ARTIVATE: A JOURNAL OF ENTREPRENEURSHIP IN THE ARTS
VOL. 8, NO. 2, SUMMER 2019

Art and Blockchain

A Primer, History, and Taxonomy of Blockchain Use Cases in the Arts

Amy Whitaker
New York University

ABSTRACT: Blockchain technology, while commonly associated with cryptocurrencies, stands to bring radical structural change to the arts and creative industries. This paper presents a history, primer, and taxonomy of blockchain use cases in the arts and then explores the implications of blockchain in three regards: the blurring of the for-profit / nonprofit distinction, changes in the ownership structure of art, and potential for new structures of public and private support and related policy changes. These developments raise important questions of governance of a technology which requires expertise in cryptography, coding, and securities law for implementation. Ultimately, blockchain holds the potential to tip the role of the arts toward democratic availability through collective ownership structures or toward further commodification of cultural assets.
DOI: https://doi.org/10.34053/artivate.8.2.2

Blockchain—the distributed append-only ledger technology associated with cryptocurrencies such as Bitcoin—is a rapidly evolving area of arts entrepreneurship. Blockchain's complex and decentralizing potential activates questions of strategy and possibility for artists (Catlow, Garrett, Jones & Skinner 2017; Brekke 2019), organizations (Schneider 2018; Bailey 2018; Adam, 2018), and systems of arts entrepreneurship (Beckman & Essig 2012; Chang & Wyszomirski 2015; Essig 2017; Ragsdale 2017; Welter 2011; White 2017; Gartner 1985). Although sometimes grouped with cryptocurrency (Brunton 2019; Golumbia 2014), blockchain itself has structural potential to reshape the landscape of entrepreneurial organizations within the arts and creative industries (Wierbicki & Rottermund 2019; Michalska 2016).

The core idea of the technology, which is described at greater length later in the paper, is that blockchain is essentially a special database structure. It is a ledger of time-stamped information (Haber & Stornetta 1991a, 1991b). The innovation of blockchain is that the

ledger is distributed, meaning that it exists in many interconnected copies. This fact profoundly alters the power dynamic around, and governance over, information because it removes the need to trust a central authority (Haber & Stornetta 1991a, 1991b; Nakamoto 2009). A museum or a government or a bank no longer needs to be the trusted keeper of the official record of anything, whether an artwork's provenance, a person's citizenship, or a checking account's balance.

In addition, financial structures have been built onto this distributed ledger to reward and incentivize people to keep those interconnected copies of the ledger up to date through a consensus mechanism. Those keepers of the ledger solve computing puzzles and receive cryptocurrency, Bitcoin and otherwise, in return (Nakamoto 2009; Brekke 2019). Although the details of the technology are more complicated, at its core, blockchain is a way of relating to knowledge by time-stamping a record into a group of other records and then trusting a distributed system, not a sole entity, to keep that record. The idea of a new database may seem technical or small. However, considering the extent to which modern corporate capitalism and nation-state structures are built on trust in central authorities—even within robust democracies—blockchain stands to invert deeply rooted power structures. Of course, the technology is still being adapted and comes with risks and challenges, which this paper discusses.

This paper offers a history of blockchain, a primer on the technology, and a taxonomy of use cases in the arts, and then explores three related transformations that follow from the decentralized and fractionalizing potential of blockchain. First, blockchain blurs the for-profit/nonprofit distinction in the arts because the decentralized structure shifts responsibility for infrastructure away from trusted central authorities. Private blockchain start-ups are recreating title registries that have to date been managed by the public sector, as well as managing provenance and authenticity research currently done by museums, foundations, and galleries. Secondly, blockchain changes the ownership structure of art by creating fractional ownership of artworks and scarcity for digital works. A great deal of variety exists within this area, with some companies focusing on collectors and others focusing on artists. These potential shared-value structures extend to resale royalties and copyright (Whitaker 2019). Third, blockchain's shared value structures generalize to new models of supporting the arts itself, including Michael Wilkerson's (2012) proposal for a true endowment for the National Endowment of the Arts and Margo Jones's (1951) proposal that theaters could become stock companies (Ragsdale 2017). These innovative cooperative financial arrangements could extend to community economic development funding, cultural festivals, and many other areas of arts management and policy design.

A technology based on not trusting a central authority also raises fundamental questions of governance (Yermack 2017a, 2017b). As Lawrence Lessig wrote in 1999, computer code is law. The question that follows is how much do we need to understand blockchain, coding, cryptography, or securities law to participate? These questions of governance feed into pedagogical practice (Brown 2007; Beckman 2007; Essig 2012; Lindemann, et. al., 2012; White

2013; Pollard & Wilson 2014; Essig & Guevara 2017; Tosher 2019) because cryptography and securities law are less developed areas for arts entrepreneurship education. Although pedagogy falls outside the scope of this paper, the entire blockchain project presents questions of self-pedagogy and the vulnerability and discomfort of confronting large quantities of technical and rapidly changing information—some of it touted in media to such an extent that the exuberance might encourage skepticism.

The perspective of this paper is that blockchain could easily not develop to its full potential or not do so for three decades. As blockchain co-inventor Stornetta said in 2019, "To me, this is the crux of the matter. Namely, the decentralization of trust at a technical level does not guarantee the democratization of the social structures built on top of it, but…such a future…beckons."[1] From first principle, blockchain is as profound a potential structural frontier as computer processing or democracy itself. Thus, we have a responsibility to try to understand it. Blockchain is also a post-sector technology, meaning that ignoring it within the field of the arts does not make it go away; ignoring it empowers actors outside the field to act without the field's participation.

Methodologically, this paper takes a hybrid approach that reflects both blockchain as an emergent technology and arts entrepreneurship as an interdisciplinary field. As David Throsby writes in the introduction to *The Handbook of the Economics of Art and Culture* (vol. 1): "Cultural economics is not well defined because it is located at the crossroads of several disciplines: art history, art philosophy, sociology, law, management, and economics" (Ginsburgh & Throsby 2006, p. 5). Andrew Taylor describes the "sprawling footprint" of arts entrepreneurship and its "older sibling" arts management (Taylor 2015). Paul Bonin-Rodriguez highlights the political resonance of field-building across artistic practice, social science, and the performative nature of policy (Bonin-Rodriguez 2014, 2015; Vakharia 2015). Linda Essig (2015b) describes arts entrepreneurship as an "ouroboros" or snake-like creature swallowing its tail, as emblematic of a holistic relationship of art and economics (2015a).[2]

Blockchain is difficult to approach methodologically because it is a microcosm of these complex interdisciplinary dynamics of arts management, at the same time that blockchain is a new enough technology to resist some methods of social-science research. As Usman Chohan writes, researchers often study blockchain through technological, monetary, legal, and ideological lenses (Chohan 2017). Although blockchain has been studied empirically in finance (see, for example, Howell, Niessner, & Yermack 2018), a survey or statistical analysis of blockchain in the arts would tend to describe past adoption or current attitudes toward a technology that holds the potential to change the field, even from the outside.

Thus, the methods of this paper draw on strategic foresight as a discipline in creating a framework with which to consider the future as unfolding (MacKay & Costanzo 2009). This

[1] W.S. Stornetta, personal communication, October 2019.

[2] "Ouroboros" is also the name of a particular consensus mechanism (Haber, personal communication, October 2019).

approach reflects the idea that the past, however well modeled and understood, does not always predict the future, and that large seismic shifts require confrontation with new and unfamiliar subjects and navigation of untemplated pathways. To invoke a near-cliched example of epochal change, studying the horse and buggy only helps so much with understanding cars.

This approach draws on Israel Kirzner's work on the economics of open-ended entrepreneurial discovery (1978). As Kirzner later writes, "We never know what real possibilities remain to be discovered; we never know what the real limits are to the elasticity of the resource constraints that circumscribe our existence" (Kirzner 1984, p. 43, as cited in Harper 2003, p. 2). Scott Shane and Sankaran Venkataraman have written about this discovery orientation in arts entrepreneurship (2000). Linda Essig has also written about this process-oriented view of entrepreneurship (2015a), contrasting Kirzner's work with the outcome orientation of Joseph Schumpeter's idea of creative destruction (1942/2008, pp. 81–86). Blockchain is confusing to parse as means and ends, because the basic scientific research and entrepreneurial process from which the technology emerged are distinct from the financial rewards it later generated. As the history section of this paper shows, Stuart Haber and Scott Stornetta, the inventors of blockchain (1991a, 1991b), were trying to deal with epistemological problems of how we trust what we believe to be true in a digital age. Shane and Venkataraman argue that discovery is not adequate, but that exploitation of opportunity is also required (2000, p. 222). It is unclear in the story if Haber and Stornetta simply failed at exploitation or if their motivation was pure inquiry. What does seem clear is their focus on solving an important question, wherever that discovery led.

In order to approach blockchain as discovered and not static, this paper relies on interviews and interactions with many of the founders of early blockchain companies in the arts, as well as in-depth interviews with the scientists, Haber and Stornetta, who developed blockchain. Henrik Berglund (2007) characterizes this approach as a "lived experience" research method in entrepreneurship. As Berglund writes, research in entrepreneurship is often characterized by positivist empiricism but that we can instead widen the scope of method to reflect the ways in which "entrepreneurship is to a great extent a form of art, a practice-oriented endeavor that requires a sensitive and committed engagement with a range of phenomena in the surrounding world" (2007, p. 75). This approach is one of research-based artistic practice, informed by business strategy and investment management.

The literature review for this paper draws on a cross-section of blockchain-related writing in finance, entrepreneurship, law, art, and computer science, as well as a literature review of related work on funding and investment in arts management and arts entrepreneurship. I have specifically looked for papers outlining market phenomena and policy proposals that could be enacted in new ways using blockchain. The rhetorical method of the paper is also to offer analogic thinking across these disciplines, for instance, likening the token structure of cryptocurrency to the investment nature of art. This paper's intention

is for this translation across fields to function as an invitation of political enfranchisement into conversations around blockchain.

I have organized the paper as follows: It introduces blockchain by telling the history of blockchain as a creative invention unto itself and then offering a technological primer. The paper then introduces a taxonomy of core use cases in the arts, followed by an analysis of three particular strategic implications of blockchain: the blurring of for-profit and nonprofit structures, the effects on the art market, and the possibilities for enacting new models of arts funding. The conclusions address governance concerns and how blockchain may tip the role of the arts toward democratic availability or commodification of cultural assets.

A Brief Liberal-Arts History of Blockchain

Although many people believe the 2008 circulation of Satoshi Nakamoto's "Bitcoin" white paper and 2009 launch of the Bitcoin blockchain (Nakamoto 2009, Wallace 2011) introduced the technology of blockchain, in fact, Bitcoin takes root in much earlier work. Nakamoto's 2009 Bitcoin white paper has eight footnotes in total. Three of those eight footnotes are to the work of Stuart Haber and Scott Stornetta, who developed the time-stamping structure we now call blockchain twenty years before Nakamoto's paper (Haber & Stornetta 1991a; Bayer, Haber & Stornetta 1993; Haber & Stornetta 1997). Haber and Stornetta's central concern—trust in information in the digital age—particularly informs applications of blockchain in the arts.

In the late 1980s, Haber, a cryptographer, and Stornetta, a physicist, were working together as researchers at Bellcore in Morristown, New Jersey.[3] The two scientists were observing the early mainstream adoption of personal computing. By 1984, eight percent of American households owned computers. By 1989, fifteen percent did (U.S. Census). Seeing this newfound reliance on digital information, Haber and Stornetta asked two questions. The first question was philosophical: If it is so easy to manipulate a digital file on a personal computer, how will we know what was true about the past? The second question was political: How can we trust what we know of the past without having to trust a central authority to keep the record? These questions led to what turned out to be an extremely thorny math problem.

Building a trustworthy registry of digital files without a central administrator proved so difficult that Haber and Stornetta almost gave up. As scientists, their idea of giving up was to try to formally prove that the problem was, in fact, impossible to solve. Then one day Stornetta was standing in a Friendly's restaurant in Morristown, New Jersey, waiting for a table with his wife and children when the germ of a possible solution came to him. Stornetta told Haber the next day, and they set out to build this system (Whitaker 2018b).

The time-stamped ledger they imagined—the basic underlying structure of a blockchain—is at once cryptographic and registrarial. The time-stamped series of records are

[3] Haber, personal communication, May 2018, W.S. and M. Stornetta, personal communication, March 2018.

linked together in such a way that one cannot tamper with one item without disrupting the whole chain. The ledgers are linked internally from one block of transactions to the next, and then many connected copies of the ledger are distributed, allowing for a ledger that requires some trust in an algorithm but not in a central administrator.[4]

Haber and Stornetta presented their work at a 1990 cryptography conference and then published it in *The Journal of Cryptography* in 1991 under the title, "How to Time-Stamp a Digital Document" (Haber and Stornetta 1991a, 1991b). They wrote their foundational paper (Haber and Stornetta 1991b) with an E.B.-White lucidity of prose and a liberal-arts epigraph from Shakespeare's *The Rape of Lucrece:*

> *Time's glory is to calm contending kings,*
> *To unmask falsehood, and bring truth to light,*
> *To stamp the seal of time in aged things,*
> *To wake the morn, and sentinel the night,*
> *To wrong the wronger till he render right.*
>
> —(Folger Digital Texts n.d. [1594])

In addition to citing *The Rape of Lucrece*, the paper supports the case for designing a system that does not require trust in a central authority by quoting Juvenal circa 100 A.D., "But who will guard the guards themselves?" and including the original Latin, "*Sed quis custodiet ipsos Custodes*?" (Haber and Stornetta 1991b, p. 4). From the paper and conversations with Haber and Stornetta, their work shows a remarkable combination of technical and humanistic thinking in the blockchain's starting point.

Legally Haber and Stornetta's employer, Bellcore, owned their blockchain invention. Haber and Stornetta were named co-inventors on the patents. In 2003, Haber and Stornetta licensed the technology from Bellcore and founded a company called Surety to time-stamp records. For example, scientists who had traditionally kept paper notebooks with numbered pages and stitched bindings—to prevent tampering with or reordering pages—could now log their scientific observations onto the Surety blockchain.[5]

Figure 1 The Blockchain Friendly's

In order to take a radically transparent approach to the verifiability of their record-keeping, each week Surety published an alphanumeric code that a computer

[4] W.S. & M. Stornetta, personal communication, March 2018.
[5] Haber, personal communication, May 2018.

scientist could use to check that no one had tampered with the Surety blockchain. They published the code in the "Notices" section of the classified advertisements of the Sunday national edition of the New York Times.

Their code is still published in the "Notices" section of the Sunday paper, making theirs the oldest blockchain in the world.[6] Surety and Bellcore did hold patents on the blockchain structure, but they lapsed because of a missed patent maintenance fee around 2004. Otherwise, the blockchain technology itself would have still been under U.S. patent the first year of the Nakamoto Bitcoin paper (Haber & Stornetta 1992).[7]

In January 2009 Bitcoin entered the world to relatively little fanfare outside of computer programming circles. The white paper proposing Bitcoin had first circulated on a cryptography listserve in the fall of 2008, and the Bitcoin blockchain launched officially on January 3, 2009 (Burniske & Tatar 2018, p. 7). The author name in the white paper, Satoshi Nakamoto, is thought to be a pseudonym for a person or a group of people. Nakamoto is aptly described by the authors Jake Goldenfein and Dan Hunter (2017, p. 7) as "a kind of crypto-libertarian mashup of Spartacus, Keyser Söze, and Jay Gatsby." Although generally evoking white male heroic tropes in that phrasing, most authors, Goldenfein and Hunter included, go out of their way to adhere to plural pronouns to avoid gendering Satoshi (who is often referred to by first name in the manner of Madonna) and to nod to the possibility that Satoshi is more than one person. The Bitcoin blockchain is generally observed to have the kind of concerted, kaleidoscopically thoughtful presentation less likely to be the work of one individual's thought process.[8]

Nakamoto took Haber and Stornetta's concept of a distributed ledger and added a financial incentive for maintaining the connected copies of the ledger. Nakamoto's key development was the invention of mining, that is, allowing people to win coins—bitcoins—

[6] There is no inherent reason for why they published in the "Notices" section; they simply needed a public registry of the code. They were fortunate to choose a paper that still exists. When they first tried to place the advertisement in "Notices," they were turned down. Haber speculated that this was because it was not long after the Cold War and the alphanumeric hash looked like a spy code. Haber, who had recently been interviewed by the journalist John Markoff for the *New York Times*, breeched the advertising-editorial wall to ask the reporter to vouch for them that they were not spies (Haber, personal communication, May 2018 and October 2019).

[7] The author conducted independent patent research with research assistance from a patent clerk and patent attorney and also corresponded with Surety to confirm.

[8] In 2011, Dan Kaminsky, a forensic Internet researcher, tried to find weaknesses in the Bitcoin code, at the behest of Joshua Davis, a technology reporter writing for the New Yorker (Davis, 2011). Davis described Kaminsky as "like a burglar who was certain that he could break into a bank by digging a tunnel, drilling through a wall, or climbing down a vent, and on each attempt,he discovered a freshly poured cement barrier with a sign telling him to go home." Kaminsky had previously and famously found a bug in one of the foundational protocols of the Internet itself, reporting it to the U.S. government, Microsoft, and Cisco and then helping them to fix it. Every time Kaminsky thought he would find a bug in the Bitcoin code, he found a line of code preempting the possible attack. Kaminsky concluded that Nakamoto was either "a team of people" or "a genius" (Davis, 2011).

by solving mathematical puzzles tied to verifying transactions in a block (Nakamoto 2009, p. 3; Narayanan, Bonneau, Felten, Miller & Goldfeder 2016). It is not the coins, in and off themselves, but the reward for building the chain that supports the tamper-resistant decentralization Haber and Stornetta had first imagined.


NOTICES & LOST AND FOUND
(5100-5102)
Universal Registry Entries:
Zone 2 -
dS8492cgVOFAoP9kyE1XzMOrQ
HgEwzkVbVafNvIkUz99qvq8/ME
p5y9EFSG8XxzMBalGQQ==
Zone 3 -
JnFCg+HCmvhj8GmmUP7VZna71
NgZup/RfuKUQNzCHWXMuqLK
durxHQV5pSHLqBGPRiv+mg==
These base64-encoded values represent the combined fingerprints of all digital records notarized by Surety between 2009-06-03Z 2009-06-09Z.
www.surety.com 571-748-5800

Figure 2 Lost and Found

Although blockchain goes well beyond cryptocurrency as a tool, one early story of Bitcoin illustrates the wildly unpredictable trajectory of the invention in its early days. On May 22, 2010, approximately fifteen months after its launch, someone tried to force a transaction in which bitcoins would be used to purchase something tangible.[9] A computer programmer named Laszlo Hanyecz offered 10,000 bitcoins to anyone who would procure two pizzas for him. The pizzas could be homemade or bought. A British man agreed and had two Papa Johns pizzas delivered to Hanyecz in Florida. The pizzas cost thirty dollars. By May 2018, the 10,000 bitcoins he received in exchange for the pizzas were worth $82 million (Suberg 2018).

These early days of cryptocurrency place Haber, Stornetta, and Nakamoto in the ranks of artists exploring frontiers that the broader world was slower to metabolize and understand. In the financial life of their invention, Haber and Stornetta are in some ways the Vincent van Gogh's of the crypto-story; they did not particularly profit from their early work. Surety never became a large enterprise, and Haber and Stornetta went on to other projects. Stornetta became a high school math teacher, where he taught the most introductory math offered to incoming ninth-graders and the most advanced math offered to graduating seniors. Haber went on to work for Hewlett Packard and various start-ups. Both work in blockchain now.[10]

Nakamoto's addition of mining ushered in a subsequent wave of cryptocurrencies whose progress moved very slowly for several years. In 2014 Vitalik Buterin introduced the Ethereum protocol—a smart-contract structure that allowed tokenization (Buterin 2013; Buterin & Obrist 2018). Whereas Bitcoin, the original blockchain protocol, requires the user to have more of a functional mastery of the mechanics, Ethereum presents a simpler interface and contributes the structure of tokens, which function financially in many regards the way that art investment does. Ethereum generalized some of the scripting language of Bitcoin to be able to run many types of programs. Over time, some of those programs—smart contracts—became standard.[11] One such standard is the token type ERC-20 (named for a line

[9] Regarding capitalization, "Bitcoin" describes the currency and "bitcoin" describes the unit of currency.
[10] Haber, personal communication, May 2018; W.S. Stornetta, personal communication, March 2018.
[11] Sean Moss-Pultz, founder of Bitmark, personal communication, October 2019.

of code). The ERC-20 is fungible, meaning it functions as cash; two tokens are interchangeable the way that two dollar bills are. The later ERC-721 non-fungible token functions more like art (ERC-721 n.d.). The non-fungible token is the basis of digital collectibles such as Cryptokitties (Evans 2019); the code links to digital images that are related but technically unique, thus able to hold value but be part of an overall oeuvre the way an artwork might be.

While blockchain technology is still very much a work in progress, it joins the ranks of technological innovations upon which large-scale societal structures are built. For instance, some of the load-bearing walls of modern financial systems result from research—granted Nobel Prize-winning research—of a relatively recent vintage: Harry Markowitz's Modern Portfolio Theory (1952), William Sharpe's Capital Asset Pricing Model (1964), and Fisher Black's and Myron Scholes's Black-Scholes Options Pricing Model (1973). These theories underpin normalized strategies and structures of stock markets; at the same time, they are no older than Abstract Expressionism, Pop Art, and Conceptual Art. Similarly, the developments in blockchain since the early 1990s may, in a relatively short time, have profound implications for art historians, artists, conservators, collectors, dealers, museums, and broader ecosystems of cultural assets and creative industries.

A Blockchain Primer

This section offers a more technical primer on blockchain, as a basis for the arguments made regarding related use cases and strategic implications in the arts. The section is standalone so that it may be read separately as the reader chooses. As introduced above, a blockchain is a time-stamped record of any kind of information, organized into blocks that are chained together by the repetition of an alphanumeric code as the first part of one "block" and the last part of the previous one. The information in the blockchain is safeguarded in a few related ways that range from cryptographic protection of each record to the linking and distribution of all records.

First, each record is protected cryptographically through what is called a one-way hash function. A hash function is a mathematical procedure that takes any input and converts it into a fixed-length output (Narayanan et. al., 2016, at 2). Any piece of information—whether the purchase price of a tube of toothpaste or the entire published output of Marcel Proust—is used to produce an alphanumeric series of a fixed output size.[12] A standard hash function is called the SHA-256 algorithm, but as computing advances, that algorithm may be improved (Brekke 2019).

[12] Hash functions have three core attributes: (a) collision resistance, meaning it is almost impossible to use two different inputs and get the same output; (b) hiding, meaning if you see the output you cannot guess the input; and (c) puzzle friendliness, meaning people will actually do the cryptographic puzzle by random trial and error and not try to find a shortcut to the end (Narayanan, et.al,. 2016, 2-10).

What is special and useful about a cryptographic hash function is that it is a reasonably efficient forward calculation for a computer to do, and an extremely difficult calculation for a computer to undo. By analogy, the difference between hashing a number and uncovering the source number from a hash is a much more extreme version of the difference between the ease of scrambling and the difficulty of solving a Rubik's Cube.

These hashes are linked together and then themselves hashed to create a summary hash for each block or group of transactions. Because it is typically the hash and not the work itself that is visible on the blockchain, the content of work is also kept private. As Haber and Stornetta write in their 1991 paper, "A particularly desirable feature of digital time-stamping is that it makes it possible to establish precedence of intellectual property without disclosing its contents" (Haber & Stornetta 1991b, p. 109).

The largest safeguard is in the design of the system. As Sean Moss-Pultz, the founder of Bitmark, emphasizes, "Blockchain security is a dynamic, emergent property that comes from the competition to find the next block. Without this dynamic part, what is described is a list (chain of blocks) that must require a trusted authority to make the next block."[13]

The starting point of a blockchain is a "genesis block," that is, the block containing the first piece of information. The genesis block of the Bitcoin blockchain was a *Times* of London headline that Nakamoto posted on January 3, 2009, that reads, "The Times 03/Jan/2009 Chancellor on brink of second bailout for banks" (Burniske & Tatar 2018, p. 8). Other records are then added to this genesis block and time-stamped into an order. The records are often called "transactions" but could be the hashes of any pieces of information. If someone tried to change a record within a block, they would alter the hash of the block. Because the hash of one block appears at the start of the next block, if someone wanted to tamper with the blockchain, they would need to change one block, and then go back and change all of the affected blocks, before the next block was verified.[14] One can think of this feature as a kind of numeric chain-link fence, with each block connected to the one before and after it.

With the introduction of the cryptocurrency Bitcoin, people were now incentivized and rewarded for operating computer nodes that verified the blocks. That incentive not only created currency, but established effectively a participatory algorithm for verifying blocks. Computers that serve as nodes in the Bitcoin system are constantly solving mathematical puzzles to verify each block. More specifically, the computers compete with each other to find the "nonce," a puzzle solved by brute trial-and-error computer processing strength and of course luck.[15] The computer that finds the nonce first verifies that block and wins an award in Bitcoin. The amount of the award halves at regular intervals over time. In 2009, a miner

[13] Moss-Pultz, personal communication, October 2019.

[14] For example, if a blockchain were up to block thirty and one wanted to change block twenty, one would have to go in and change blocks twenty to thirty, before block thirty-one was established (Moss-Pultz, personal communication, October 2019).

[15] Nonces depend on random-number generation, itself a source of idiosyncratic risk in the blockchain ecosystem. See, for example, Bonneau, Clark, and Goldfelter, 2015.

completing a block received fifty bitcoins. In 2012, they received 25, and in 2016 that number was halved again to 12.5 bitcoins. There will only ever be 21 million bitcoins (BTC) in circulation, a supply that is expected to be fully tapped around 2040 (Hayes 2019; Burniske & Tatar 2018, p. 16).

Despite the cryptographic functions and linked blocks, these structures do have vulnerabilities. Advances in computing power to what is called "quantum computing" raise concerns over how differential computing power could affect blockchain governance. If one bad actor has this computing power and no one else does, the bad actor could theoretically find others' private keys and authorize transactions, but it is unlikely that computing power will advance so disproportionately. Blockchain observers also write of the "51 percent Attack" to describe the state in which the majority of a blockchain's nodes are corrupted (Hertig 2019).

In addition, the mining is theoretically done by many disconnected actors and thus is decentralized in the spirit of the blockchain. But in practice, mining is concentrated geographically and by organization (Aki 2018). Special servers with special chips are used for mining so that one has the advantage of the best available computing power. Because of economies of scale, it is more economical to operate a group of mining machines than to set up a single one. The operation of a larger group of servers also gives the advantage of smoothing the flows of irregular, probabilistic income over time. A mining pool or mining farm of twelve computers, or 1200 computers, would have smoother earnings than a single computer, incentivizing this centralization of mining.

Mining also consumes enormous computing power, owing to its reliance on "proof of work"—meaning computing effort used to find the nonce. Other systems being explored are based on "proof of stake," meaning proof of ownership in a system as opposed to proof of puzzle-solving force (Harper 2018; Burniske & Tatar 2018 p. 15). By some estimates, the computer power required by the Bitcoin network alone is equivalent to all the power consumed by Ireland (Why Bitcoin uses so much energy 2018). Many proponents of blockchain are working on reducing this environmental impact, and the original inventors of blockchain have spoken about the need to address these costs.[16] Perhaps computers finding the nonce could simultaneously be performing other labor in the process of mathematical puzzle-solving, in the same way that reCAPTCHA allows the human labor used to verifies that a computer user is a person and not a robot to double as labor toward digitizing books.[17] Or perhaps environmental impact can be addressed by the sustainability of the source of energy used to power the blockchain.

[16] W.S. Stornetta, personal communication, May 2019.

[17] Techcrunch contributor. (2007). reCaptcha: Using Captchas to Digitize Books," Techcrunch: "ReCaptcha's founders, Luis von Ahn and Ben Maurer estimate that about 60 million CAPTCHAs are solved every day. Assuming that each CAPTCHA takes 10 seconds to solve, it' this is over 160,000 human hours per day (that's about 19 years)."

Other factors in blockchain design include whether a company is built on the Bitcoin or Ethereum or another protocol and whether the blockchain is public or private/permissioned. Of the current blockchain companies in the arts, some are built on Bitcoin and some on Ethereum, some are built on public blockchains and some are built on private, permissioned blockchains. Blockchain start-ups in the arts manage questions of access, technological expertise, and privacy in varying ways. Their strategies are all threaded with larger questions of diversity, inclusion and equity both in general terms and in ways that are particular to the arts (Westermann, Schonfeld & Sweeney 2018) and to the legal and technological fields inclusive of blockchain and artificial intelligence (Johnson, Evans & King 2018; West, Whittaker & Crawford 2019).

Use Cases of Blockchain in the Arts

Blockchain has core use cases in the arts including provenance and authenticity registries (M. McConaghy, McMullen, Parry & T. McConaghy 2017), digital scarcity (O'Dwyer 2018) for new media and generative art (Bailey 2019; Dash 2014), fractional equity and shared upside structures, (Whitaker & Kräussl 2018; Whitaker 2018a; Lotti 2016), and new forms of copyright registry (Evans 2019; Waugh 2018; Savelyev 2018; Towse 2010; Whitaker 2019). Ethereum-based smart contracts and tokens also enable specific investment and intellectual property structures (McKinney, Landy &Wilka 2018; Gürkaynak, Yılmaz, Yeşilaltay, & Bengi 2018).

Provenance research is a time-consuming part of gallery preparation for art fairs and a differentiating factor in the business model of art fairs including The European Fine Art Fair (TEFAF), which has developed some of the strictest vetting standards in the world (Shaw 2018). Costs of vetting are embedded within the mark-up fee structures of galleries selling on commission (David, Huemer & Oosterlinck 2019). Provenance is also central to museum practice as institutions revisit their own collections. For example, following from 2001 resolutions by the American Alliance of Museums (AAM) on the "Unlawful Appropriation of Objects During the Nazi Era" (AAM 2001) and by the International Council of Museums (ICOM 2001) on "Spoliation of Jewish Cultural Property" (ICOM 2001), the Museum of Modern Art, New York, began a "Provenance Research Project" to study the 800 works in the MoMA collection that were made before 1946 and acquired after 1932 (MoMA n.d.).

Good provenance is foundational not only to price but to being able to sell the works at all. One can consider how blockchain would have hypothetically supported the return of artworks stolen during World War II. Blockchain would have arguably substantially changed the provability of theft or sale under duress of well known restitution cases such as Egon Schiele's *Portrait of Wally* (1912) (Carroll, 2012; O'Donnell, 2017 pp. 61–74) and Gustav Klimt's *Portrait of Adele Bloch-Bauer* (c. 1907) (O'Donnell, 2017 pp. 83–97).

While blockchain is not, of course, a magical technology that can undo abhorrent human behavior, going forward blockchain can powerfully counteract the lack of documentation and

the burden of proving ownership. These cases show the potential power of an immutable and decentralized record. If a blockchain database becomes a registry of title, meaning legal ownership, then the legal ownership of the work is inseparable from the blockchain provenance. Without transfer of the blockchain record, the artwork's title does not transfer. If market actors chose to transfer a work "off chain," the subsequent market would have to decide whether to recognize the title to sell the work.

Provenance travels closely with authenticity. Where provenance describes the chain of ownership, authentication proves the correct authorship. Authentication of art occurs through various methods, including personal expertise, scientific analysis, and certificate of authenticity. Leonardo da Vinci's *Salvator Mundi* exemplifies authentication by an expert. Had renowned Leonardo scholar Martin Kemp not concluded that the work was a real da Vinci, and had the work not, on that recommendation, been included in a 2011 exhibition of Leonardo's work at the National Gallery in London (Syson 2011), it is unlikely that the painting would have sold for $450.3 million at auction Christie's New York in November 2017. The authenticity has been subsequently contested (Kirkpatrick 2019).

Scientific analysis authenticates other works. James Martin, the forensic conservator and founder of Orion Analytical, exemplified this work as a key witness in the case brought by Dominico and Eleanor de Sole against Knoedler Gallery for selling a "Rothko" which turned out to be a fake (Cascone 2016). Authentication is also done by a certificate of authenticity, as in the work of conceptual artists Sol LeWitt and Felix Gonzalez-Torres. Without the certificate, one does not technically own the work (Lydiate 2012; Halperin 2018; Pereira 2015). In that case, the authentication is held by a contract.

Blockchain combines provenance and authentication, providing a chained record of ownership that is dependent on the validity of the starting point of the blockchain record. Diana Wierbicki and Amanda Rottermund (2019) highlight these issues of vetting for error and fraud in *Trusts & Estates,* writing:

> One of the biggest problems with using blockchain technology in the development of art registries, especially in situations like the Old Master painting example in which the artwork has previously changed hands a number of times, may be an unrealistic optimism on behalf of the technology companies that the information stored on a blockchain will be accurate and free from misinformation, mistakes, or even fraud.

Crucially, the blockchain records can function not only as a seal of approval but as a trusted library of source material. The blockchain record does not have to be determinative automatically but it can certify the information being vetted by human experts.

The blockchain companies that are active in provenance have generally tried to be trusted arbiters in different ways. For example, the company Verisart launched in 2015 to provide a trusted database for artworks. Headed by Robert Norton, the former CEO of Saatchi Art, Verisart allowed anyone to list an artwork (Butcher 2015). In June 2018, a man named

Terence Eden listed the *Mona Lisa* on the Verisart blockchain with himself as the artist and 1506 as the creation date (Eden 2018; Woo 2018).

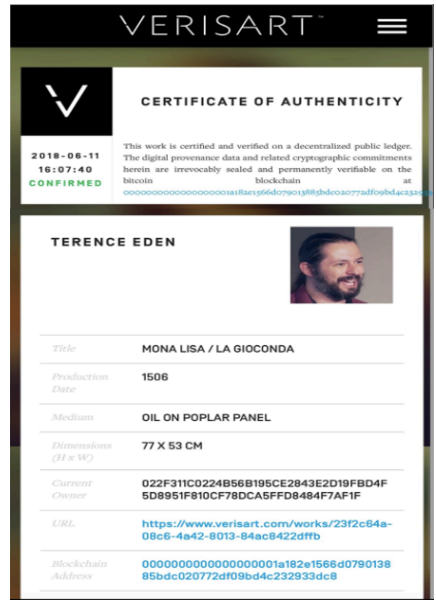

Figure 3 *Mona Lisa* by Terence Eden

Although Verisart has some advantage in being publicly accessible as a database, another company Artory has managed for this vulnerability of vetting the initial listing of an artwork on the blockchain. In fall 2018, Artory became the first company to list a major auction sale on the blockchain when it became the registrar of the Ebsworth Collection, sold at Christie's New York for $318 million on November 13, 2018. The November 13, 2018, sale included forty-two pieces of art and set numerous records (Kinsella 2018). Artory, built on the Ethereum blockchain, offered collectors essentially a certificate of authenticity encoded to the blockchain. Artory only lists works that have been vetted by a partner organization—for instance, an auction house or gallery—that would already be engaged in a high level of provenance research. Artory also took the business decision to make the registry double-blind—meaning Artory itself does not know the identity of the collectors; it only lists the works. The founder of Artory, Nanne Dekking, is also the Chairman of TEFAF (The European Fine Art Fair).

The other main company operating in this space is Codex Protocol which also partners with auction houses to vet the entry point of records onto the blockchain. Co-founded by Mark Lurie, Jessica Houlgrave, and John Forrest, Codex partners with the Liveauctioneers consortium of 5,000 regional auction houses. Codex Protocol uses a token they developed, BidDex, to store information posted by collectors, at the collector's discretion (Hanson 2018; Michalska 2016).

Verisart, Artory, and Codex all have the challenge of managing the "blockchain air gap," between the blockchain listing and the physical artwork (Schneider 2018). To link blockchain records to physical artworks, companies have explored everything from physical tagging to DNA analysis to the ways in which the physical surface of an artwork can be recognizably photographed in the manner of a fingerprint. This challenge has not yet been resolved. Some applications of blockchain for digital art avoid this problem in interesting ways.

Blockchain has been used to deal with a central challenge to selling digital art: how to create a limited edition of a file that can be easily reproduced (Bookoiit, Cimbol, Collins & Newman 2019). In 2014, the artist Kevin McCoy and technologist Anil Dash collaborated in Rhizome's "Seven on Seven" event in which artists are paired with technologists to create

projects (Connor 2014). McCoy and Dash created the prototype of Monegraph—short for "monetized graphics"—a venture that allows artists to record digital works on the blockchain. Built on a Bitcoin blockchain, Monegraph uses the same principles as the Robert Projansky and Seth Siegelaub Artist's Contract (van Haaften-Schick 2016), to allow creators to specify sales conditions and sharing rights for their work (Zeilinger 2018). As Dash wrote, "in a realm where novelty, rarity and exclusivity underpin so much of the 'real or perceived' value of a work, copy and paste goes from being an act of creation to an act of destruction" (Zeilinger 2014, p. 17; Dash 2014).

Alongside the possibility of digital scarcity through editioned works, the blockchain also allows fractional or shared ownership of individual artworks. From a collector's point of view, the possibility of fractionalizing a single artwork allows investors to diversify their art holdings in ways that limited to the secondary art market and generally do not encompass the livelihood of artists. For example, the company Maecenas purchased an Andy Warhol artwork, *14 Electric Chairs*, and divided it up into shares sold as ART tokens. The company sold 31.5 percent of the $14 million artwork (Adam 2018). By purchasing tokens through companies such as Maecenas and Masterworks, collectors can have a small investment exposure to an artwork.

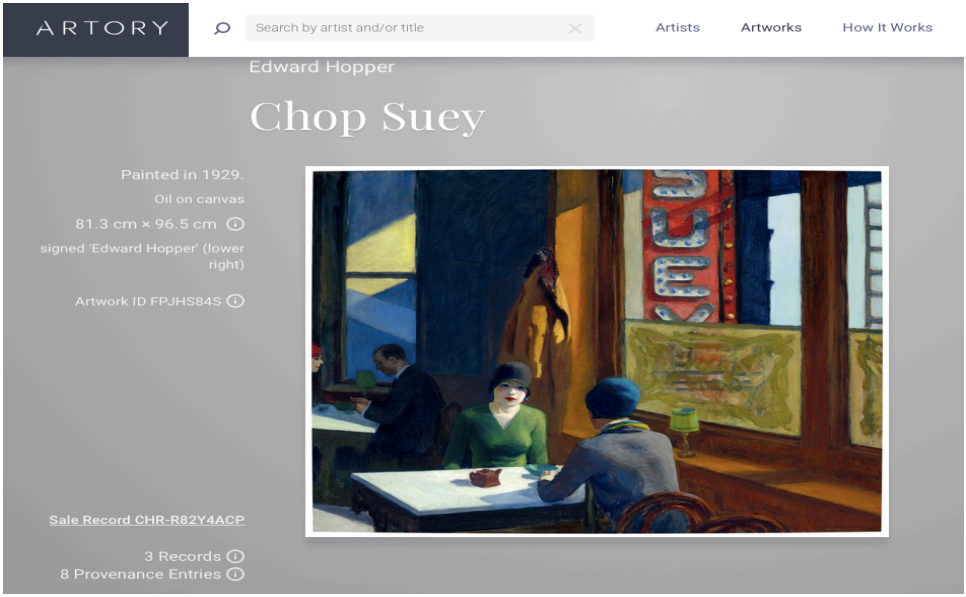

Figure 4 Artory page, *Chop Suey* by Edward Hopper

From an artist's point of view, selling tokens or retaining equity can replicate the effect of regulated resale royalties (Whitaker 2018). Whitaker and Kräussl (2018) have analyzed empircally what would have happened if artists had retained equity in works sold in the

primary market in the 1960s to 1990s and found that many artists would have outperformed stock markets substantially. Blockchain could make these speculative systems of fractional equity possible. Such a registry of fractional shares could also enable a secondary market that allowed collectors to diversify, while still rooting the art market with artists. The vetted listing problem—addressed by provenance companies such as Artory in partnering with auction houses—would be addressed in this case by having blockchain records originate with artists' studios.

In the case of the company Dada, blockchain represents shared ownership of collaborative work. Dada is a drawing software app located on blockchain (Mustatea 2018). Artists on Dada make artworks that build on each others' drawings. At the time of writing, Dada has not yet connected its business model directly to the collaborative creation but chosen to print editions from time to time. Still, the company represents a collaborative and artist-centric approach that may remain a speculative art project or represent a new form of interwoven shared value creation and cooperative ownership.

In addition to companies such as Maecenas that fractionalize existing artworks, a new breed of digital collectible has challenged both the investment nature of and the definition of art. In November 2017, Dapper Labs released the Cryptokitties, which are unique yet related cartoon images of cats that can be collected, traded, and bred (Evans 2019). Like Verisart and Artory records, Cryptokitties are based on the ERC-721 non-fungible token. More uniquely, the Cryptokitties are digital collectibles that function, arguably, as something like a Warhol panel of flowers or a Damien Hirst dot painting—related yet technically separable objects. A Cryptokitty does not currently have the same institutional and critical support of Warhol or Hirst. Writing in *Art in America,* Artie Vierkant, described Cryptokitties as "a sort of virtual Beanie Baby" after the collectible stuffed animal rage of the 1990s (Vierkant 2018). At their peak, a Cryptokitty sold for $140,000 (Vierkant 2018). Vierkant also described the "almost satirically dystopian-sounding Verisart and Codex Protocol" and went on to say that "[su]ch publications [as the Codex white paper] express a transactional view of art" (Vierkant 2018, pp. 27–28). Thus, these digital collectibles offer interesting models for art investment but are not yet viewed as art by some critics.

These blockchain applications may offer new ways of clearing copyright and of reflecting the collaborative nature of creativity and the increasingly complex nature of fair use for art (Adler 2016; Towse 2010). These systems are still speculative; at the same time, they stand to reorganize certain systems of investment and rights management radically. In the same way that fractional equity can create shared ownership structures for art, blockchain can support clearinghouses for royalties for artists who wish to use others' images without risking fair-use litigation (Whitaker 2019).

These applications in securitization and contract draw on early artists' projects including Sarah Meyohas' creation of the currency Bitchcoin which was tied to a set surface area of her photographs (Ghorashi 2015), as well as recent work by Kevin and Jennifer McCoy. Entitled *Public Key/Private Key,* the McCoys's work is a 16-millimeter film that is registered on the

blockchain and donated to the Whitney on behalf of the public. Members of the public could apply by short essay to be holders of one of the fifty shares and therefore donors of record (K. McCoy & J. McCoy 2019). This project raises speculative questions of tax implication and perhaps conversation among the donors of record to coordinate future experimental action.

Additionally, artist Eve Sussman founded the cryptocurrency platform Snark.art (Ngo 2018). In 2019, the design collective Larva Labs, founded by Matt Hall and John Watkinson, which had previously developed Cryptopunks digital collectibles, launched Autoglyphs, small collectible generative artworks that took as their inspiration the conceptual work of the artist Sol LeWitt (Bailey 2019) and the ways in which conceptual art particularly requires a certificate of authenticity (Pereira 2015). Hall and Watkinson designed the Autoglyphs to be not images but instructions that would create those images so that the file size was small enough to fit on the blockchain directly. These artists' experiments converge with for-profit ventures in digital collectibles such as Cryptokitties (Vierkant 2018) and Rare Pepes (Roeder 2018), and investment structures that allow collectors to purchase generative art in secondary markets such as OpenSea or to purchase shares of art alongside shares of sneakers on platforms such as Otis.

In addition to seismic shifts to the art market, blockchain technology may also allow the arts to inform other kinds of investment. The non-fungible token allows investment in collectibles in ways that are, in fact, like art investment. If the idea of a Cryptokitty as art gains wider acceptance, museums and other public-facing arts entities may contend with populist definitions of artistic value—the proverbial question of the Museum of Modern Art vs. the Museum of Ice Cream—even more strongly than they do already. At the same time, these other areas of cultural asset may, for better or worse, learn from the arts as they create markets and financial structures.

Managerial Implications of Blockchain for Arts Entrepreneurship

This paper highlights three areas of greatest impact of blockchain on arts entrepreneurship. First, blockchain blurs the for-profit and nonprofit distinction in arts organizations by replicating nonprofit and public-domain functions within private start-ups. The inclusion of these governmental and nonprofit functions within start-ups reflects Jennifer Woolley's argument (2014) that new technologies often create business opportunities for which infrastructure does not yet exist and that new firms, therefore, need to build this infrastructure themselves in order to operate in the field. These functions include provenance research (Butcher 2015; Hanson 2018; Moskov 2018) and title registry. In other industries such as real estate, this fair title function is performed by a governmental land registry (Alt, Moss-Pultz, Whitaker & Chen 2016; de Soto 2003). Blockchain companies such as Artory, Verisart, and Codex Protocol could become trusted registries of the ownership of art.

In addition, these questions of infrastructure are more complicated because of blockchain's fundamentally decentralized nature. Existing records-keeping infrastructure is

operated by centralized platforms—e.g., governments, museums, rights management agencies—that blockchain, by design, intends to replace with the authority of the algorithm and the consensus of the crowd. Furthermore, this title registry function is so important that the start-ups appear to be vertically integrated from registry to sales, leading to business structures that follow vertical market strategy (Stuckey & White 1993).

It is important to the construction of the field that we are mindful of private companies taking on what have, to date, been public registrarial activities. This vigilance is not because it is inherently bad for private companies to keep these records, but because we need to design governance structures that protect this information and allow various forms of access to it. Wyszomirski and Cherbo (2001) have written on associational infrastructure in the arts. Blockchain's decentralized structure presents unique challenges and opportunities to create consortia. Cutolo, Kenney, and Zysman (2019) have written of "platform dependent entrepreneurs" to describe start-ups that depend on larger technology platforms such as Facebook or Google. Here, blockchain can pixelate platform businesses, making them collectively owned; instead of Facebook owning one's data, one can assert property rights to their own data rather than be a product sold by a company to advertisers.[18] On the other hand, new platforms and standards are being built by private companies, raising the possibility of a future in which one company prevails as a registry of authenticity. Following from Brea Heidelberg's work (2019), these questions of platform dependency will create significant opportunities for policy entrepreneurship.

After infrastructure needs and the blurring of for-profit and nonprofit structures, the second greatest area of potential impact of blockchain in arts entrepreneurship is on novel funding structures for organizations and for governments. As Diane Ragsdale (2017) writes of Margo Jones's research (1951), theater organizations can theoretically be structured as stock companies. Blockchain allows for a theater to create an investment structure by which patrons buy tokens and own part of the theater instead of only buying tickets or donating philanthropically. These models shift from the economics of consumption—buying tickets—to investment models of ownership—buying shares. These investment models can apply to nonprofit arts organizations entrepreneurially as well (Preece 2011; Benz 2009).

These models can also apply to governments. In a 2012 article in the *Journal of Arts Management, Law and Society,* Michael Wilkerson proposes various models of "using the arts to pay for the arts." Wilkerson's endowment and tax-revenue approaches could be realized using blockchain. In the proposed "real endowment approach," an endowment of $6 billion, at a 5 percent spending rate, would yield roughly the $150 million annual budget of the NEA.

[18] The company Bitmark (www.bitmark.com) manages a plug-in on IFFT.com that allows anyone to automatically "bitmark" social media posts so that one asserts property rights before the picture or text is posted to Facebook or Instagram. In practice, such a speculative project would probably need to be litigated, but the shift in property rights is, from first principle, enabled by blockchain and thus part of the structural potential of the technology (IFFT, n.d.).

Rather than stemming from government appropriation, the endowment could be structured as a token offered to members of the public. One can also imagine a hybrid in which the endowment is partially funded over time through tax revenue connected to, for instance, ticket sales, hotel bookings, or other measures of arts-related revenue. Although the politics of these funding proposals would be contestable, structurally blockchain enables a variety of new models for community support of the arts. These possibilities are particularly timely given activated conversations around wealth concentration (Piketty 2014; Fraser 2018), nonprofit board representation, and museum decolonization (Black, Finlayson, & Haslett 2019).[19]

The third key impact of blockchain on arts entrepreneurship is in the new structures of financialization for art. Although artworks, of course, hold many kinds of social and cultural values that are not reducible to the financial (see, for example, Klamer 1997; Gerber 2017), certain developments in blockchain hold the potential to radically change the ways in which artworks circulate in markets. For instance, a non-fungible token of, for instance, a Cryptokitty, is a unique image but also a type, the same way that a single Andy Warhol painting is a unique but relatable part of the overall body of Andy Warhol's work. Especially the Ethereum-based non-fungible tokens (ERC-721s) function financially like artworks. Because some of these start-ups, including Portion, Otis, and others, allow investment in art but also in sneakers or other collectibles, these companies function as change agents for the way we conceptualize art as an asset. Jennifer Lena's work on how objects are legitimized as art may guide some of our understanding of how to consider sneakers alongside digital collectibles and fine art (Lena 2019).

As companies build platforms for investment in art and in cultural assets, they stand to change two fundamental aspects of the arts: First, they can change the art market, including the complex economic and cultural signifiers of art investment (Bourdieu 1979; Velthuis 2011), and also link art investment more closely to collecting of luxury goods. While these shared investment structures can solve for problems of diversification and liquidity in art investing (Horowitz 2014), they can also potentially destabilize and burst bubbles in the art market (Kräussl, Lehnert, & Martelin 2016). Second, these forms of fractional art investment can also reorient art markets to artists if the equity shares originate with the artists' studio. This point of origination brings the art market in line with operating companies by focusing

[19] Most recently, a number of museums have stopped accepting donations from the Sackler family based on ties to the opioid crisis. Warren Kanders, whose company manufactures tear gas canisters among other products, was forced to resign from the board of the Whitney Museum of American Art. Although outside the scope of this paper to approach this topic in depth, one can consult the work of Decolonizing the Museum, W.A.G.E., and other activist efforts, especially the essay "The Tear Gas Biennial" by Hannah Black, Ciarán Finlayson, and Tobi Haslett in *Artforum* (2019) on Mr. Kanders. This essay arguably tipped the balance of many other forms of protest leading to several artists asking to withdraw their work from the Whitney Biennial before Mr. Kanders stepped down from the board. The artists subsequently reinstated their work in the exhibition.

on the studio as a producer (Whitaker 2018). That idea could be critiqued as neoliberal or explored as a dynamic alternative to previous attempts at an Artist Pension Trust or other format for shared investment among artists.

In addition to these conceptual pathways, blockchain faces numerous more practical and tangible challenges, ranging from the challenges of physical artworks to the risks of governmental regulation. Regarding the physicality of artworks, there is not yet a standard way of relating a blockchain record to a physical art object. Very few artworks—Autoglyphs (Bailey 2019) being an exception—exist on the blockchain itself, and Autoglyphs are there as an intentional speculative act of conceptual practice toward blockchain itself. With regard to regulatory risk, the US government has been metabolizing the ways in which cryptocurrencies fit into existing systems of taxation and regulation. Both federal and state systems in the United States have been under substantial development and uncertainty, with the federal government periodically ruling on specific company cases. State law is rapidly evolving, and Wyoming currently leads states in the development of cryptocurrency law, akin to the way that Delaware is the state with highly developed corporate law. These areas are evolving so rapidly that some of the most reliable sources of information are experts who post the Securities and Exchange Commission (SEC) determinations and the various legislative updates on Twitter.[20]

Toward Questions of Governance and Pedagogy

In the most optimistic outcomes of blockchain, the technology democratizes access to art and energizes conversations about the role of art in society. The arts may also contribute important financial innovations for broader investments in creative work and labor compensation. In the pessimistic view, the technology is subsumed by platform companies such as Facebook and existing central authorities such as banks and then regulated into a re-centralized version of itself. Its wings are clipped. Just as pessimistically, the idealistic and lucid ideas of blockchain fall prey to the vagaries of forgotten private keys and the near-universal need, for most of the population, to rely on information technology infrastructures designed by other people.

Given these areas of impact on the field, blockchain raises important questions of governance. David Yermack has written (2017a, 2017b) on corporate governance both for blockchain and for museum boards of trustees. Especially because blockchain is a

[20] For SEC rulings, see Andrew Hinkes, attorney and NYU law professor (@propelforward). For Wyoming blockchain news and other developments, Caitlin Long, the former investment banker, Wyoming native, and founder of the Wyoming Blockchain Task Force has been a pioneer. See her blog, https://caitlin-long.com/about/, and Twitter feed: https://twitter.com/caitlinlong_/. While it may be unusual in academic writing to suggest social media, the function of these sources of that of experts in real time, before their work is digested by academic papers and even journalistic sources, and without the search cost of monitoring SEC notices and legislative actions.

decentralized technology, the community governance mechanisms of blockchain are critical to the health of the system. These governance mechanisms determine who has a voice or vote in changes to the code or solutions to problems or errors.

For arts entrepreneurship, in an already interdisciplinary field, to what extent do the potential ramifications of blockchain technology require arts entrepreneurs, scholars, and managers to understand programming or securities law? In a speculative world, blockchain is as potentially transformative as democracy. Yet democracy depends on both popular participation and some forms of judgment by experts. The arts have always had this tension between popular audiences and rarified tastemakers (Whitaker 2009), and answering these questions for blockchain requires further attention to the history of the arts in expanding spheres of taste and participation (Lena 2019).

Blockchain creates a call to participation that requires us to confront our vulnerability and also our mortality—the reality that if we have not done so already, we will not reverse engineer our lives to have been undergraduate math and computer science majors with joint J.D/M.B.A. training. At the same time, there are matters of degree. We may not all ever learn to pass a bill in the U.S. House of Representatives, but we may learn to register to vote and try to maintain a level of knowledge of important legislative issues. Whether blockchain takes decades to be widely adopted or is grounded on take-off, the potential of the technology begins to call anyone's bluff on maintaining disinterest. The structural machinations of change are abstract, yet blockchain's origin is specific—to the hard efforts in sheer thought of a physicist turned math teacher and a cryptographer who once worked professionally as a juggler. In spite of blockchain's technological abstraction or media frenzy, Haber and Stornetta's story offers a human entry point and story of continuing inquiry.

The robustness of Haber and Stornetta's (1991b) original research question—how will we know what was true about the past—transcends money and presents itself as a renewing art project of our time. Their question dovetails with some of the highest values of the arts as a field—worthy novelty, authenticity, and public participation. As a field, our responsibilities toward blockchain are those of scholars and practitioners but also of art audiences toward new and unfamiliar work. As Sir Nicholas Serota, former director of Tate, once implored the audience of the Dimbleby lecture (2003), "Essentially this…is a plea for patience…that your skepticism will gradually diminish and your fear will turn to love…All art was modern once."

References

American Alliance of Museums (2001). Unlawful appropriation of objects during the Nazi era. Retrieved from https://www.aam-us.org/programs/ethics-standards-and-professional-practices/unlawful-appropriation-of-objects-during-the-nazi-era/

Adam, G. (2018, October 4). Interested in a square inch of a Warhol? Fractional ownership hits the art market. *The Art Newspaper*. Retrieved from https://www.theartnewspaper.com/comment/interested-in-a-square-inch-of-a-warhol

Adler, A. (2016). Fair use and the future of art. *New York University Law Review*, *91*(3), 559–626.

Aki, J. (2018, October 10). Report links 74% of Bitcoin mining to China, sees threat to network. *Bitcoin Magazine*. Retrieved from https://bitcoinmagazine.com/articles/report-links-74-bitcoin-mining-china-sees-threat-network/

Alt, C., Moss-Pultz, S., Whitaker, A., and Chen, T. (2016). Defining property in the digital environment. *DCG Insights Report*. Retrieved from https://insights.dcg.co/defining-property-in-the-digital-environment-4ec3b9b79403

Bailey, J. (2019, April 8). Autoglyphs, generative art born on the blockchain. *Artnome*. Retrieved from https://www.artnome.com/news/2019/4/08/autoglyphs-generative-art-born-on-the-blockchain

Bailey, J. (2018, July 21). Art world, meet blockchain. *Artnome*. Retrieved from https://www.artnome.com/news/2018/7/21/art-world-meet-blockchain

Bayer, D., Haber, S., and Stornetta, W.S. (1993). Improving the efficiency and reliability of digital time-stamping. In R. Capocelli, A. De Santis & Ugo Vaccaro (Eds.), Sequences II: Methods in communication, security and computer science (pp. 329–334). New York: Springer-Verlag.

Becker, H. S. (1982). Art worlds. Berkeley: University of California Press.

Beckman, G. (2007). Adventuring arts entrepreneurship curricula in higher education: An examination of Present Efforts, Obstacles, and Best Practices. *The Journal of Arts Management, Law, and Society, 37*(2), 87-112.

Beckman, G. & Essig, L. (2012). Arts entrepreneurship: A conversation. *Artivate: A Journal of Entrepreneurship in the Arts 1*(1), 1-8.

Benz, M. (2009). Entrepreneurship as a nonprofit-seeking activity. *International Entrepreneurship and Management Journal, 5*(1), 23–44.

Berglund, H. (2007). Researching entrepreneurship as lived experience. In H. Neergaard and J.P. Ulhøi (Eds.), Handbook of qualitative research methods in entrepreneurship (pp. 75-93). Cheltenham, UK: Edward Elgar.

Buterin, V. (2013). Ethereum white paper: A next generation smart contract and decentralized application platform. Retrieved from http://blockchainlab.com/pdf/Ethereum_white_paper_next_generation_smart_contract_and_decentralized_application_platform-vitalik-buterin.pdf

Black, F. & Scholes, M. (1973). The pricing of options and corporate liabilities. *The Journal of Political Economy, 81*(3), 637–654.

Black, H. Finlayson, C. and Haslett, T. (2019, July 17). The tear gas biennial. *Artforum.* Retrieved from https://www.artforum.com/slant/a-statement-from-hannah-black-ciaran-finlayson-and-tobi-haslett-on-warren-kanders-and-the-2019-whitney-biennial-80328

Bookoiit, J. Cimbol, L. Collins, S.L., & Newman, D.L. (2019). A brief introduction to digital art & blockchain. *Cardozo Arts & Entertainment Law Journal, 37*(3), 553-559.

Bonin-Rodriguez, P. (2014). *Performing policy: How contemporary politics and cultural programs redefined U.S. artists for the twenty-first century*. London: Palgrave MacMillan.

Bonin-Rodriguez, P. (2015). Putting a term to good use. *Artivate: A Journal of Entrepreneurship in the Arts, 4*(1), 5.

Bonneau, J., Clark, J., & Goldfelder, S. (2015). On bitcoin as a public randomness source. *IACR Cryptography ePrint Archive*. Retrieved from https://eprint.iacr.org/2015/1015.pdf

Bourdieu, P. (1979). *Distinction: A social critique of the judgment of taste*. London: Routledge.

Brekke, J.K. (2019). The white paper guide. In J.K. Brekke & B. Vickers (Eds.), The white paper by Satoshi Nakamoto (pp. 19–63). London: Ignota.

Brown, R. (2007). Promoting Entrepreneurship in Arts Education. In H.C., Entrepreneurship in the creative industries: An international perspective (pp.126-142). Cheltenham, UK: Edward Elgar.

Brunton, F. (2019). *Digital cash: The unknown history of anarchists, utopians, and technologists who created cryptocurrency*. Princeton: Princeton University Press.

Burniske, C. & Tatar, J. (2018). *Cryptoassets: The innovative investor's guide to Bitcoin and beyond.* New York: McGraw-Hill.

Butcher, M. (2015, July 7). Verisart plans to use the blockchain to verify the authenticity of artworks. *Techcrunch*. Retrieved from https://techcrunch.com/2015/07/07/verisart-plans-to-use-the-blockchain-to-verify-the-authencity-of-artworks/

Buterin, V., & Obrist, H.U. (2018). Vitalik Buterin interview with Hans Ulrich Obrist. *Tank Magazine*, 74. Retrieved from https://tankmagazine.com/issue-74.

Carroll, M. (2012, May 23). The painting that launched a thousand lawsuits. *Hyperallergic*. Retrieved from https://hyperallergic.com/51575/andrew-shea-portrait-of-wally/

Cascone, S. (2016, December 5). Expert forgery-spotter James Martin to head Sotheby's Scientific Research Department, *artnet News*. Retrieved from https://news.artnet.com/market/james-martin-sothebys-scientific-research-771905.

Catlow, R. Garrett, M., Jones, N., & Skinner, S. Eds. (2017). *Artists re:thinking the blockchain.* Liverpool, UK: Torque Editions, Furtherfield & Liverpool University Press.

Chang, W. J., & Wyszomirski, M. J. (2015). What is arts entrepreneurship? Tracking the development of its definition in scholarly journals. *Artivate: A Journal of Entrepreneurship in the Arts, 4*(2), 11–31.

Cheng, I., Obrist, H.U., Vickers, B. and Whitaker, A. (2018, December 4). The Art of blockchains: A look forward [Video recording]. Retrieved from https://www.youtube.com/watch?v=x6DB05-sa_c

Chohan, U.W. (2017). The leisures of blockchains: Exploratory analysis. *SSRN.* Retrieved from https://ssrn.com/abstract=3084411

Connor, M. (2014, May 5). Seven big ideas from Seven on Seven 2014. *Rhizome* [Web log post]. Retrieved from http://rhizome.org/editorial/2014/may/05/seven-ideas-seven-seven-2014/

Cutolo, D., Kenney, M. & Zysman, J. (2019). Platform-dependent entrepreneurs as private regulators in the platform economy. *SSRN.* Retrived from https://ssrn.com/abstract=3431467

Dash, A. (2014, May 9). A Bitcoin for digital art. *Medium* [Web log post]. Retrieved from https://medium.com/message/a-bitcoin-for-digital-art-8c7db719e495

David, G., Huemer, C. & Oosterlinck, K. (2019). Art dealers' strategy: The case of Goupil, Boussod & Valadon from 1860 to 1914. *London: Centre for Economic Policy Research.* Retrieved from https://cepr.org/active/publications/discussion_papers/dp.php?dpno=13941

Davis, J. (2011, October 3). The crypto-currency. *The New Yorker.* Retrieved from https://www.newyorker.com/magazine/2011/10/10/the-crypto-currency

De Soto, H. (2000). *The mystery of capital: Why capitalism triumphs in the West and fails everywhere else.* New York: Basic Books.

Eden, T. (2018, June 12). How I became Leonardo da Vinci of the blockchain [Web log post]. Retrieved from https://shkspr.mobi/blog/2018/06/how-i-became-leonardo-da-vinci-on-the-blockchain/

ERC-721. (n.d.). What is ERC-721? Retrieved from http://erc721.org

Essig, L. (2015a). Means and ends: A theory framework for understanding entrepreneurship in the US arts and culture sector. *Journal Of Arts Management, Law & Society, 45*(4), 227.

Essig, L. (2012). Frameworks for educating the artist of the future: Teaching habits of
mind for arts entrepreneurship. *Artivate: A Journal of Entrepreneurship in the Arts, 1*(2), 65–77.

Essig, L. (2015b). The ouroboros of arts entrepreneurship. *Artivate: A Journal of Entrepreneurship in the Arts, 4*(1), 5–7.

Essig, L. (2017). Editor's introduction to the Winter 2017 issue. *Artivate: A Journal of Entrepreneurship in the Arts, 6*(1), 1-2.

Essig, L. and Guevara, J. (2017). A landscape of arts entrepreneurship in US higher education. Alliance for the Arts in Research Universities Tempe AZ: Linda Essig and Joanna Guevara.

Evans, T.J. (2019). Cryptokitties, cryptography, and copyright. *American Intellectual Property Law Association Quarterly Journal, 47*(2) [in publication].

Fincham, D. (2019). Assessing the viability of blockchain to impact the antiquities trade. *Cardozo Arts & Entertainment Law Journal, 37*(3), 607–628.

Fraser, A. (2018). Artist writes no. 2: Towards a reflexive resistance. *X-Tra Contemporary Art Quarterly, 20*(1). Retrieved from https://www.x-traonline.org/article/artist-writes-no-2-toward-a-reflexive-resistance

Gartner, W.B. (1985). A conceptual framework for describing the phenomenon of new venture creation. *Academy of Management Review, 10*(4), 696–706.

Gerber, A. (2017). *The work of art: Value in creative careers.* Stanford, CA: Stanford University Press.

Ghorashi, H. (2018, February 18). A new cryptocurrency enters the art market. *ArtNews.* Retrieved from http://www.artnews.com/2015/02/18/a-new-cryptocurrency-enters-the-art-market-bitchcoin/

Goldenfein, J. & Hunter, D. (2017). Blockchains, orphan works, and the public domain. *Columbia Journal of Law & the Arts, 41*(1), 1–43.

Golumbia, D. (2014). *Bitcoin: The cryptopolitics of cryptocurrencies.* Cambridge, MA: Harvard University Press.

Gürkaynak, G., Yılmaz, I., Yeşilaltay, B. & Bengi, B. (2018). Intellectual property law and practice in the blockchain realm. *Computer Law & Security Review, 34*(4), 847–862.

Haber, S. & Stornetta, W.S. (1991a). How to time-stamp a digital document. In A. Menezes & S.A. Vanstone (Eds.), Proceedings of the 10th annual International Cryptography Conference on Advances in Cryptography (pp. 437–455). Berlin: Springer-Verlag.

Haber, S. & Stornetta, W.S. (1991b). How to time-stamp a digital document. *Journal of Cryptology, 3*(2), 99–111.

Haber, S. & Stornetta, W.S. (1992). Method for secure time-stamping of digital documents. US Patent 5,136,647.

Haber, S. & Stornetta, W.S. (1997). Secure names for bit-strings. In Proceedings of the 4th ACM Conference on Computer and Communications Security (pp. 28–35). New York: ACM. Retrieved from https://dl.acm.org/citation.cfm?id=266430

Halperin, J. (2018, January 18). One Texas woman's paradoxical and controversial quest to prove she rediscovered a major work of conceptual art. *arnet News.* Retrieved from https://news.artnet.com/art-world/sol-lewitt-drawing-menil-texas-1201514

Hanson, S.P. (2018, January 30). New art registry will use blockchain technology. *The Art Newspaper 298.* Retrieved from https://www.theartnewspaper.com/news/new-art-registry-will-use-blockchain-technology

Harper, C. (2018, January 24). Making sense of proof of work vs. proof of stake. *CoinCentral.* Retrieved from https://coincentral.com/making-sense-of-proof-of-work-vs-proof-of-stake/

Harper, D.A. (2003). *Foundations of entrepreneurship and economic development.* London: Routledge.

Hayes, A. (2019, May 14). How Does Bitcoin Mining Work? *Investopedia*. Retrieved from https://www.investopedia.com/tech/how-does-bitcoin-mining-work/

Heidelberg, B. (2019). Learning from negative space: Categorizing success in arts policy entrepreneurship. *Artivate: A Journal of Entrepreneurship in the Arts, 8*(1), 23–44.

Hertig, A. (2019, May 24). Bitcoin Cash miners undo attacker's transactions with 51% attack. *CoinDesk*. Retrieved from https://www.coindesk.com/bitcoin-cash-miners-undo-attackers-transactions-with-51-attack

Horowitz, N. (2014). *Art of the deal: Contemporary art in a global financial market* (2nd ed.). Princeton, NJ: Princeton University Press.

Howell, S. Niessner, M. & Yermack, D. (2018). Initial coin offerings: Financing growth with cryptocurrency token sales. *European Corporate Governance Institute (ECGI) Finance Working Paper No. 564/2018.* Retrieved http://dx.doi.org/10.2139/ssrn.3201259

ICOM. (2001). Resolution no. 8: Spoliation of Jewish cultural property. Retrieved from http://archives.icom.museum/spoliation.html#resolution

IFFT. (n.d.). How to Bitmark your digital life—and why. Retrieved from https://ifttt.com/discover/how-to-bitmark-your-digital-life-and-why

Johnson, J.S., Evans, T.M. & King, Y.M. (2018). Diversifying intellectual property law: Why women of color remain "Invisible" and how to provide more seats at the table. *Landslide, 10* (4). Retrieved from https://www.americanbar.org/groups/intellectual_property_law/publications/landslide/2017-18/march-april/diversifying-intellectual-property-law/

Jones, M. (1951). *Theatre-in-the-round.* Westport, CT: Greenwood Press.

Kalosh, A. (2018, May 4). Cruise industry mourns visionary Barney Ebsworth. *Seatrade Cruise News*. Retrieved from http://www.seatrade-cruise.com/news/news-headlines/cruise-industry-mourns-visionary-barney-ebsworth.html

Kinsella, E. (2018, November 14). New auction records for Hopper and de Kooning lead Christie's booming $318 million Ebsworth sale. *artnet News*. Retrieved from https://news.artnet.com/market/edward-hopper-barney-ebsworth-sale-christies-1395328

Kirkpatrick, D.D. (2019, March 30). A Leonardo made a $450 million splash. Now there's no sign of it. *New York Times.* Retrieved from https://www.nytimes.com/2019/03/30/arts/design/salvator-mundi-louvre-abu-dhabi.html

Kirzner, I.M. (1978). *Competition and entrepreneurship.* Chicago, IL: University of Chicago Press.

Kirzner, I.M. (1984). The entrepreneurial process. In C.A. Kent (Ed.), The environment for entrepreneurship (pp. 41-58). Lexington, MA: Lexington Books.

Klamer, A. (1997). The value of culture. In A.J. Klamer (Ed.), The value of culture: On the relationship between economics and arts (pp. 13-28). Amsterdam: Amsterdam University Press.

Kolb, B. M. (2015). *Entrepreneurship for the creative and cultural industries.* New York: Routledge.

Kräussl, R., Lehnert, T. & Martelin, N. (2016). Is there a bubble in the art market? *Journal of Empirical Finance, 35*(1), 99–109.

Lena, J.C. (2019). *Entitled: Discriminating tastes and the expansion of the arts.* Princeton, NJ: Princeton University Press.

Lessig, L. (1999). *Code and other laws of cyberspace.* New York: Basic Books.

Lindemann, D.J., Tepper, S.J., Gaskill, S., Jones, S.J., Kuh, G.D., Lambert, A.D., Lena, J., Miller, A. L., Park, K., Rudolph, E. B., & Vanderwerp, L (2012). *Painting with broader strokes: Reassessing the value of an arts education (SNAAP Special Report No. 1).* Bloomington, IN: Indiana University and Vanderbilt University, Strategic National Arts Alumni Project.

Lotti, L. (2016). Contemporary art, capitalization and the blockchain: On the autonomy and automation of art's value. *Finance and Society, 2(*2), 96–110.

Lydiate, H. (2012). Authenticating Sol Lewitt. *Art Monthly 358*.

MacKay, R.B. & Costanzo, L.A. (2009). Introduction. In R.B. MacKay & L.A. Costanzo (Eds.), Handbook of Research on Strategy and Foresight (pp. 1-12). Cheltenham, UK: Edward Elgar.

Markowitz, H. (1952). Portfolio selection. *Journal of Finance, 7*(1), 77–92.

McConaghy, M., McMullen, G., Parry, G. & McConaghy, T. (2017). Visibility and digital art: Blockchain as an ownership layer on the Internet. *Strategic Change, 26*(5), 461–470.

McKinney, S.A., Landy, R. & Wilka, R. (2018). Smart contracts, blockchain, and the next frontier of transactional law. *Washington Journal of Law, Technology & Arts, 13*(3), 313–347.

Michalska, J. (2016, September 1). Blockchain: how the revolutionary technology could change the art world. *The Art Newspaper 282*. Retrieved from https://www.theartnewspaper.com/analysis/blockchain-how-the-revolutionary-technology-behind-bitcoin-could-change-the-art-market

MoMA Provenance Research Project. (n.d.). Retrieved from https://www.moma.org/collection/provenance

Moskowitz, T. (2019). The illicit antiquities trade as a funding source for terrorism: Is blockchain the solution? *Cardozo Arts & Entertainment Law Review, 37*(1), 193–227.

Moskov, A. (2018, April 26). Codex Protocol's Jess Houlgrave on the blockchain art world and crypto entrepreneurship. *CoinCentral*. Retrieved from

https://coincentral.com/interview-jess-houlgrave-codex-protocol/
Mustatea, K. (2018, July 15). Can blockchain eliminate the myth of the starving artist? *Forbes*. Retrieved from https://www.forbes.com/sites/katmustatea/2018/07/15/can-blockchain-eliminate-the-myth-of-the-starving-artist/#680e08f96769
Nakamoto, S. (2009). Bitcoin: A peer-to-peer electronic cash system. Retrieved from https://bitcoin.org/bitcoin.pdf.
Narayanan, A., Bonneau, J., Felten, E., Miller, A. & Goldfeder, S. (2016). *Bitcoin and cryptocurrency technologies: A comprehensive introduction.* Princeton, NJ: Princeton University Press.
Ngo, D. (2018, November 7). Snark.art brings blockchain to visual art with new collaboration with Eve Sussman. *CoinJournal*. Retrieved from https://coinjournal.net/snark-art-brings-blockchain-to-visual-art-with-new-collaboration-with-eve-sussman/
O'Donnell, N. (2017). *A tragic fate: Law and ethics in the battle over Nazi-looted art.* Chicago, IL: American Bar Association.
O'Dwyer, R. (2018). Limited edition: Producing artificial scarcity for digital art on the blockchain and its implications for cultural industries. *Convergence: The International Journal of Research into New Media*. Retrieved from https://doi.org/10.1177/1354856518795097.
Pereira, L. (2015, April 14). Why is having a certificate of authenticity essential in conceptual art collecting? *Widewalls.* Retrieved from https://www.widewalls.ch/certificate-of-authenticity-for-conceptual-art/
Piketty, T. (2014). *Capital in the Twenty-First Century* (A. Goldhammer, trans.). Cambridge, MA: Harvard University Press. (Original work published in 2013)
Pollard, V. & Wilson, E. (2014). The entrepreneurial mindset in creative and performing arts higher education in Australia. *Artivate: A Journal of Entrepreneurship in the Arts, 3*(1), 3–22.
Preece, S.B. (2011). Performing arts entrepreneurship: Toward a research agenda. *Journal of Arts Management, Law, and Society, 41*(2), 103–120.
Ragsdale, D. (2017). On entrepreneurialism and publicness (or whose theatre is it, really? *Artivate: A Journal of Entrepreneurship in the Arts, 6*(1), 4-7.
reCaptcha: Using Captchas to Digitize Books. (2007, September 16). *Techcrunch*. Retrieved from https://techcrunch.com/2007/09/16/recaptcha-using-captchas-to-digitize-books/
Roeder, O. (2018, March 6). People are paying thousands of dollars to own pictures of Pepe the Frog. *Five Thirty-Eight*. Retrieved from https://fivethirtyeight.com/features/pepe-the-frog-symbolism-cryptoart-blockchain/.
Savelyev, A. (2018). Copyright in the blockchain era: Promises and challenges. *Computer Law & Security Review, 34*, 550–561.
Schumpeter, J. (2008). *Capitalism, socialism, and democracy* (3rd ed.). London and New York: Routledge. (Original work published 1942).
Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance, 19*(3), 425–444.
Shaw, A. (2018, November 6). TEFAF drops dealers and auction house specialists from vetting committees. *The Art Newspaper.* Retrieved from https://www.theartnewspaper.com/news/tefaf-drops-dealers-and-auction-house-specialists-from-vetting-committees
Schneider, T. (2018, March 22). Cryptocurrencies explained, *artnet News*. Retrieved from https://news.artnet.com/art-world/cryptocurrencies-explained-part-three-1248863
Serota, N. (2000, November 21). Who's afraid of modern art?. Dimbleby Lecture [Transcript], London: Tate Archives, 6-7.
Shakespeare, W. (n.d.). *Lucrece*. In Mowat, P.W., Poston, M. & Niles, R. (Eds.), *Shakespeare's plays, sonnets and poems* (n.p.). Washington, DC: Folger Shakespeare Library. Retrieved from https://www.folgerdigitaltexts.org/?chapter=5&play=Luc&loc=poem
Shane, S., & Venkataraman, S. (2000). The Promise of entrepreneurship as a field of research. *Academy of Management Review, 25*(1), 217–226.
Sharpe, W.F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance, 19*(3), 425–442.
Stuckey, J. & White, D. (1993). When and when not to vertically integrate. *Sloan Management Review, 34*(3), 71–83.
Suberg, W. (2018, May 22). Bitcoin Pizza Day 2018: Community celebrates a takeout order now worth $82 million. *CoinTelegraph*. Retrieved from https://cointelegraph.com/news/bitcoin-pizza-day-2018-community-celebrates-a-takeout-order-now-worth-82-mln
Syson, L. (2011). Leonardo da Vinci: Painter at the Court of Milan, National Gallery London [Exhibition]. November 9, 2011–February 5, 2012.
Taylor, E.A. (2015). Arts entrepreneurship vs. the sum of its parts. *Artivate: A Journal of Entrepreneurship in the Arts, 4*(1), 3–5.
Throsby, D. (2006). Introduction and overview. In V. Ginsburgh & D. Throsby (Eds.), Handbook of the economics of art and culture, vol. 1. (pp. 3–22). Amsterdam: Elsevier.
Tosher, B. (2019). Entrepreneurial learning in arts entrepreneurship education: A conceptual framework. *Artivate: A Journal of Entrepreneurship in the Arts, 8*(1), 3–22.
Towse, R. (2010). Creativity, copyright and the creative industries paradigm. *Kyklos, 63*(3), 461–478.
US Census Bureau. Percentage of households with a computer at home in the United States from 1984 to 2010. Retrieved from

https://www.statista.com/statistics/184685/percentage-of-households-with-computer-in-the-united-states-since-1984/
Vakharia, N. (2015). Book review: Performing policy: How contemporary politics and cultural programs redefined US artists for the twenty-first century (London: Palgrave MacMillan), by Paul Bonin-Rodriguez. *Artivate: A Journal of Entrepreneurship in the Arts, 4*(1), 49–52.
Van Haaften-Schick, L. (2016, April 14). The aesthetics of paperwork and cultural theory according to Seth Siegelaub. *Hyperallergic*. Retrieved from https://hyperallergic.com/290637/the-aesthetics-of-paperwork-and-cultural-theory-according-to-seth-siegelaub/
Velthuis, O. (2011). The venice effect. *The Art Newspaper Magazine, 2*(225), 21–24. Retrieved from https://pure.uva.nl/ws/files/2528669/160949_art_newspaper_biennale_effect_1.pdf
Vierkant, A. (2018, September 1). The new property regime. *Art in America*. Retrieved from https://www.artinamericamagazine.com/news-features/magazines/issues-commentary-new-property-regime/
Wallace, B. (2011, November 23). The rise and fall of Bitcoin. *Wired*. Retrieved from https://www.wired.com/2011/11/mf-bitcoin/
Waugh, M. (2018, August 15). We owe artists the crucial income resale royalties provide. Artsy. Retrieved from https://www.artsy.net/article/artsy-editorial-owe-artists-crucial-income-resale-royalties-provide
Welter, F. (2011). Contextualizing entrepreneurship—conceptual challenges and ways forward. *Entrepreneurship: Theory and Practice, 35*(1), 165–184.
Westermann, M., Schonfeld, R., and Sweeney, L. (2019). *Art Museum Staff Demographic Survey 2018*. Andrew W. Mellon Foundation and Ithaka S+R. Retrieved from https://sr.ithaka.org/publications/art-museum-staff-demographic-survey-2018/
What is ERC-721?, ERC-721. Retrieved from http://erc721.org.
Whitaker, A. (2009). *Museum legs: Fatigue and hope in the face of art*. Tucson, AZ: Hol Art Books.
Whitaker, A. (2018a). Artist as owner not guarantor: The art market from the artist's point of view. *Visual Resources, 34*(38), 48–64.
Whitaker, A. (2018b, May 25). The eureka moment that made Bitcoin possible. *Wall Street Journal*. Retrieved from https://www.wsj.com/articles/the-eureka-moment-that-made-bitcoin-possible-1527268025
Whitaker, A. (2019). Shared value over fair use: Technology, added value, and the reinvention of copyright. *Cardozo Art & Entertainment Law Journal, 37*(3), 635–657.
Whitaker, A., and Kräussl, R. (2018). Blockchain, fractional ownership, and the future of creative work. *Goethe University Center for Financial Studies, Working Paper No. 594*. Retrieved from https://www.econstor.eu/bitstream/10419/182451/1/1031263918.pdf
White, J. (2013). Barriers to recognizing arts entrepreneurship education as essential to professional arts training. *Artivate: A Journal of Entrepreneurship in the Arts, 2*(3), 28–39.
White, J. (2017). Analyzing entrepreneurship in the US arts sector: Identifying arts entrepreneurs' demographics and shared characteristics. *Artivate: A Journal of Entrepreneurship in the Arts, 6*(1), 8–32.
Why Bitcoin Uses So Much Energy. (2018, July 9). *The Economist*. Retrieved from https://www.economist.com/the-economist-explains/2018/07/09/why-bitcoin-uses-so-much-energy
Wierbicki, D. & Rottermund, A.A. (2019, April). The newest technological trend in the art market. *Trusts & Estates Special Report*, A15–A17.
Wilkerson, M. (2012). Using the arts to pay for the arts: A proposed new public funding model. *Journal of Arts Management Law and Society, 42*(3), 103–115.
Williams, S.P. (2019). *Blockchain: The next everything*. New York: Simon and Schuster.
Woo, W. (2018, June 13).'Leonardo da Vinci' puts Mona Lisa painting on the blockchain. *Bitcoinist*. Retrieved from https://bitcoinist.com/leonardo-da-vinci-mona-lisa-blockchain-verisart/
Woolley, J. L. (2014). The creation and configuration of infrastructure for entrepreneurship in emerging domains of activity. *Entrepreneurship: Theory & Practice, 38*(4), 721–747.
Wyszomirski, M. J., & Cherbo, J. M. (2001). The associational infrastructure of the arts and culture. *Journal of Arts Management, Law & Society, 31*(2), 99–102.
Yermack, D. (2017a). Corporate Governance and Blockchains, *Review of Finance, 21*(1), 7–31. Retrieved from https://doi.org/10.1093/rof/rfw074
Yermack, D. (2017b). Donor governance and financial management in prominent U.S. art museums. *Journal of Cultural Economics, 41*(3), 215–235.
Zeilinger, M. (2018). Digital art as 'monetized graphics': Enforcing intellectual property on the blockchain, *Philosophy & Technology, 31*, 15–41.