions of and attitudes towards NFTs as they are expressed in an online, social media context—an approach that has thus far remained scarce in existing studies. Specifically, this is, to our knowledge, the first study with a direct focus on concerns that arise in the human usage, perception of, and experience with NFTs as people express them in social media settings. The theoretical contribution of our findings stands out along three core dimensions. First, our finding of a set of concerns relating to attacks and threats by third parties—with topics including 'security', 'crime', 'security and safety', 'warning, spread the word', and 'risk and opportunity', as well as topics indicating anticipation of financial risk—can be understood broadly to align with a wider cluster of concerns already identified in the wider state-of-the-art literature on NFTs, namely that of concerns related to security and fraud [72], [80], [81]. Hence, on that basis, our findings strengthen those identifications as core concerns related to the use of NFTs, from a research context of direct, unprompted expressions in a social media setting. We refer the reader to [82] for a much more detailed exposition of the findings.

Second, our results also show topics with concerns related to trading and the role of marketplaces. While these could be understood to relate, broadly, to the theme of concerns about the *practical use and usability of NFTs* [9], e.g. [83] and [84], they nonetheless foreground a more specific phenomenon. The results namely indicate that some of the (intentional) design and operational decisions implemented on NFT trading platforms trigger concerns among users—a point which has thus far not received much attention in studies of NFT marketplaces [85], [86], [87]. From our findings, these are associated with barriers to joining or (fully) participating on a platform—such as invite-only access, verification, concerns about getting locked out of an account, or about collections being taken down. These findings are both interesting and important, because concerns about on-platform access and

operations have not been explicitly brought up in prior studies. Hence, our findings identify this additional, specific set of concerns about NFT use as expressed on Twitter.

Third, and surprisingly, themes from the state-of-the-art literature on NFT use which did not obviously resurface from the topics with concerns about NFTs as expressed on Twitter are those about the *general status and impact of NFTs* [78], viz. [88], [89]. This includes concerns such as those about the legal status of NFTs, privacy issues, or environmental concerns (for instance, about the use of energy and resources to facilitate NFT trade). Hence, our study does not offer additional support for this as constituting a major topic of concern as expressed on Twitter among those who engage with NFTs.

In addition, our findings can form a theoretical basis for significant practical implications and suggestions for both NFT marketplaces and individuals who are engaged with NFT trading, as well as for policymakers. First, with respect to the NFT marketplaces, the results of this research can provide a basis for developing practical improvements, for instance in the users' experience of trading environments, as well as information or support that could be provided to users e.g. [90]. If NFT marketplaces are aware of the type and range of concerns that users express around NFT trade, these platforms could more easily identify pain points, make design or operational adjustments, offer improved support to address existing uncertainties, as well as work to anticipate potential needs of users.

Second, people who are either currently trading NFTs or those who are considering doing so, could benefit from this study by learning the specific perceived obstacles or risks associated with NFT trading that are currently being expressed in a social media context. Users or prospective users could harness these insights to inform their own decision making about whether or not to start trading in NFTs, as well as about which specific perceived risks they themselves would be comfortable taking, and take precautions. These considerations could be especially salient given the crash in crypto-assets that had been observed in the period April–June 2022 [91].

Third, our findings could be used as a basis to inform policy. As a still comparatively a new type of digital asset, NFT trading has, to some extent, still not fully crystallized status in terms of regulation [92], [93], [94]. Insight into the range of concerns and perceived dangers—in particular those concerns relating to perceived scams, fraud, or money laundering—that users express might be a step for policy makers in identifying where regulation might be needed, and of what sort.

B. LIMITATIONS AND FUTURE RESEARCH

Our study does have certain limitations. First, data gathering for this study took place during a limited period of time. Given that individual and group behavior might vary depending on (atypical) specific historical events occurring during any selected period, there is always the risk that such data could

FIGURE 4. Top 10 most frequent terms per topic in Study 1.

Top 10 most frequent terms for topic 8 (25.0% of tokens)

Term
art
link
projects
spotify
jheneaiko
qtiptheabstract
hiatuskaiyote
eth
polygon
drop

Term frequency: 0, 50, 100, 150, 200

Top 10 most frequent terms for topic 12 (20.7% of tokens)

Term
page
dollypad
listed
earn
auction
🚀
🕹
platform
🤝
holding

Term frequency: 0, 28, 55, 83, 110

Top 10 most frequent terms for topic 9 (26.0% of tokens)

Term
⬇
😍
project
check
opportunity
miss
ido
great
beautiful
grab

Term frequency: 0, 50, 100, 150, 200

Top 10 most frequent terms for topic 13 (33.0% of tokens)

Term
hope
platform
create
join
abstract
misanharriman
driftershoots
verified
castles
verify

Term frequency: 0, 43, 85, 128, 170

Top 10 most frequent terms for topic 10 (24.3% of tokens)

Term
thehighapesclub
love
thcarmy
photography
life
beautiful
eye
❤️
wonderful
piece

Term frequency: 0, 45, 90, 135, 180

Top 10 most frequent terms for topic 14 (29.6% of tokens)

Term
🙏
❤️
🟫
🤗
collection
🤣
🙂
support
check
piece

Term frequency: 0, 100, 200, 300, 400

Top 10 most frequent terms for topic 11 (33.3% of tokens)

Term
collection
dogecola
eth
dogecolanft
children
project
present
interesting
make
attention

Term frequency: 0, 75, 150, 225, 300

Top 10 most frequent terms for topic 15 (24.6% of tokens)

Term
💥
check
🎉
🔥
march
amazing
twistpad
ready
trading
listing

Term frequency: 0, 45, 90, 135, 180

FIGURE 4. *(Continued.)* Top 10 most frequent terms per topic in Study 1.

Top 10 most frequent terms for topic 16 (30.5% of tokens)

Top 10 most frequent terms for topic 20 (29.3% of tokens)

Top 10 most frequent terms for topic 17 (32.5% of tokens)

Top 10 most frequent terms for topic 21 (37.4% of tokens)

Top 10 most frequent terms for topic 18 (26.4% of tokens)

Top 10 most frequent terms for topic 22 (38.8% of tokens)

Top 10 most frequent terms for topic 19 (19.0% of tokens)

Top 10 most frequent terms for topic 23 (23.6% of tokens)

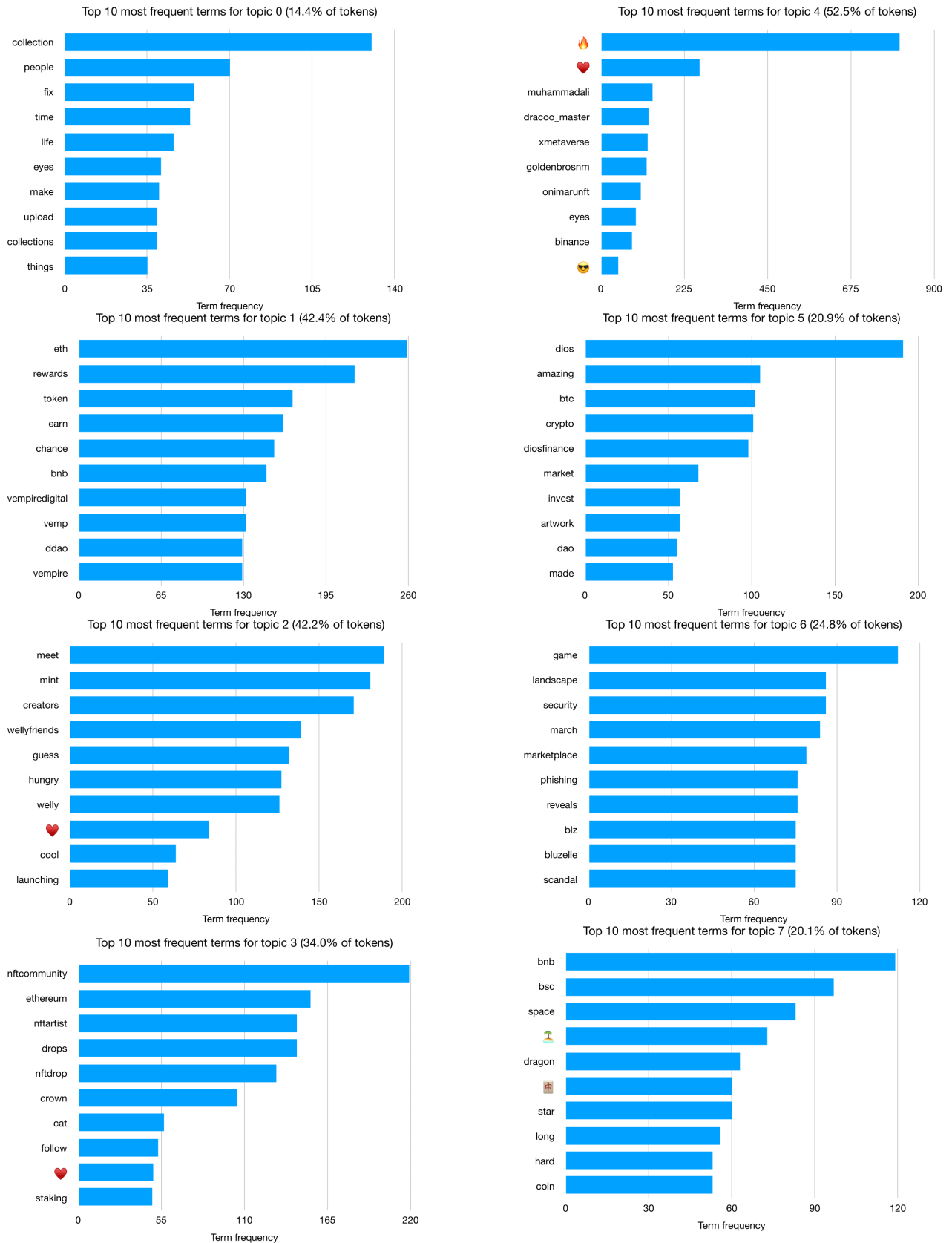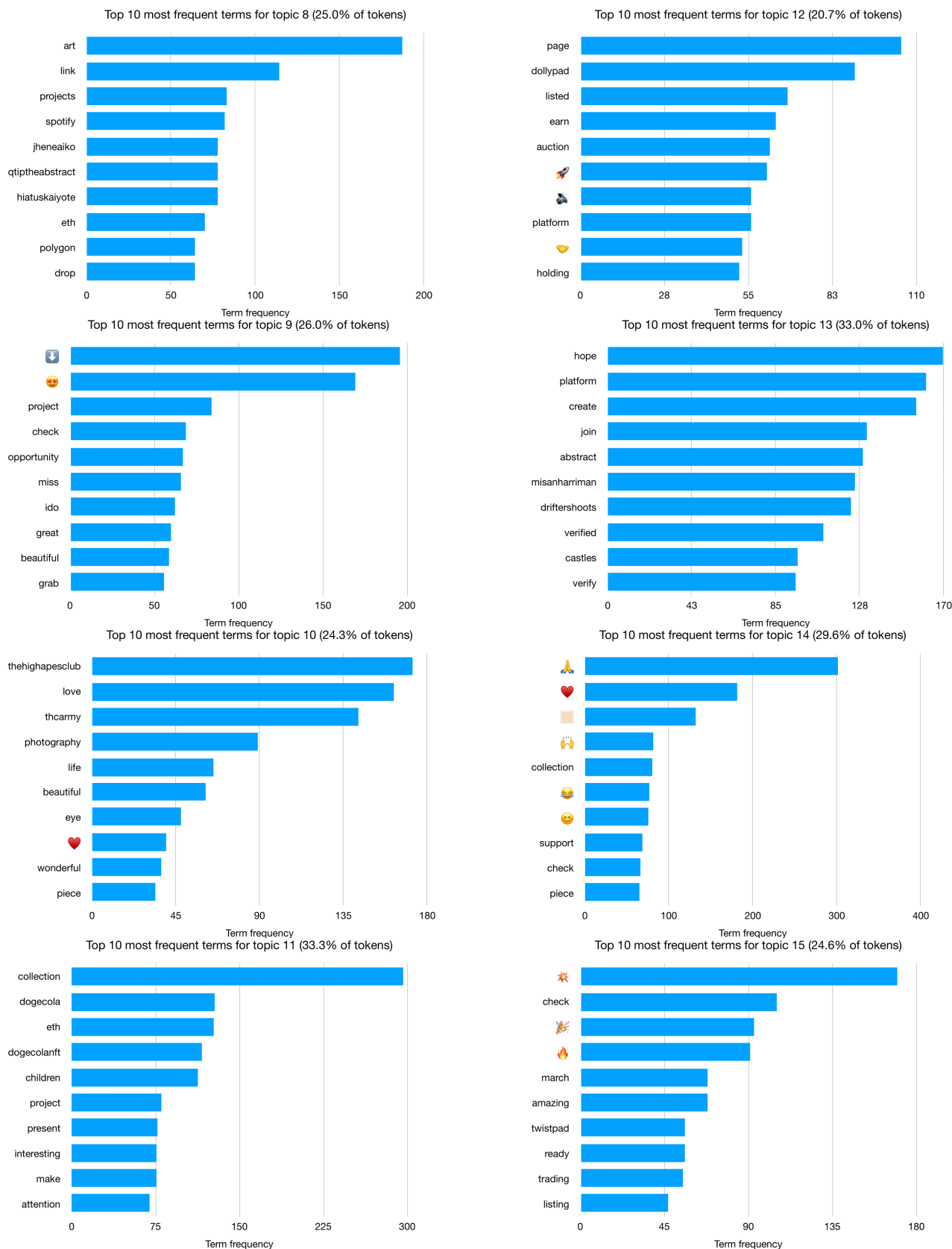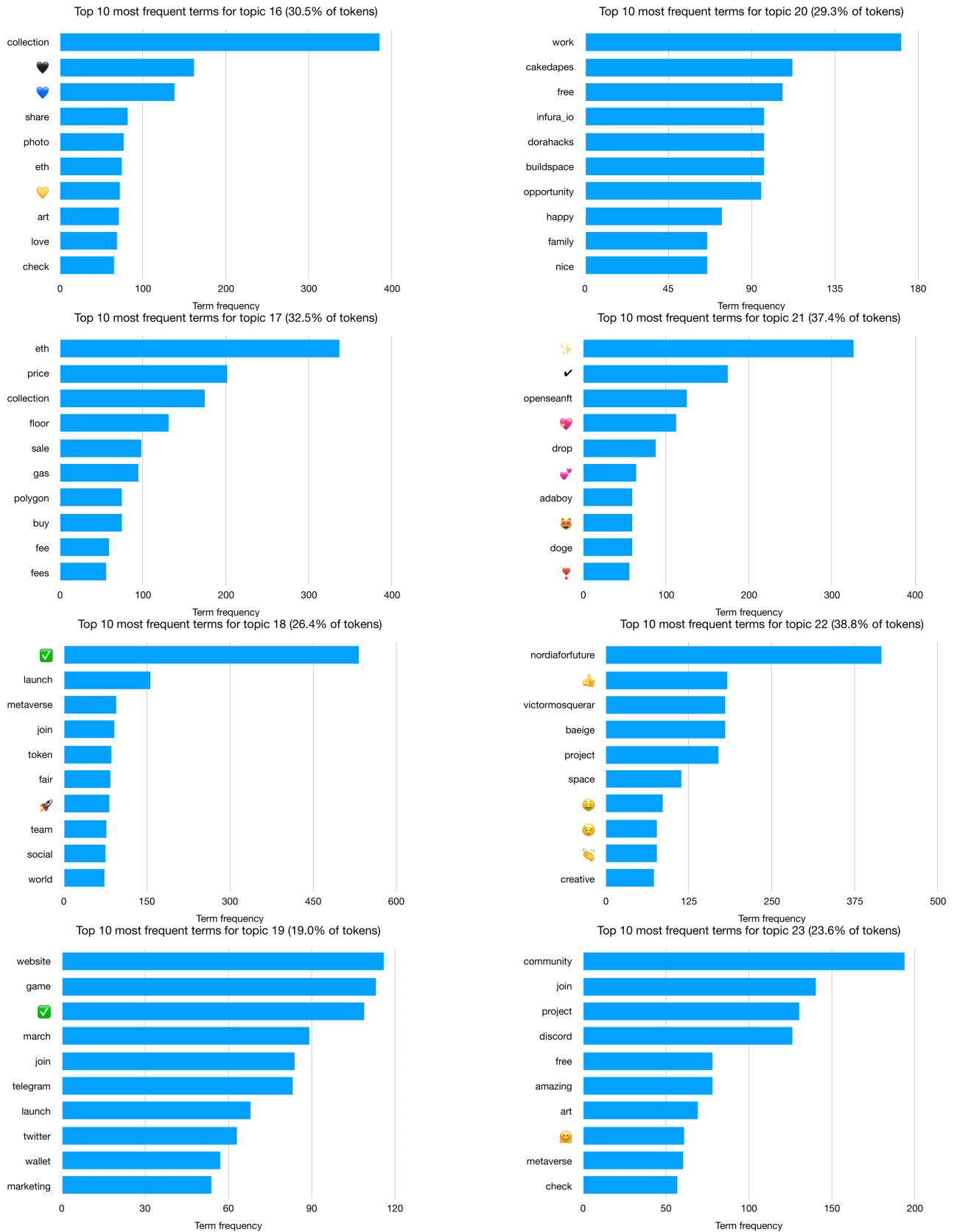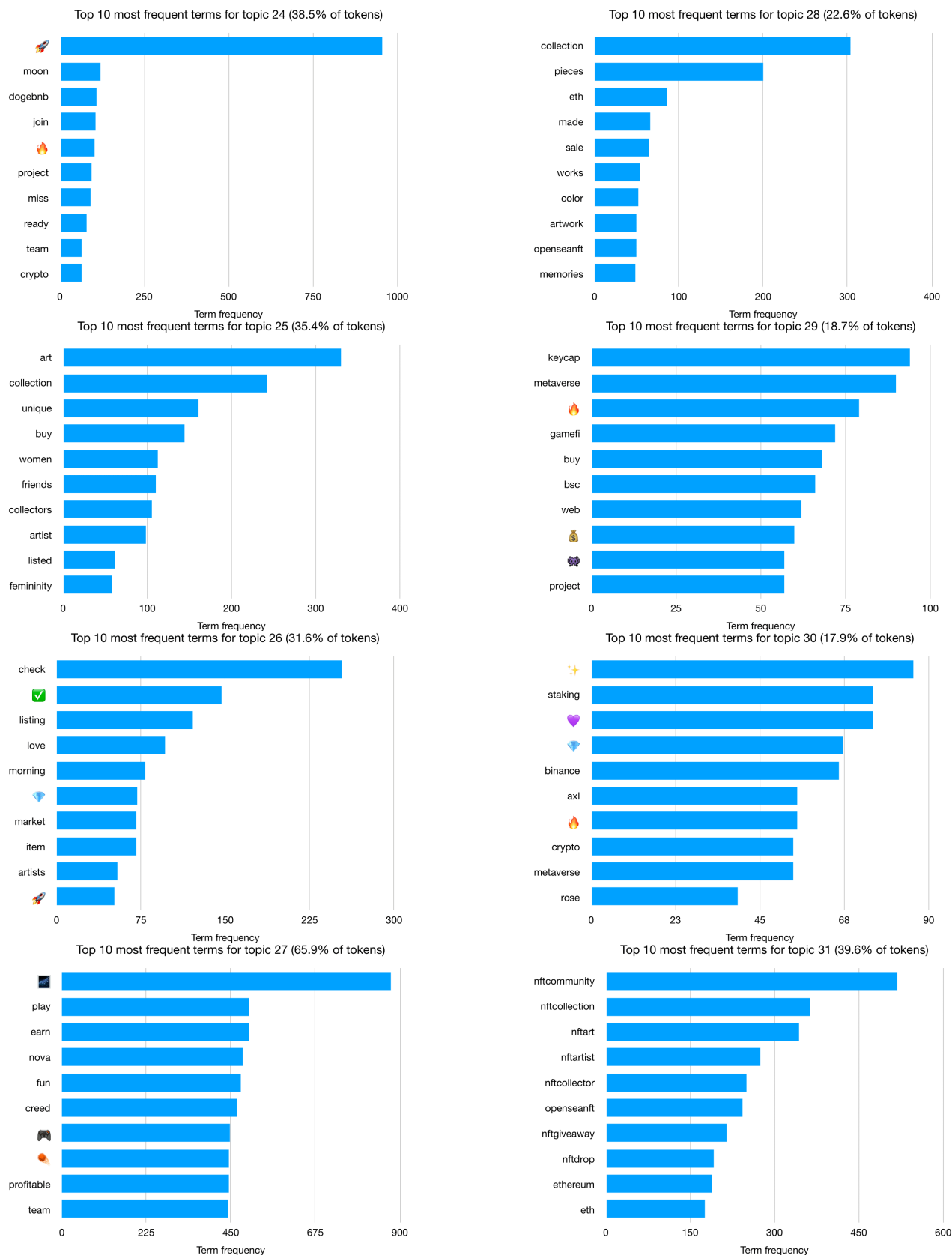**FIGURE 4.** *(Continued.)* **Top 10 most frequent terms per topic in Study 1.**

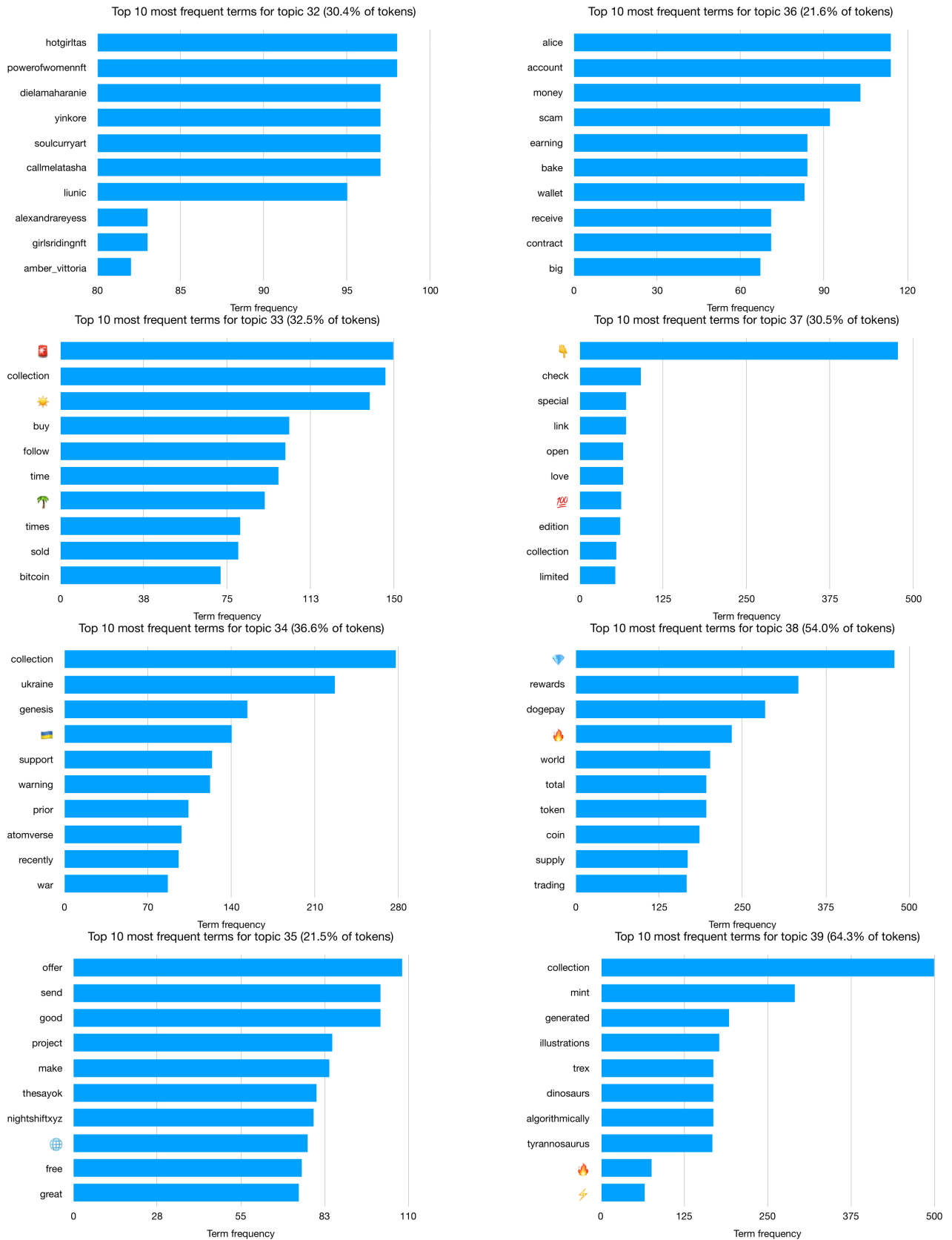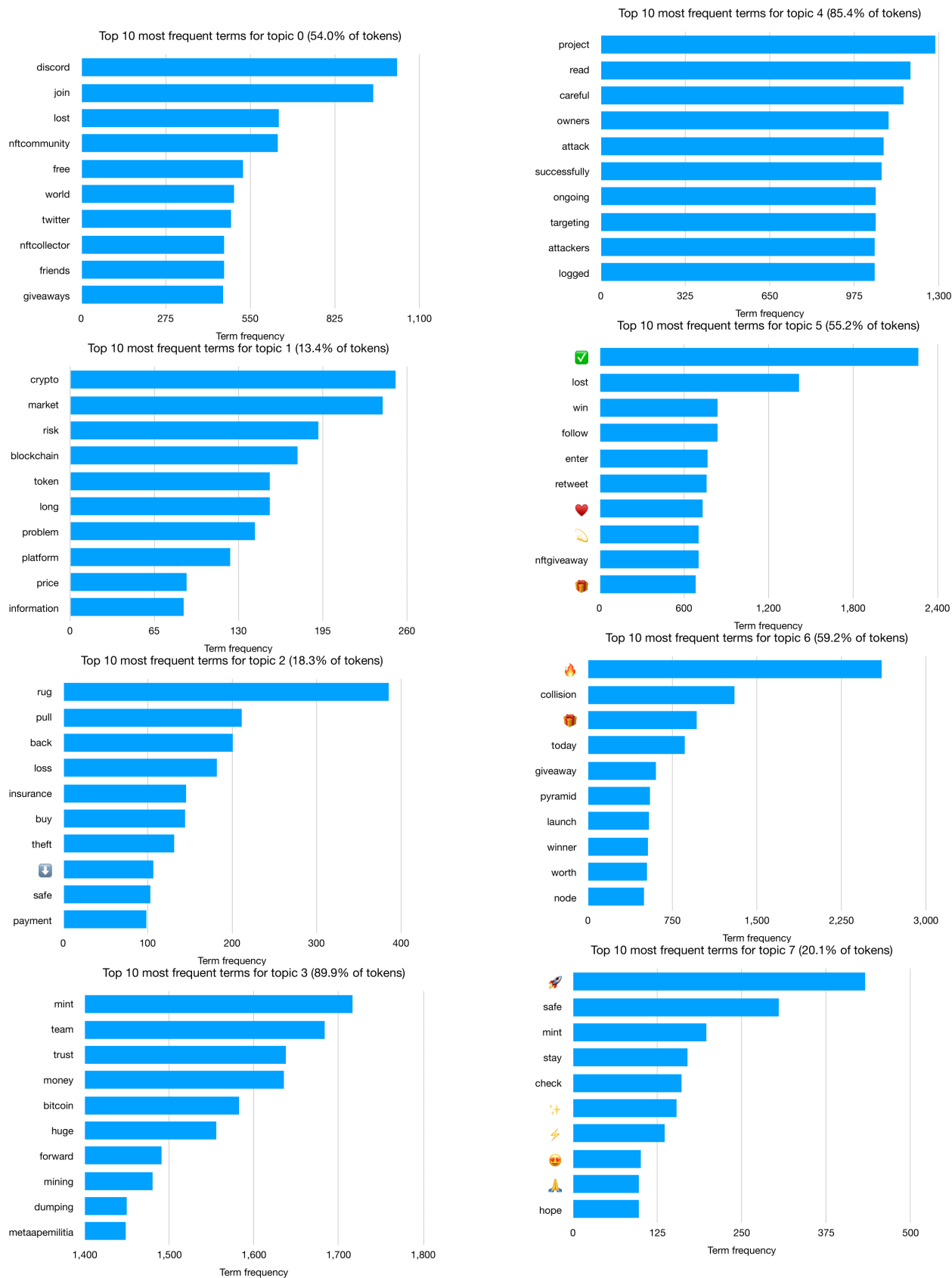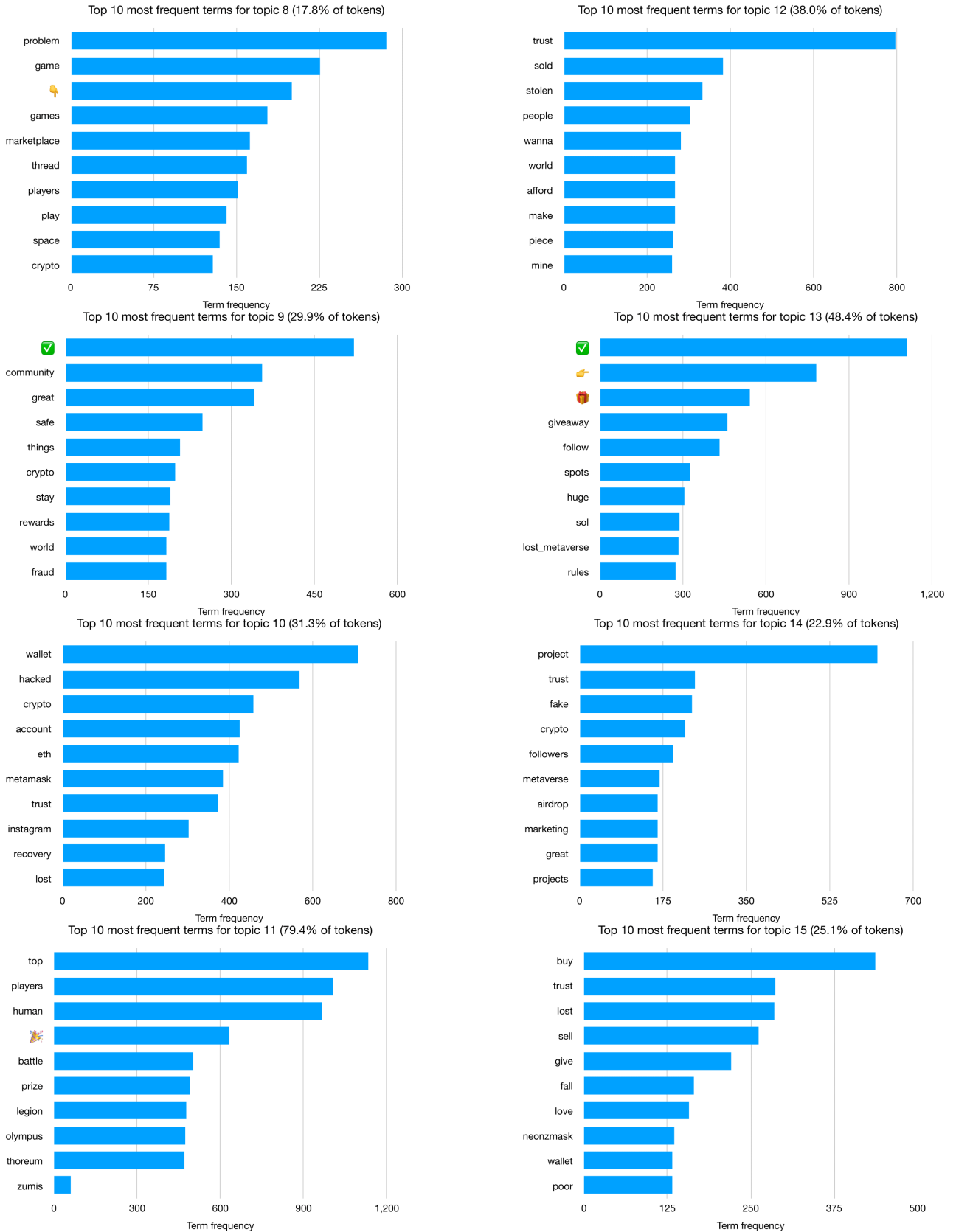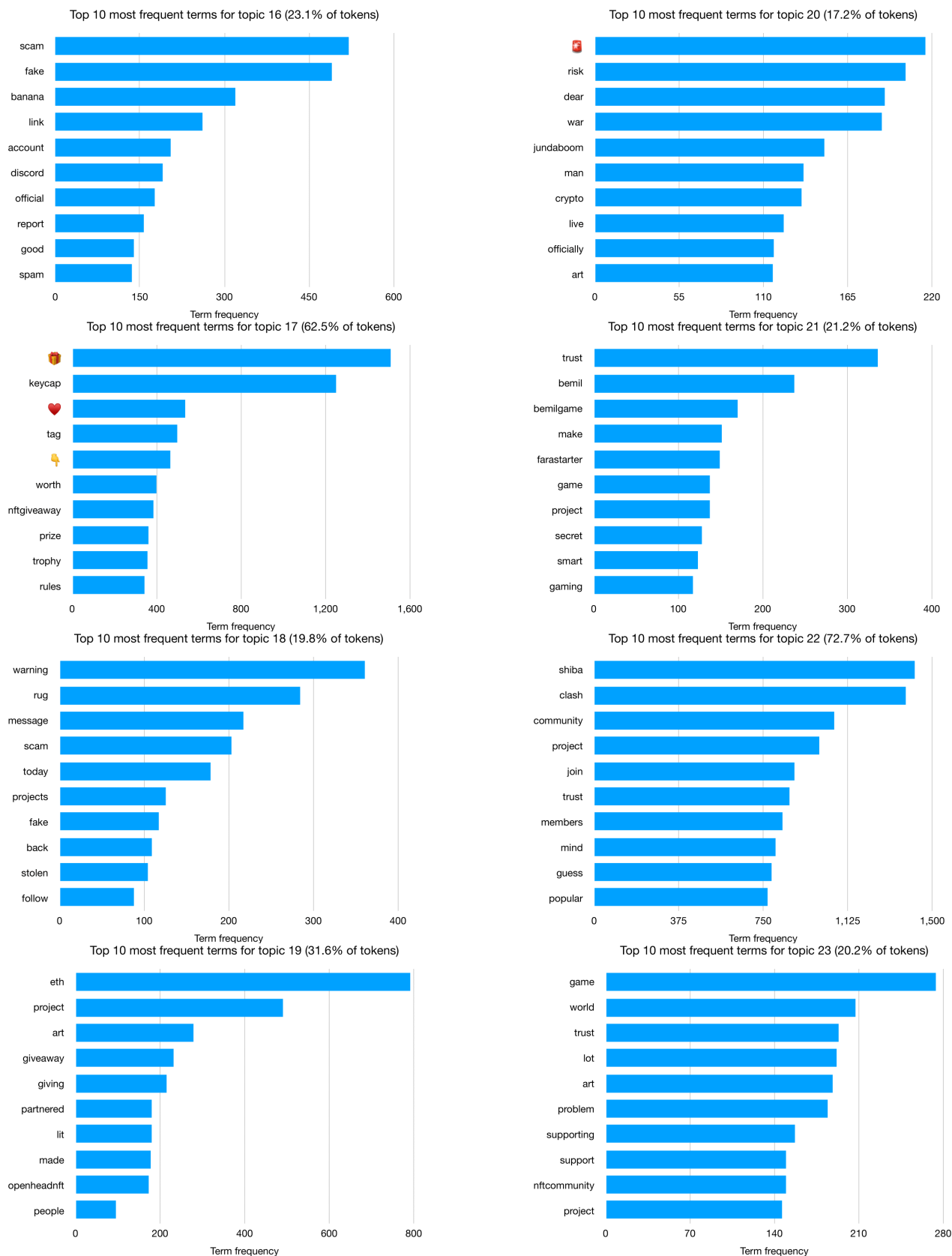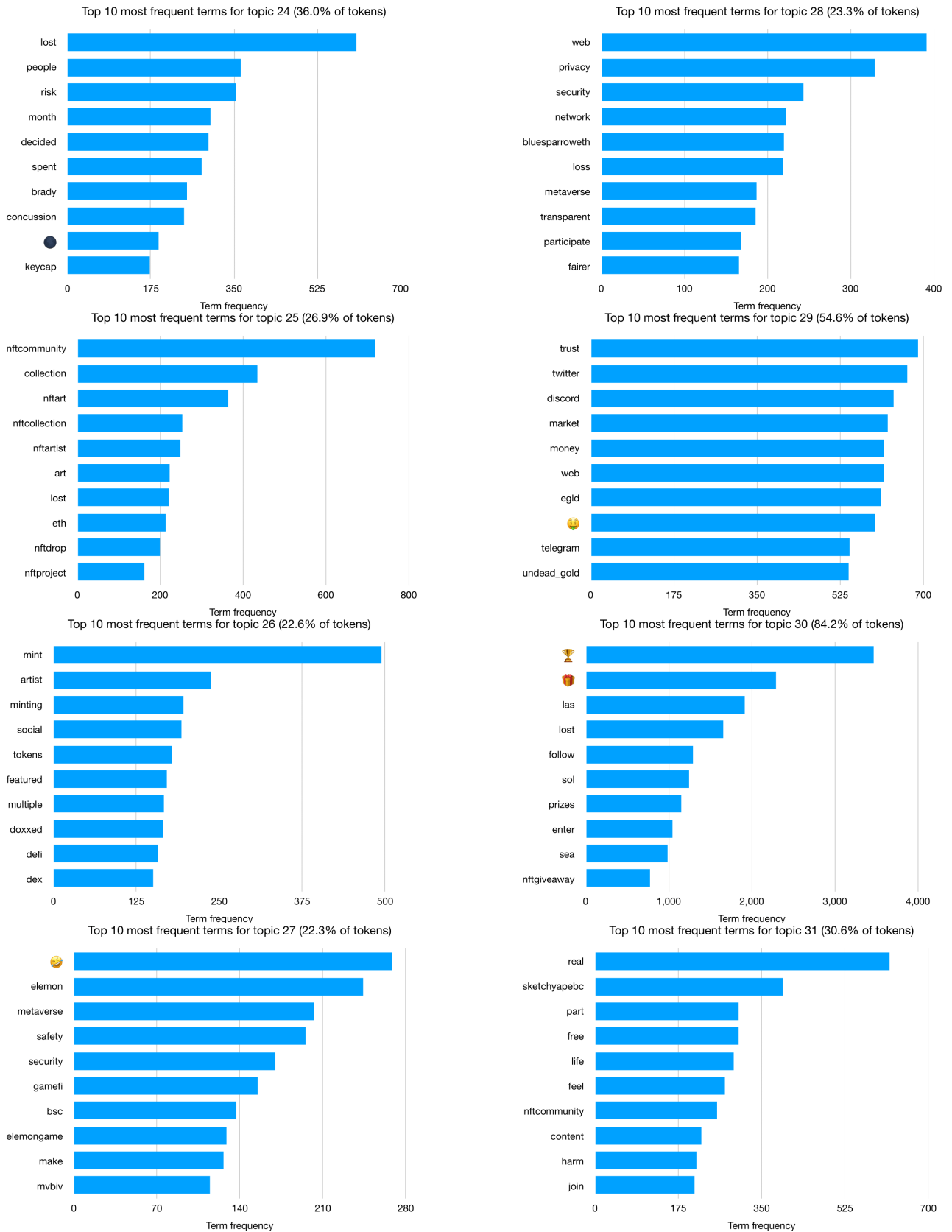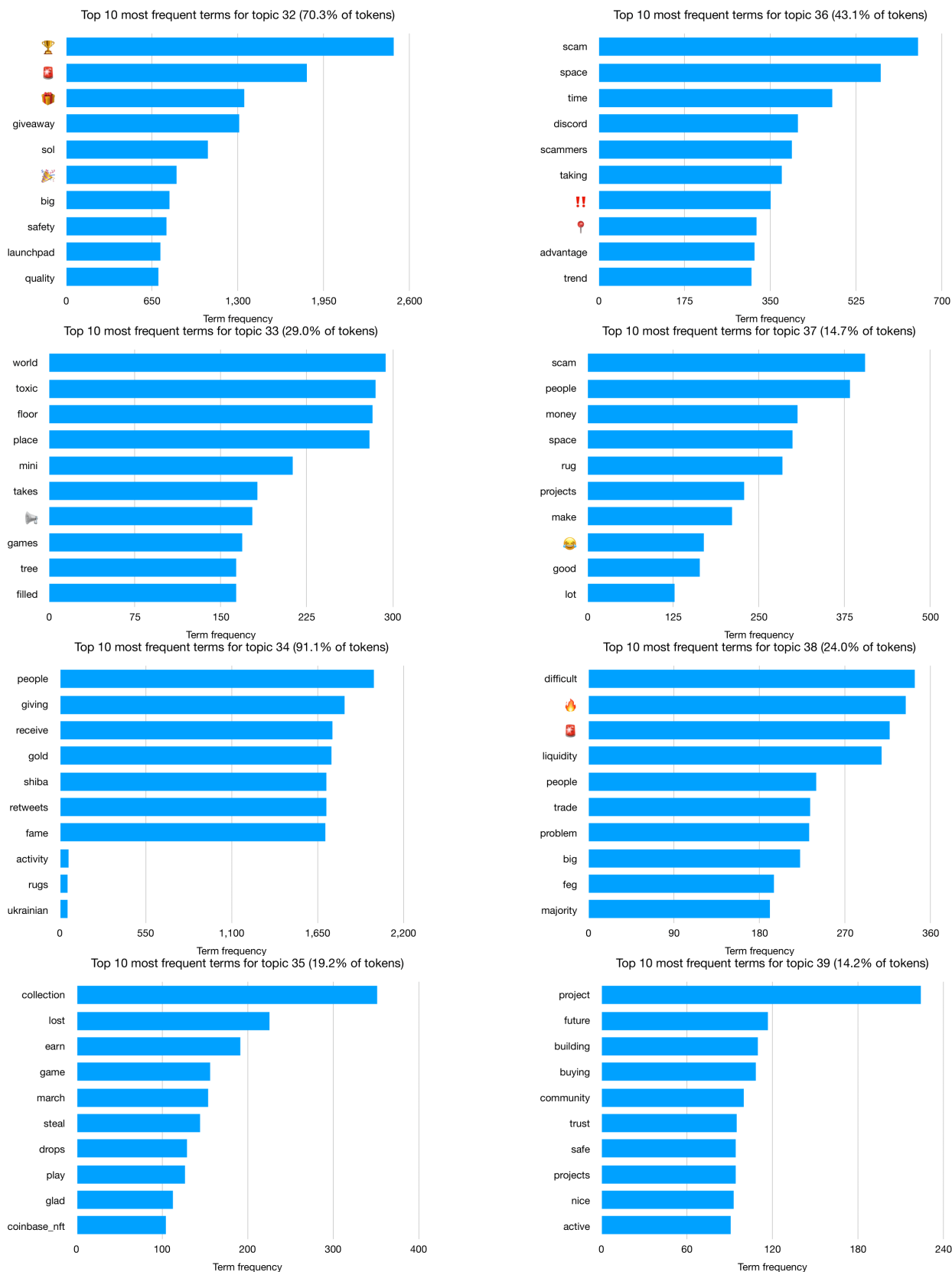FIGURE 4. *(Continued.)* Top 10 most frequent terms per topic in Study 1.

Top 10 most frequent terms for topic 32 (30.4% of tokens)

Term
hotgirltas
powerofwomennft
dielamaharanie
yinkore
soulcurryart
callmelatasha
liunic
alexandrareyess
girlsridingnft
amber_vittoria

Term frequency (80, 85, 90, 95, 100)

Top 10 most frequent terms for topic 36 (21.6% of tokens)

Term
alice
account
money
scam
earning
bake
wallet
receive
contract
big

Term frequency (0, 30, 60, 90, 120)

Top 10 most frequent terms for topic 33 (32.5% of tokens)

Term
🔺
collection
☀️
buy
follow
time
🌴
times
sold
bitcoin

Term frequency (0, 38, 75, 113, 150)

Top 10 most frequent terms for topic 37 (30.5% of tokens)

Term
👇
check
special
link
open
love
💯
edition
collection
limited

Term frequency (0, 125, 250, 375, 500)

Top 10 most frequent terms for topic 34 (36.6% of tokens)

Term
collection
ukraine
genesis
🇺🇦
support
warning
prior
atomverse
recently
war

Term frequency (0, 70, 140, 210, 280)

Top 10 most frequent terms for topic 38 (54.0% of tokens)

Term
💎
rewards
dogepay
🔥
world
total
token
coin
supply
trading

Term frequency (0, 125, 250, 375, 500)

Top 10 most frequent terms for topic 35 (21.5% of tokens)

Term
offer
send
good
project
make
thesayok
nightshiftxyz
🌐
free
great

Term frequency (0, 28, 55, 83, 110)

Top 10 most frequent terms for topic 39 (64.3% of tokens)

Term
collection
mint
generated
illustrations
trex
dinosaurs
algorithmically
tyrannosaurus
🔥
⚡

Term frequency (0, 125, 250, 375, 500)

FIGURE 4. *(Continued.)* **Top 10 most frequent terms per topic in Study 1.**

Top 10 most frequent terms for topic 0 (54.0% of tokens)

Top 10 most frequent terms for topic 1 (13.4% of tokens)

Top 10 most frequent terms for topic 2 (18.3% of tokens)

Top 10 most frequent terms for topic 3 (89.9% of tokens)

Top 10 most frequent terms for topic 4 (85.4% of tokens)

Top 10 most frequent terms for topic 5 (55.2% of tokens)

Top 10 most frequent terms for topic 6 (59.2% of tokens)

Top 10 most frequent terms for topic 7 (20.1% of tokens)

FIGURE 5. Top 10 most frequent terms per topic in Study 2.

Top 10 most frequent terms for topic 8 (17.8% of tokens)

Term	
problem	
game	
🤏	
games	
marketplace	
thread	
players	
play	
space	
crypto	

Term frequency (0, 75, 150, 225, 300)

Top 10 most frequent terms for topic 12 (38.0% of tokens)

Term	
trust	
sold	
stolen	
people	
wanna	
world	
afford	
make	
piece	
mine	

Term frequency (0, 200, 400, 600, 800)

Top 10 most frequent terms for topic 9 (29.9% of tokens)

Term	
✅	
community	
great	
safe	
things	
crypto	
stay	
rewards	
world	
fraud	

Term frequency (0, 150, 300, 450, 600)

Top 10 most frequent terms for topic 13 (48.4% of tokens)

Term	
✅	
👉	
🎁	
giveaway	
follow	
spots	
huge	
sol	
lost_metaverse	
rules	

Term frequency (0, 300, 600, 900, 1,200)

Top 10 most frequent terms for topic 10 (31.3% of tokens)

Term	
wallet	
hacked	
crypto	
account	
eth	
metamask	
trust	
instagram	
recovery	
lost	

Term frequency (0, 200, 400, 600, 800)

Top 10 most frequent terms for topic 14 (22.9% of tokens)

Term	
project	
trust	
fake	
crypto	
followers	
metaverse	
airdrop	
marketing	
great	
projects	

Term frequency (0, 175, 350, 525, 700)

Top 10 most frequent terms for topic 11 (79.4% of tokens)

Term	
top	
players	
human	
🎉	
battle	
prize	
legion	
olympus	
thoreum	
zumis	

Term frequency (0, 300, 600, 900, 1,200)

Top 10 most frequent terms for topic 15 (25.1% of tokens)

Term	
buy	
trust	
lost	
sell	
give	
fall	
love	
neonzmask	
wallet	
poor	

Term frequency (0, 125, 250, 375, 500)

FIGURE 5. *(Continued.)* **Top 10 most frequent terms per topic in Study 2.**

FIGURE 5. *(Continued.)* **Top 10 most frequent terms per topic in Study 2.**

FIGURE 5. *(Continued.)* **Top 10 most frequent terms per topic in Study 2.**

FIGURE 5. *(Continued.)* Top 10 most frequent terms per topic in Study 2.

be less representative of typical behavior than when a longer period of data gathering had been used. To mitigate this point, data gathering for this study took place over multiple days, and it was ensured that those days included both weekend- and weekdays. Future studies could further address this point by engaging in longer-term data collection, which could potentially also reveal whether patterns of concerns develop over time.

Second, our study is limited in that the method of social media web data mining that it uses can only capture those perceptions and attitudes that users themselves express in their posts. We chose this method to be able to identify concerns in NFT-related posts and online conversations in a natural online setting, without researcher intervention. However, given that participants might hold attitudes and beliefs that they do not express or do not express fully, this means that some users' perceptions and attitudes are likely to go undetected in this research. Future research could extend our findings by interviewing or surveying NFT users to prompt them to explicate any concerns they might have. In doing so, a more diverse overview of concerns about NFT trading could be established.

Third, data gathering took place on a single social media platform, namely Twitter. Hence, conclusions drawn from this research could be limited by relying on peculiar characteristics of posts and interactions as they take place on this platform. Future research could expand the range of platforms investigated, and determine whether different concerns about NFT trading come up in different online settings. Going yet further, such studies could investigate the relationship between expressions of concern, as well as the types of concerns expressed, about NFTs, and actual trading behavior on NFT marketplaces. For instance, do people who express concerns trade more riskily, or more cautiously? Do they exhibit other distinctive trading behaviors? Such an investigation could expand current insights into concerns about NFTs and NFT trading.

In addition, while the current research concentrates on topics that are prominent in what users tweet on NFTs, future work in this area could expand on these findings by conducting a full sentiment analysis of NFT-focused tweets. Such a sentiment analysis would be relevant not just in itself. Rather, it could moreover identify whether, and if so, how, such tweet sentiments relate to the topics that are tweeted about; which would provide further insight into how certain NFT-related topics are salient to users.

VI. CONCLUSION

The present research is the first study to analyze the opinions and perceptions of users on NFTs as expressed in a social media setting using big data capabilities. We used a text mining approach to identify a range of perceptions and statements that indicated concerns around NFTs or NFT trading in posts on the social media platform Twitter. Our research contributes to the literature by providing a better grasp of the patterns of topics expressed. For one, we found a range of concerns relating to safety and security in NFT trade, which strengthens existing studies that had noted this

as a domain of potential concern. However, in addition, our research found topics related to concerns about the NFT marketplaces on which NFT trading takes place themselves—a realm of concern which had thus far not received much attention in other studies. Overall, these findings enrich the literature and can be used as a basis for potential practical contributions that NFT marketplaces, individuals seeking to engage in NFT trade, or policymakers may take to respond to these concerns about NFTs and NFT trading that are being expressed in a social media context. In addition, we hope our findings would encourage other scholars to further explore NFT related concerns expressed on social media platforms and inspire practitioners to design sustainable regulations that dictate legal rules for the NFT market and its representatives.

APPENDIX

A. TOP 10 MOST FREQUENT TERMS PER TOPIC FOR STUDY 1
See Figure 4.

B. TOP 10 MOST FREQUENT TERMS PER TOPIC FOR STUDY 2
See Figure 5.

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