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NFTs and Blockchain Applied to Product Design

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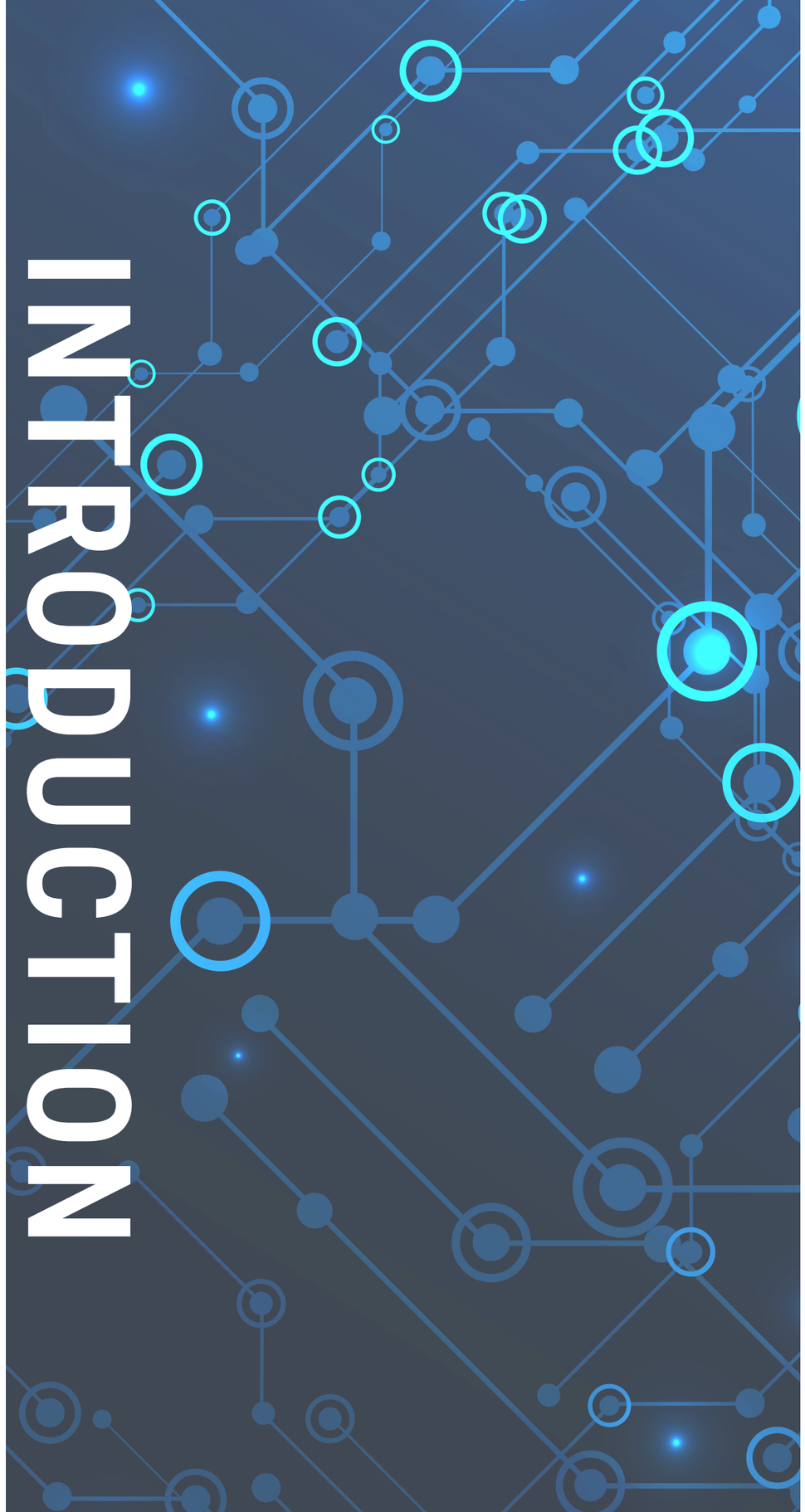
TABLE OF CONTENT

ABSTRACT

This thesis explores the transformative potential of blockchain technology and NFTs (Non Fungible Tokens) in product design emphasizing how blockchain's decentralized, immutable framework and NFT's unique digital assets can improve transparency, security, and consumer engagement. Together, they reduce reliance on intermediaries, build trust, and create tamper proof records that lower costs and simplify verification processes. Using these features, blockchain and NFTs can potentially drive efficiency across industries, with a primary focus on product design. This study explores blockchain's evolution from its early applications in cryptocurrency to advanced implementation in Blockchain 4.0, which integrates IoT (internet of things) and AI (artificial intelligence) within frameworks like Web 3.0 and Industry 4.0. Emphasizing the role of smart contracts in automating agreements and interactions, and NFTs in establishing digital ownership, this thesis shows how these technologies create new possibilities for product design, from ensuring verifiable authenticity to enabling dynamic consumer interactions. These advancements can potentially support trackable product lifecycles, customizable experiences, and seamless phygital interactions, allowing designers to merge physical and digital elements in new and innovative ways.

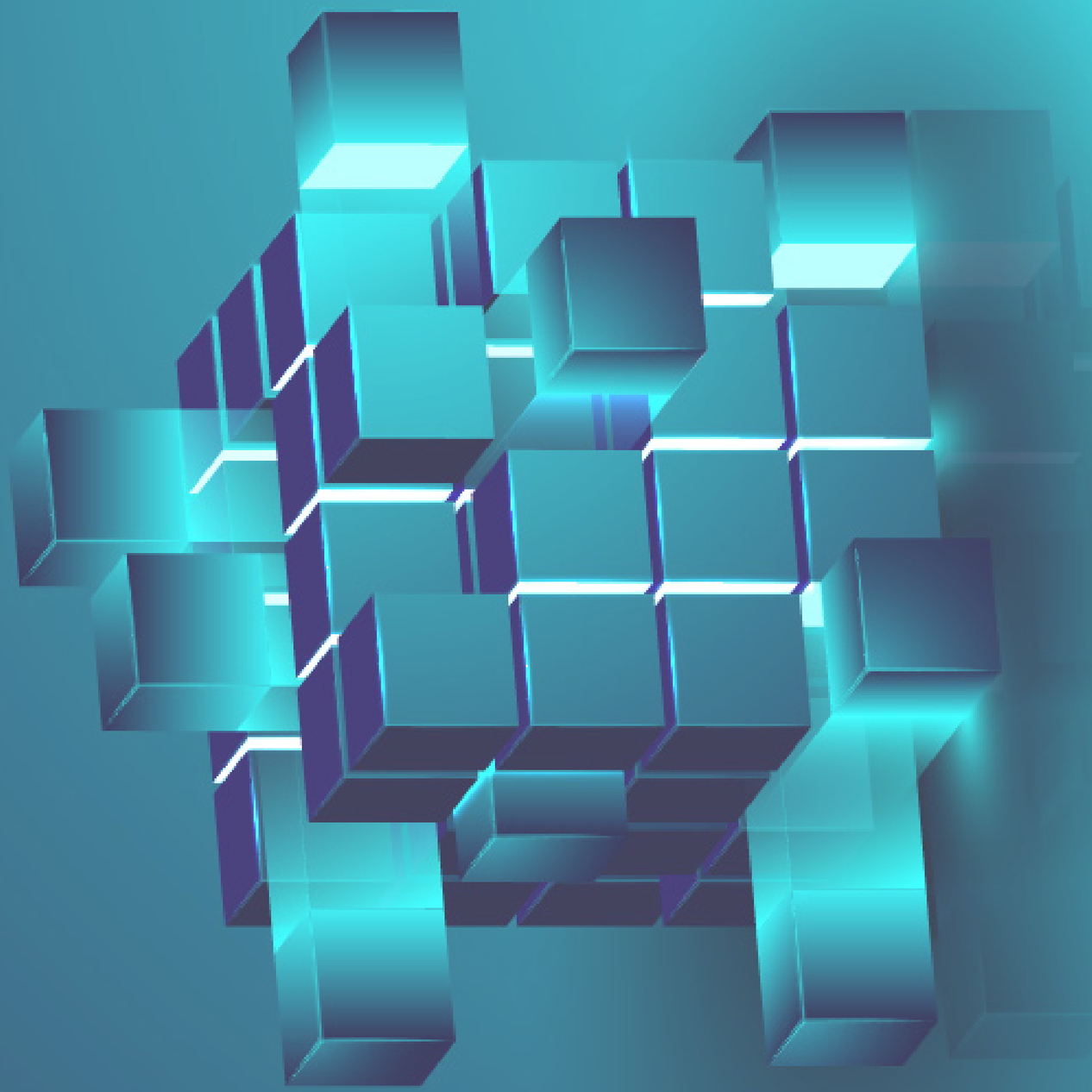


INTRODUCTION

The integration of blockchain technology and NFTs into the product design industry can change how products are made and how consumers interact with them. Blockchain provides a decentralized and secure system that improves trust, efficiency, and transparency. NFTs (Non-Fungible Tokens) bring digital ownership to digital goods and provide new ways to interact with products. Together, these technologies introduce a new product category, which is called phygital products. Phygital products combine physical and digital elements to provide users with more engaging experiences.

Phygital products combine the physical and digital worlds through the use of blockchain and NFTs. With the use of these technologies, it can offer features like personalization, secure ownership, and added value. This thesis explores how these technologies can be used in product design to create things like digital twins for real time updates, transparent supply chains using blockchain, and smart contracts for smoother and automated processes. NFTs can also provide special product features, build online communities, and create strong connections between brands and their customers.

The thesis starts by introducing blockchain, smart contracts, and NFTs and how they have developed over time. It then explains topics like Web 3.0, Industry 4.0, and design to create the foundation for understanding phygital products. These topics provide the tools necessary to create phygital products that combine physical and digital features. By connecting these concepts, this thesis shows how blockchain and NFTs can create new products (digital or physical) that can change how people use and experience them.



BLOCKCHAIN

1.1 INTRODUCTION TO BLOCKCHAIN

1.1.1 What is Blockchain?

Blockchain technology is a decentralized and secure system for recording digital transactions and events. It works as a distributed database shared among network participants (also called nodes). These participants verify data entries, creating an immutable and tamper-proof record. This makes blockchain a reliable system and reduces the need for third party data verification, lowering costs and significantly reducing potential errors.

Originally known for its use in cryptocurrencies like Bitcoin, blockchain technology has many other use cases. Its immutable nature makes it perfect for recording ownership of different assets, such as artwork and collectibles. This reduces the need for paperwork and legal procedures, making asset management and verification more efficient.

Blockchain's impact can also extend beyond its basic functions, leading to many new and innovative applications. Decentralized finance (DeFi) platforms leverage blockchain technology to provide peer-to-peer (P2P) financial services, presenting alternatives to traditional banking systems. Non-fungible tokens (NFTs) use blockchain to create unique digital assets, changing the ownership and monetization of creative work in the digital space. Furthermore, smart contracts allow the secure and automated execution of agreements without the need for intermediaries, making processes more efficient.

1.1.2 History of Blockchain

Phase 1 – 2008-2013: Blockchain 1.0 (Emergence of Bitcoin)
Blockchain 1.0 began with the introduction of Bitcoin and changed the financial landscape with its decentralized, distributed, and immutable online ledger for transactions. The idea behind Blockchain 1.0 was to increase transparency and provide public access to the global financial system. This foundational technology, known as Distributed Ledger Technology (DLT), led the way for the development of various cryptocurrencies and innovative projects, all focused on creating decentralized digital currencies. While there was initial doubt, Bitcoin and Blockchain 1.0 became an important step toward a fairer and more transparent financial system, reducing the influence of centralized authorities.

Phase 2 – 2013- 2015: Blockchain 2.0 (Ethereum Development)
Blockchain 2.0, introduced by the development of Ethereum, started the beginning of the era of smart contracts. Smart contracts allowed businesses to automate agreements across organizations, functioning as self executing codes on blockchain. They execute automatically when predefined conditions are met, eliminating the need for intermediaries.

The appeal of smart contracts comes from their tamper proof nature, lower verification costs, ability to handle exceptions, arbitration, fraud protection, and the support for automated, permissionless execution. With the ability to automate processes while ensuring transparency, they allow all involved parties to have equal control over the agreements.

Ethereum was developed by Vitalik Buterin with the idea of extending Bitcoin's capabilities beyond simple P2P networks. He introduced new features with the integration of smart contracts, which allowed the development of decentralized applications (dApps) and the recording of digital assets (NFTs), setting

Ethereum apart from the Bitcoin blockchain. This development transformed Ethereum from a simple cryptocurrency into a powerful platform for decentralized applications.

Launched in 2015, Ethereum has become an important part of blockchain technology. Its support for smart contracts, which allow a wide range of functions, along with the growth of a developer community, has contributed to its leadership in daily transaction processing and increasing market capitalization in the cryptocurrency space.

Phase 3 – 2016-2018: Blockchain 3.0 (DApps)
With Blockchain 3.0, developers are focusing more on integrating blockchain technology into various industries to improve their efficiency.

The potential of blockchain technology to transform data and information management is limitless. Blockchain 3.0 represents the phase where this technology is widely used in our daily lives. It has already shown its potential to transform industries such as healthcare, transportation, and voting.

These examples demonstrate the innovative applications of blockchain technology beyond just cryptocurrency and financial systems. Blockchain 3.0 is aimed at developing solutions for services and industries beyond economics, representing a significant step in using distributed ledger technology (DLT) for a wider range of applications and finding new ways to manage data. The global adoption of blockchain technology is underway as private companies develop customized solutions for different industries. The transformative potential of Blockchain 3.0 is evident, with the journey toward global adoption started by cryptocurrency, followed by smart contracts and decentralized applications (DApps), now driving improvements across numerous industries.

Phase 4 – The Future: Blockchain 4.0 (Industry)
Blockchain technology is fast evolving, having passed the phase of discovery and experimentation and now in the implementation and expansion phase. Blockchain 4.0 focuses on innovations within the blockchain space, with expectations of rapid advancements as businesses across various industries increasingly use this technology.

In this phase, Blockchain 4.0 aims to expand blockchain as a practical platform for creating and operating more advanced and mainstream decentralized applications. Blockchain 4.0 focuses on improving speed, user experience, and usability, addressing a broader and more common user base.

Blockchain 4.0 applications can be categorized into three main sectors: Web 3.0, Metaverse, and Industry 4.0.

- **Web 3.0:** Web 3.0 is the next phase of the internet. It combines technologies like IoT (Internet of Things), Blockchain, and artificial intelligence (AI), with a focus on decentralization. Its goal is to create an autonomous, open, and intelligent internet through the use of decentralized blockchain systems.

  Some third generation blockchains already support Web 3.0, but Blockchain 4.0 is expected to bring more specialized chains. These platforms will focus on smooth integration between systems, automation with smart contracts, and censorship resistant storage for peer-to-peer (P2P) data files.

- **Metaverse:** Tech companies like Meta and Nvidia see the Metaverse as the next frontier, a concept connecting users to virtual worlds through social interaction, gaming, work, and more, using advanced technologies like AI, IoT, AR (augmented reality), VR (virtual reality), cloud computing, and blockchain.

Users in the Metaverse engage with realistic computer generated environments, with applications ranging from gaming to virtual concerts and work meetings. While a centralized Metaverse model creates cybersecurity risks, there is a shift towards decentralization with the emergence of digital worlds based on blockchain technology. Decentralized Metaverse platforms give users greater autonomy and address specific needs like security, ownership, and authenticity.

- **Industry 4.0:** Industry 4.0 represents the fourth industrial revolution, focusing on using modern technologies like Blockchain and smart technologies (like IoT, AI, ML (machine learning), robotics) to transform industries. Just like the importance of the steam engine and the internet in shaping past revolutions, Blockchain is now becoming an important force in shaping the fourth industrial revolution. According to the experts at the World Bank, blockchain is a very useful tool for fighting against corruption as it makes transactions and operations in businesses, governments, and supply chains more transparent. This shows its significant role in Industry 4.0 and its potential to impact society positively.

1.2 CORE COMPONENTS OF BLOCKCHAIN

1.2.1 Decentralized Network

What is Decentralization?
In blockchain, decentralization is about shifting the control and decision making from a central authority, like an organization, to a distributed network. The main goal is to reduce the need for trust between participants and prevent any single entity from gaining excessive control, which could compromise the network's efficiency, security, or functionality.

Although decentralization is a fundamental aspect of blockchain technology, the concept itself is not new. It is often compared to centralized and distributed systems when designing technology solutions. While blockchain often uses decentralized networks, calling a blockchain application fully decentralized can be an oversimplification. Decentralization exists on a spectrum and influences various parts of a blockchain application. By distributing control and access to resources like data, networks, and digital assets, decentralized systems aim to make services more fair and accessible for everyone *(What Is Decentralization in Blockchain?, n.d.)*.

Benefits of Decentralization:

- **Improves Data Access:** Traditional data exchange involves sharing and transforming data among collaborating companies, leading to storage in separate data silos. This process introduces risks of data loss or inaccuracies during each transformation. A decentralized data storage system allows entities to have real time access to a shared data view, reducing the risk of errors and ensuring more efficient data handling.

- **Optimizes Resource Distribution:** Decentralization helps distribute resources more efficiently, making sure that the services are provided with better performance and reliability. It also reduces the chances of system failures.

- **Creates a Trustless Environment:** In a decentralized blockchain network, trust is eliminated, as each member in the network has a copy of the data in a distributed ledger. Any attempt to alter or corrupt a member's ledger will be rejected by the majority of the network, ensuring the integrity of the system.

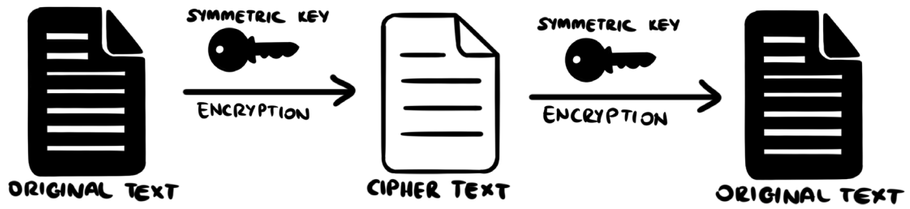
- **Reduces Single Points of Failure:** Decentralization reduces vulnerabilities in systems that rely too much on specific actors. Such reliance can lead to issues like failure to provide promised services, slow or inefficient services, outages, poor service quality, or even corruption *(What Is Decentralization in Blockchain?, n.d.)*.

1.2.2 Cryptography

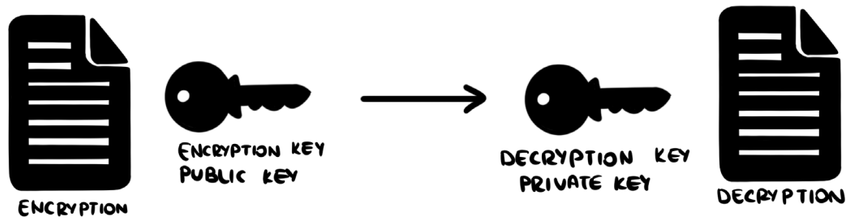
What is Cryptography in Blockchain?
Cryptography is an important component of blockchain because it secures data and transactions across the network. It mainly uses two techniques: encryption, which secures messages in the P2P network, and hashing, which secures block information and connects blocks together. These methods work together to strengthen blockchain security by protecting participants, preventing double spending, and ensuring transparency *(Tripathi, 2023)*.

Types of Cryptography:

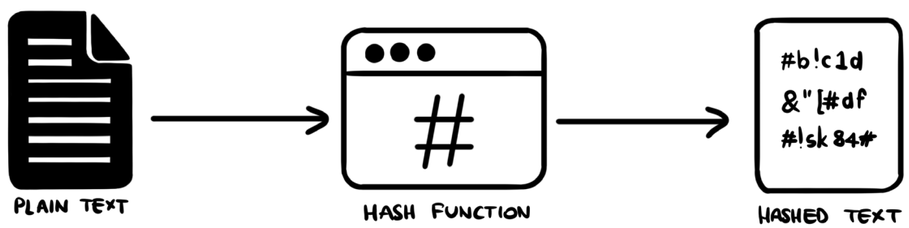
- **Symmetric Cryptography:** This method uses the same key for both encryption and decryption to transform information into a cipher. It is known for its simplicity and the ability to process data quickly *(Tripathi, 2023)*.



- **Asymmetric Cryptography:** This method uses two keys: a public key for encryption and a private key for decryption. The sender uses the public key of the receiver to encrypt, and the receiver uses their private key to decrypt *(Tripathi, 2023)*.



- **Cryptographic Hashing:** Hashing transforms plaintext data into a unique hash using cryptographic algorithms. The irreversible nature of this process distinguishes it from other cryptographic techniques. Hashing can also be used to compress data into a shorter text string, making it useful for reducing the size of large datasets *(Tripathi, 2023)*.



Benefits of Cryptography:

- **Security:** The hashing process in blockchain records root hashes for each transaction. In the event of tampering, the hash changes completely, indicating that the data has been compromised.
- **Reliability:** Cryptographic hashing is an irreversible process, ensuring that data cannot be changed after it has been processed. This ensures the information accuracy in digital ledgers.
- **Scalability:** Cryptographic techniques enable the secure processing and recording of large numbers of transactions across a network *(Tripathi, 2023)*.

1.2.3 Blockchain Wallet

What is a Blockchain Wallet?
A blockchain wallet enables the management and use of cryptocurrencies and other blockchain based digital assets, such as NFTs. There are two primary types of blockchain wallets: software wallets, such as web wallets (or crypto exchange), mobile wallets, and desktop wallets; and hardware wallets, which are physical devices that provide offline security for accessing cryptocurrencies *(Rossolillo, 2023)*.

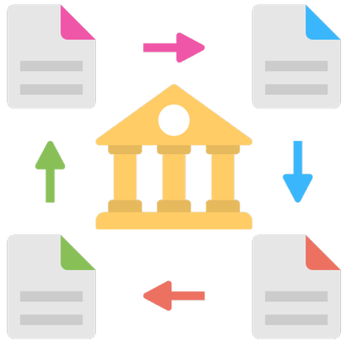
Web Based Wallets:
Web based wallets, provided by cryptocurrency exchanges, internally manage and protect security keys. This method, referred to as hot storage because it is connected to the internet, offers an easy way for managing cryptocurrency transactions and making purchases, despite security concerns such as exchange hacking.

Mobile Wallets:
Mobile wallets are softwares designed for smartphones or tablets to manage cryptocurrencies. Some mobile wallets are non hosted, requiring users to save and manage their security keys. When linked to a cryptocurrency exchange, mobile wallets may offer hot storage, providing convenient access to funds. Additionally, some mobile wallets offer added security features, including offline options known as cold storage, to protect security keys.

Dekstop Wallets:
A desktop wallet is a software designed for pc users to manage their cryptocurrencies. Many of these blockchain wallets offer cold storage options to enhance security.

Hardware Wallets:
A hardware wallet is a physical device that securely stores cryptocurrency access offline. It can be connected to a computer via USB for transactions and ensures high security by requiring users to manage their private key *(Rossolillo, 2023)*.

1.2.4 Distributed Ledger Technology



Distributed Ledger Technology (DLT) is a system that keeps track of asset transactions across multiple locations without relying on a central authority. This allows simultaneous access, validation, and updating of records across a network. A well known example of DLT is blockchain.

Interest in DLT grew after Bitcoin's launch, which demonstrated its functionality and security. Many industries are now exploring its potential applications, particularly in supply chain management.

One of the main benefits of DLT is its ability to optimize and potentially eliminate time consuming reconciliation processes. It provides real-time access to the most current and trustworthy version of the ledger for all participants.

1.2.5 Consensus Mechanism

What is a Consensus Mechanism?
In blockchain, a consensus mechanism is a protocol designed to achieve distributed agreement on the state of the ledger within a network of diverse processes and users. These mechanisms provide significant benefits to cryptocurrencies, blockchains, and distributed ledgers by eliminating the need for slower human verifiers.

For instance, the Bitcoin blockchain uses Proof-of-Work (PoW) as its consensus mechanism. PoW involves solving a cryptographic puzzle, known as a hash, using computational power. Once a miner or a group of miners solves the hash, Bitcoin's PoW mandates that every network node verifies the changes by examining elements such as data structure, block header hash, block timestamp, block size, and the first transaction. If the block is valid, it is added to the blockchain, and the miner is rewarded.

Types of Consensus Mechanism:

- **Proof of Work (PoW):** PoW is the first consensus mechanism, originally used by cryptocurrencies such as Bitcoin and Litecoin. In PoW, participants (miners) compete to solve a complex cryptographic puzzle. The first participant (miner) who solves the cryptographic puzzle gets to update the blockchain with the latest verified transactions and is rewarded by the network with a predetermined amount of cryptocurrency. While PoW provides an easy way of maintaining a secure decentralized blockchain, it also requires substantial energy and computational power, which makes it a resource intensive process.

- **Proof of Stake (PoS):** PoS was developed as an energy efficient alternative to PoW. Rather than relying on miners, PoS uses randomly chosen validators to create and validate new blocks. These validators "stake" tokens by locking them into the blockchain, and in return, they receive rewards based on their total stake. Validators are selected to propose and verify blocks in proportion to their stake in the network, significantly reducing the need for energy intensive computations. This mechanism creates an honest environment because validators risk losing their staked tokens if they attempt to add invalid blocks.

1.2.6 Smart Contracts

Smart contracts are self executing programs stored on a blockchain, designed to run automatically when specific conditions are met. They streamline agreements by ensuring all parties can immediately verify the outcome without needing intermediaries or losing time. Beyond automating agreements, smart contracts can also automate workflows by triggering the next step in a process as soon as the required conditions are met *("Smart Contracts on Blockchain," n.d.)*.

How Smart Contracts Work?
Smart contracts function using encoded "if/when...then..." statements on a blockchain. They automatically execute when certain conditions are met and confirmed by a network of nodes. This automation simplifies various processes, such as releasing funds. Once a transaction is completed, it becomes a permanent part of the blockchain, creating an immutable record.

In smart contracts, participants can define multiple conditions for completing tasks. It is very important to define the terms, agreements, and rules for "if/when...then..." scenarios, take exceptions into account, and establish a mechanism for resolving disputes to accurately represent transactions and data on the blockchain *("Smart Contracts on Blockchain," n.d.)*.

Benefits of Smart Contracts:

- **Speed, Efficiency and Accuracy:** Smart contracts execute automatically once their conditions are met. Since they are digital and automated, they also eliminate the need for paperwork and reduce the errors that often come with manual document handling, saving both time and effort.

- **Trust and Transparency:** Blockchain removes the need for intermediaries and shares encrypted transaction records with all participants. This ensures that the information remains unchanged and removes concerns about manipulation or tampering.

- **Security:** Blockchain uses encryption to protect transaction records, making them highly resistant to hacking. Additionally, because each record is linked to both the previous and next ones on a distributed ledger, changing just one record would require altering the entire chain, which is virtually impossible.

- **Savings:** Smart contracts eliminate the need for intermediaries to process transactions, which helps reduce both delays and fees related to them *("Smart Contracts on Blockchain," n.d.)*.

1.3 BLOCKCHAIN ARCHITECTURE

Blockchain architecture is the structure of a P2P network that serves as the foundation for various systems and applications. This decentralized structure works smoothly without the need for a central authority to control how the nodes interact *(Blockchain Architecture - How It Works, n.d.)*.

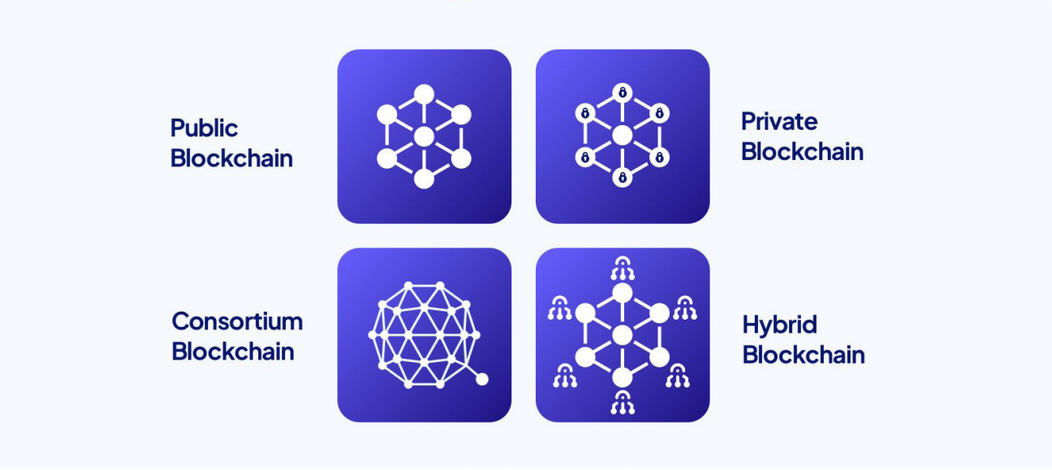
1.3.1 Types of Blockchain Architecture

- **Private Blockchain:** A private blockchain is owned and controlled by an individual, business, or organization, and only the owner can decide who joins the network. One of the main benefits of private blockchains is their high level of customization and the simplicity of implementing upgrades, as there are fewer participants involved in the decision making. However, they also have some limitations. Private blockchains are less secure compared to other types of blockchain architecture because they rely on a central authority, which can be vulnerable to attacks. Additionally, they are more open to censorship and do not provide true immutability, as the owner can easily change the rules.

- **Consortium Blockchain:** A consortium blockchain is a collaborative network managed by several organizations. Each organization operates a node and takes part in the decision making. Participants in the network must verify their identities, and joining often requires meeting certain conditions, such as paying a fee.

- **Public Blockchain:** A public blockchain allows anyone to join the P2P network and set up a node without needing permission. To keep the system secure and to encourage participation, participants are often rewarded through staking or mining. Its high level of decentralization significantly improves security. However, there are some challenges with public blockchain, especially during upgrades because of the potential disagreements in governance, which can make these blockchains less flexible when changes are needed.

- **Hybrid Blockchain:** A hybrid blockchain works on two levels: a foundational public P2P network and a private blockchain developed by an entity. The private blockchain leverages the security of the highly decentralized public blockchain, allowing businesses and entities to create and customize a blockchain according to their needs *(Blockchain Architecture - How It Works, n.d.)*.



Murtaza, A. (2022). 4 Main Types of Blockchain

1.3.2 Blockchain Architecture Components

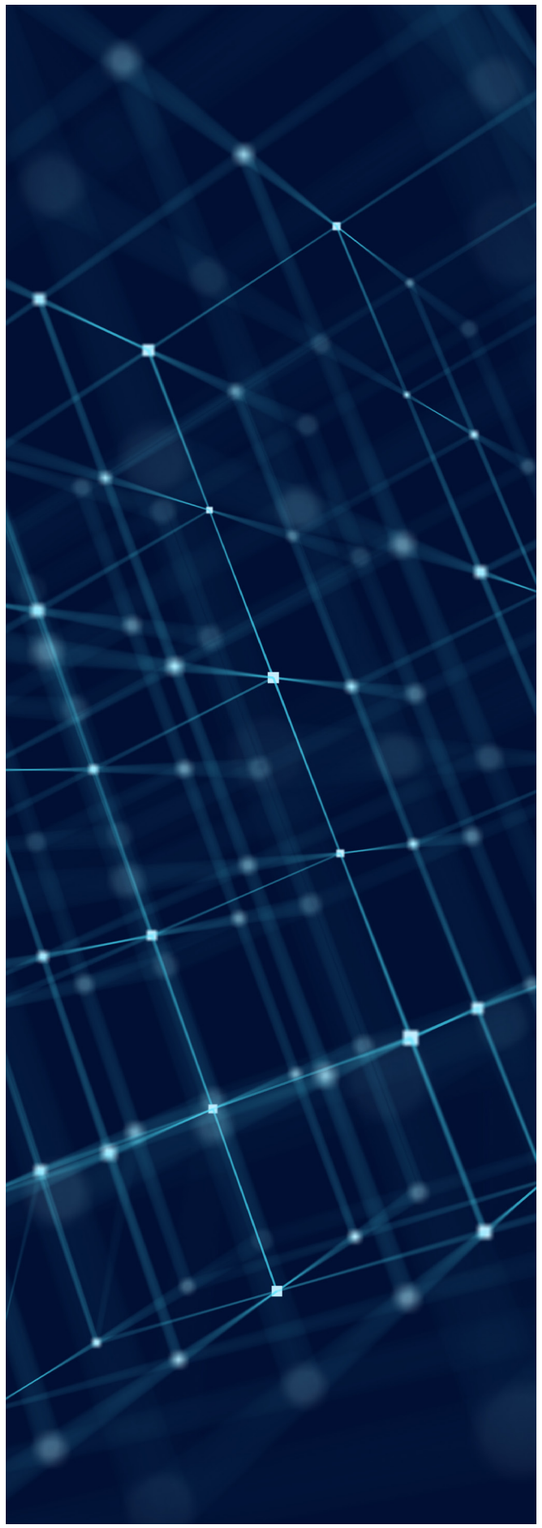
- **Node:** In a P2P network, a node is a computer that is connected to the internet and has the necessary software to work with other participants in the network. The functions of a node include updating the shared ledger, storing that ledger, and transmitting data to other nodes within the network.

- **Transactions:** A transaction is an entry recorded on the blockchain's shared ledger. It can include transferring digital assets, like coins, from one address to another or changing the state of a smart contract.

- **Block:** A block is a group of transactions that the P2P network processes and validates together on the shared ledger. For example, in the Bitcoin blockchain, all transactions made within about ten minutes are verified and added to the chain as a new block.

- **Chain:** A chain is made up of blocks that are connected together, starting with the first block, called the genesis block, and continuing to the latest one. Each block is connected to the previous one through specific metadata, creating a secure chain. The term "blockchain" comes from this connection of blocks.

- **Miners:** In the blockchain, the term "miners" has two meanings. The first meaning is the machine that performs network functions like sharing data, approving transactions, and storing the shared ledger. The second meaning is the person who sets up and operates a node to earn rewards from the blockchain *(Blockchain Architecture - How It Works, n.d.)*.



1.4 WORKING OF BLOCKCHAIN

Blockchain is a secure and immutable DLT that allows the recording and verification of different transactions in a decentralized P2P network. It provides a high level of transparency and significantly reduces the possibility of fraud. Within this network, transactions taking place between nodes are validated by the blockchain's P2P network, and the verified transactions are then grouped into blocks. These blocks are added to the blockchain through a consensus mechanism.

The process of adding a new block includes the use of a consensus mechanism, such as PoW or PoS. In PoW, nodes, often known as miners, solve a mathematical puzzle of a certain difficulty level. This process requires substantial computational power, making it a resource intensive and expensive process. Successfully solving the problem results in the creation of a new hash value for the block.

As more nodes find the correct answer and validate the block, it becomes a permanent part of the blockchain. To encourage participation and validate the efforts of contributing nodes, rewards are often distributed, commonly in the form of cryptocurrencies such as Bitcoin. Each block in the blockchain is assigned a unique block number and timestamp, showing its order of addition. Furthermore, blocks are linked through hashing, providing a unique digital signature for each block and ensuring a high level of security in the overall blockchain network.

1.5 ADVANTAGES AND DISADVANTAGES OF BLOCKCHAIN

Advantages of Blockchain:

- **Transparency:** Since blockchain is decentralized, any participant can validate data added to it. This transparency creates trust, as the integrity of the network can be verified by anyone.
- **Security:** Blockchain's decentralized and cryptographic structure provides improved security compared to traditional systems. Once a block is added to the chain, changing the data becomes almost impossible.
- **Elimination of Intermediaries:** Blockchain allows direct transactions between people without the need for intermediaries. This P2P approach reduces costs and makes processes faster and more efficient.
- **Traceability:** Every transaction on the blockchain is recorded and connected to the one before it. This creates a transparent record of every transaction and event. This is especially useful in areas like supply chain management, as it can help verify the authenticity of the products and prevent fraud.
- **Reducing Costs:** By reducing the need for intermediaries and improving efficiency with the use of smart contracts, blockchain can reduce the costs.

Disadvantages of Blockchain:

- **Scalability Issues:** Blockchain's design causes scalability issues, which can cause delays as the network's user base grows in time.
- **High Energy Consumption:** Some blockchains require substantial computational power caused by the mining process, which involves solving a mathematical puzzle with a certain difficulty level. The process of solving this requires a lot of energy.
- **Legal and Regulatory Challenges:** Blockchain's decentralized nature creates legal and regulatory challenges, as there is not a single authority in control. Additionally, different countries have different laws and regulations around blockchain, which can lead to uncertainties in the space.
- **Potential for Misuse:** While blockchain provides security and privacy, these same features can be used for illegal activities like money laundering.
- **Complexity:** Blockchain technology can sometimes be highly technical, which may make it difficult for the average person to understand and use. The complex nature of it slows down its wider adoption.

1.6 BLOCKCHAIN IN DIFFERENT INDUSTRIES

1.6.1 Finance and Banking

In today's digital age, the banking and financial services industry processes transactions worth trillions of dollars every day. Ensuring transparency, security, and profitability in this environment becomes a big challenge. Reports show that 45% of financial intermediaries, such as payment networks, stock exchanges, and money transfer services, face cyber attacks each year, showing the weaknesses in the current system.

Blockchain presents a powerful solution to these challenges by providing a secure, transparent, and economical framework for digital transactions. Its decentralized design reduces the need for intermediaries like banks, allowing smooth, direct transactions while minimizing risks and operational costs.

In addition to providing solutions to these challenges, blockchain has the potential to reshape the banking industry by introducing new solutions to many of its current challenges. Here are some ways that blockchain technology can change the banking industry *(Miracle Software Systems, Inc, 2023)*:

- **Financial Inclusion:** Blockchain can expand financial inclusion by allowing banks to reach unbanked populations where traditional banking is unavailable. With the use of digital wallets and cryptocurrencies, people can make P2P transactions without needing traditional banking services.
- **Smart Contracts:** Blockchain allows the use of smart contracts, which are self executing agreements built on blockchain. These contracts can automate different types of banking processes, making the whole system more efficient and reliable.
- **Transparency and Efficiency:** Blockchain can transform banking by increasing transparency and efficiency. It eliminates the need for intermediaries, streamlining processes and speeding up transactions while reducing costs.
- **Cross-Border Payments:** Blockchain allows direct, P2P cross-border payments, removing intermediaries, which results in faster and cheaper transactions.
- **Tokenization of Assets:** Blockchain makes it possible to tokenize assets by creating digital versions of real world items. These tokens can then be traded on blockchain networks *(Miracle Software Systems, Inc, 2023)*.

1.6.2 Healthcare Industry

1.6.2.1 Decentralized Electronic Health Records

Decentralized Electronic Health Records (EHRs) represent digital health record systems that distribute and store patient data across multiple nodes or servers, serving as the blockchain version of health records. They offer several advantages *(Günthner, 2023)*:

- **Improved Data Security:** Decentralized EHRs protect patient health records by using techniques like encryption and digital signatures. These tools help to keep the information secure and prevent it from being changed without permission. This increases security against unauthorized access or tampering with sensitive data.
- **Interoperability:** One of the main challenges in today's healthcare system is that different providers usually use EHR systems that don't work well together. This makes sharing patient information difficult and slows down the healthcare system. Decentralized EHR on the other hand could help solve this problem by allowing healthcare providers to share data more easily and securely. This would improve interoperability while ensuring that patient information stays safe.
- **Patient-Centric Healthcare:** Blockchain technology gives patients more control over their personal health records. This allows them to decide who can access and share their data. This method puts patients at the center of healthcare, making the system more focused on their needs *(Günthner, 2023)*.

1.6.2.2 Supply Chain Management and Tracking

Blockchain technology can also transform the healthcare supply chain. By addressing issues like counterfeit medicines, inefficiencies, and lack of transparency, it can make the system more reliable and efficient.

- **Drug Traceability:** Blockchain's secure and transparent characteristics allow tracking of every stage of the pharmaceutical supply chain, from production to patient. This ensures that patients receive real medications, reducing the risk of counterfeit drugs and improving their safety.
- **Medical Device Authentication:** Blockchain can be used to verify the authenticity of medical devices, making sure that only approved and real products are reached to patients.
- **Efficient and Transparent Supply Chains:** Blockchain creates a permanent and reliable record of transactions, helping to optimize the healthcare supply chain. It reduces delays, improves transparency, and makes processes more efficient. This can lower costs and lead to better care for patients *(Günthner, 2023)*.

1.6.3 Manufacturing Industry

Blockchain technology offers manufacturers a way to simplify operations, improve supply chain transparency, and track assets.

In the manufacturing industry, products are often made using parts provided by different suppliers. Blockchain can help track every component throughout the process, from sourcing to production and beyond. For example, car manufacturers assemble vehicles using thousands of parts from different sources. They are responsible for the car's safety and reliability, and if a flaw is found and recall is needed, they must identify and replace the faulty parts.

By using a private blockchain in the automotive industry, manufacturers can track components from all their suppliers. As suppliers create and deliver parts, they record the details as blockchain transactions. As the process continues additional information can be added as parts are inspected and used in production. If something goes wrong, the manufacturer can trace the problem back to the specific part, figure out which vehicles are affected, and check the part's entire journey through the supply chain. This speeds up problem solving and makes the manufacturing process more efficient *(Blockchain in Manufacturing, 2023)*.

How Blockchain Can Improve Manufacturing?
Blockchain technology has the potential to improve manufacturing in many ways. By providing a secure and reliable source of information, it brings several key benefits. These include improved traceability of components, better inventory management, and streamlined supply chain operations. Beyond these, blockchain can automate payment processes and make HR tasks more efficient. Here are some of the most important ways that blockchain can improve the manufacturing industry *(Blockchain in Manufacturing, 2023)*:

- **Improved Traceability:** Blockchain improves traceability by allowing manufacturers to track every step of the supply chain and the entire product lifecycle. It creates a secure and immutable record of all transactions related to the components used in manufacturing. This level of traceability is very valuable for ensuring that parts come from trusted suppliers and for quickly identifying the source of any product issues.
- **Improved Human Resource Management:** Blockchain can simplify many time consuming HR tasks. For example, companies that hire seasonal or part time workers can use blockchain to easily track hours worked and streamline their payment process. Additionally, if we consider a more conceptual case, in the future, employment histories can be securely recorded and verified on the blockchain, allowing employers to quickly confirm a candidate's experience and achievements.
- **Better Data Security:** Blockchain provides better data security when implemented correctly. Each transaction is verified by multiple parties before it is added to the blockchain, ensuring accuracy. Once the data is recorded on a blockchain, it becomes difficult to change, making it highly secure against tampering.
- **Improved Inventory Management:** Blockchain keeps a detailed record of shipped items, such as who received them and when. This reduces errors from manual data entry and lowers the need for manual inventory checks. It also helps manufacturers better manage perishable goods and ensures timely restocking to meet demand.
- **Automated Payments:** Smart contracts make payment processes easier by automating them. This reduces the need for manual work and lowers the chance of errors. For example, a smart contract could handle payments based on an agreed service contract. A maintenance provider would be paid directly from a digital wallet as soon as they perform maintenance on factory equipment *(Blockchain in Manufacturing, 2023)*.

SMART CONTRACTS

2.1 INTRODUCTION TO SMART CONTRACTS

2.1.1 What is a Smart Contract?

Smart contracts are agreements on a blockchain that automatically execute specific actions when certain conditions are met. They leverage the secure and transparent nature of blockchain to handle tasks reliably, making transactions based on specific rules quicker and more efficient. While they were first inspired by Bitcoin's P2P approach, platforms like Ethereum have developed smart contracts to include more advanced features and wider range of uses.

2.1.2 History of Smart Contracts?

The concept of smart contracts was introduced in the 1990s by Nick Szabo, a computer scientist and cryptographer. He described them as digital protocols that could automate and secure transactions using mathematical algorithms. However the technology at the time was not advanced enough to bring his ideas to life. There were also concerns about a central point of control, which could make the system vulnerable to attacks. These challenges slowed down the wider adoption of smart contracts.

The real advancement for smart contracts came with the invention of blockchain technology. When Bitcoin was introduced in 2008, it made decentralized, P2P transactions possible, which aligned closely with the ideas Szabo had described. Blockchain provided the secure and practical system needed to make smart contracts a reality.

The development of other cryptocurrencies, especially Ethereum, significantly improved the use cases of smart contracts. Unlike Bitcoin, Ethereum was developed specifically to support smart contracts, making them easier, faster, and more secure to use. This was a very important turning point that helped smart contracts become an important part of how blockchain is used today.

2.2 FEATURES OF SMART CONTRACTS

- **Distributed:** Smart contracts are shared across the entire network and this ensures that everyone involved has a copy of the terms. These terms cannot be changed by any single party which makes the contract secure and reliable. After a smart contract is created, it is copied and stored on all the nodes in the network. This ensures that it is always available and the same for everyone.
- **Consistent:** Smart contracts automatically execute specific actions when the required conditions are met. No matter who triggers it, the result is always the same, which ensures consistency and reliability.
- **Autonomous:** Smart contracts can automate various tasks, functioning as self executing programs. They usually remain inactive and do not execute any actions unless triggered by a specific event.
- **Immutable:** Once a smart contract is added to the network, it is not possible to change it. Modification is impossible and the only way to remove it is if a specific function for removal was added when it was created.
- **Customizable:** Smart contracts can be customized to meet specific requirements before being launched.
- **Trustless:** Smart contracts eliminate the need for third parties to verify the process and confirm that conditions are met.
- **Transparent:** Smart contracts are stored on a blockchain, allowing anyone, participant or not, to view the code *(Smart Contracts in Blockchain, 2024)*.

2.3 HOW SMART CONTRACTS WORK?

A smart contract is a digital agreement that operates on the blockchain and works automatically. The terms and conditions of the agreement are written as code, which explains what actions or events are required to trigger the contract. Deadlines or time limits can also be included in the contract. Once it is uploaded to the blockchain, the smart contract gets its own unique address, allowing individuals to interact with it directly.

Smart contracts work on simple logic, often using IF-THEN rules. For example:

- IF you send item A, THEN the agreed cryptocurrency amount will be sent to you.
- IF you send a specific amount of digital currency (like Ethereum or Bitcoin), THEN item A will be transferred to you.
- IF I complete the task in the contract, THEN I will receive the agreed digital payment.

Because there is no limit to the number of IF-THEN conditions that can be included, smart contracts are very flexible. Adding a WHEN condition also makes it possible to set time limitations, which ensures that actions must happen within a certain timeframe for the contract to work. This makes smart contracts an efficient and reliable way to automate and enforce agreements *(Smart Contracts in Blockchain, 2024)*.

How does a Smart Contract Work:

- **Identify Agreement:** Parties should identify desired outcomes in an agreement.
- **Code Business Logic:** A computer program is created that will work automatically when specified conditions are met.
- **Network Updates:** Every node on the network updates its ledger to show the new state after the smart contract is executed. Once the record is added and verified on the blockchain, it cannot be changed. The blockchain only allows new records to be added, keeping the history secure and permanent.
- **Better Security with Encryption and Blockchain Technology:** Encryption ensures secure authentication and data transfer among parties involved in smart contracts.
- **Execution and Processing:** In blockchain systems, the code is executed only after all parties agree on the authentication and verification process. Once the actions are completed, the results are recorded on the blockchain, making them easy to check later for verification and compliance.
- **Set Conditions:** Smart contracts can be activated in two ways: manually by the involved parties, or automatically when certain conditions are met *(Smart Contracts in Blockchain, 2024)*.

2.4 USE CASES OF SMART CONTRACTS

- **Government Voting System:** By lowering the possibility of manipulation, smart contracts can increase the security of government voting systems. Votes are virtually impossible to change or manipulate when they are recorded on a blockchain, adding another layer of security. Additionally, by replacing old voting systems with a simpler and more user-friendly online voting process, smart contracts can encourage more people to vote.
- **Healthcare:** Blockchain provides a secure way to store health records by encoding them and using private keys to ensure only authorized individuals can access them. Blockchain can make healthcare more efficient by automatically sharing hospital receipts with insurance companies as proof of service. In addition to patient records, it can be used for tasks like managing the supply chain, tracking medications, and ensuring compliance with regulations.
- **Supply Chain:** Normally , supply chains rely on paper based processes, which can slow the whole process as documents go through multiple approval steps. This increases the possibility of fraud or documents getting lost. Blockchain provides a secure digital solution that everyone in the supply chain can access. It reduces these risks and allows smart contracts to improve inventory management, automate payments, and speed up tasks.
- **Financial Services:** Smart contracts are very useful in financial services, making processes like insurance claims faster and more efficient. They can automatically check for errors, handle tasks, and transfer payments as soon as the required conditions are met. Smart contracts also secure bookkeeping by protecting accounting records from tampering. They also increase transparency by allowing shareholders to participate in decision making actively. In trade settlements, smart contracts make fund transfers simpler by completing payments automatically once the calculations are finished *(CFI Team, n.d.)*.

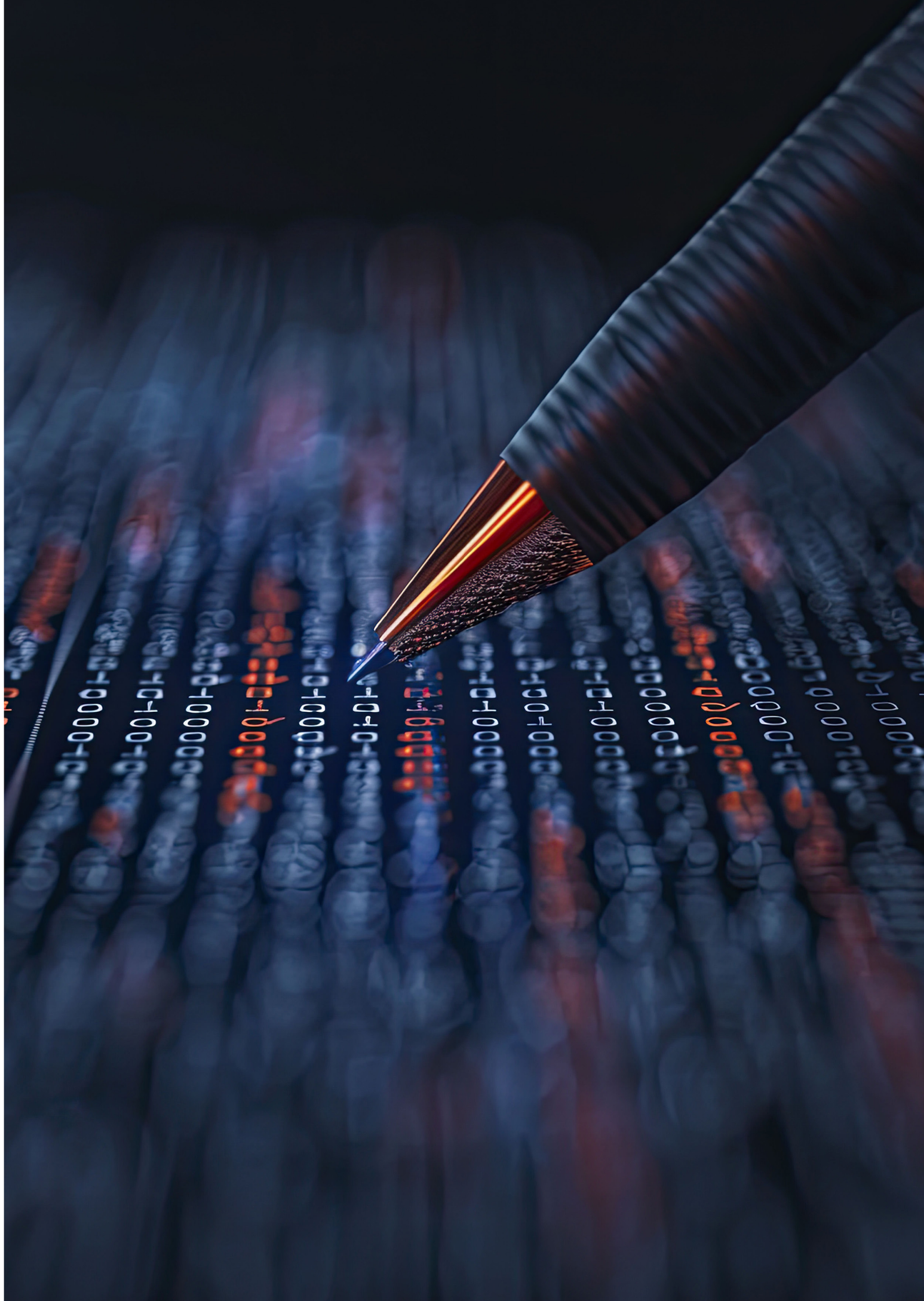
2.5 ADVANTAGES AND DISADVANTAGES OF SMART CONTRACTS

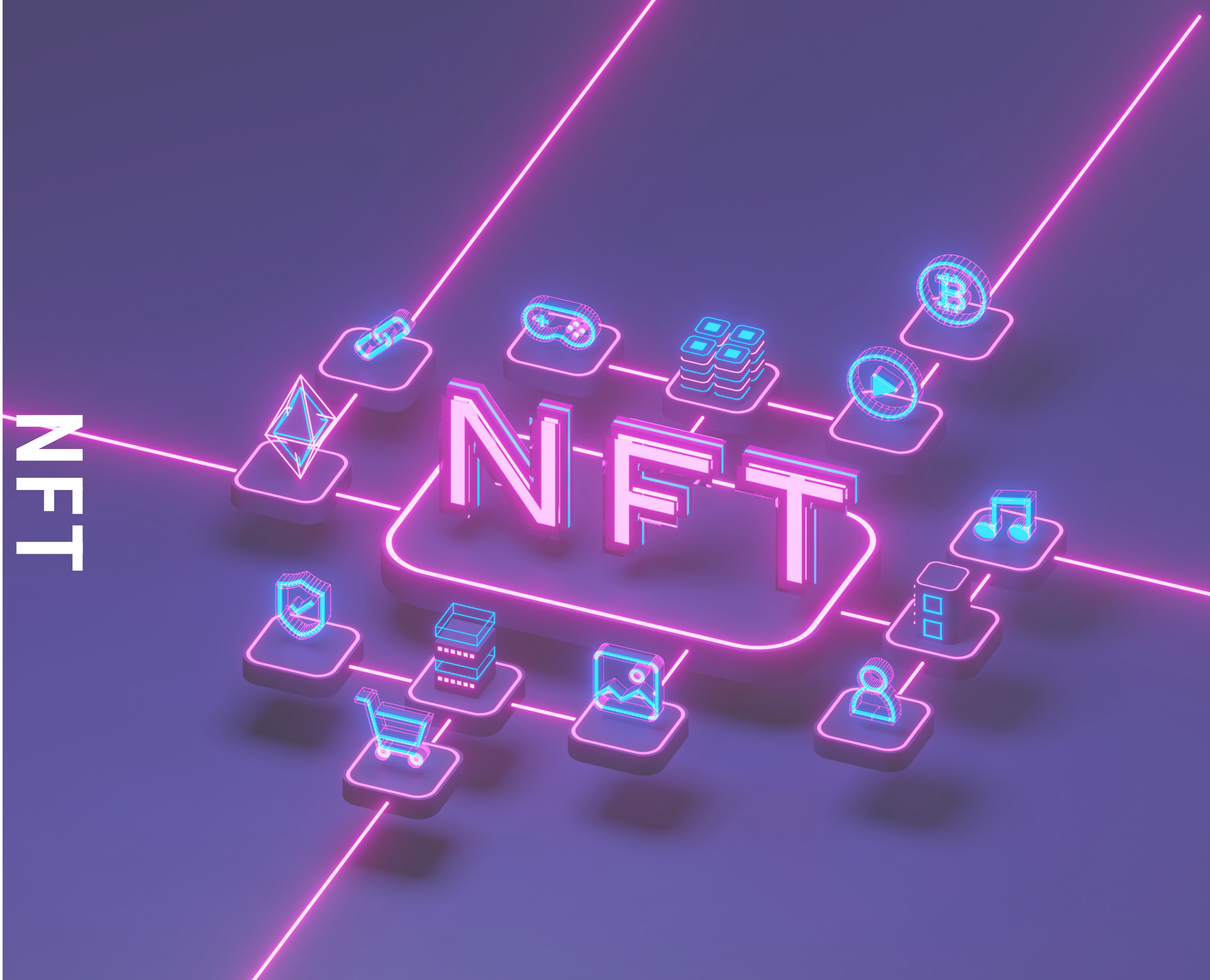
Advantages of Smart Contracts:

- **Autonomy:** Smart contracts automate agreements, reducing reliance on third parties and related transaction costs.
- **Backup:** Blockchain can securely store important documents. Its tamper proof design ensures that any changes are recorded, and the original version can always be verified.
- **Safety:** Smart contracts use encryption for protection, and cryptography ensures that all documents stay secure and cannot be accessed without permission.
- **Speed:** Smart contracts use computer protocols to handle tasks automatically, helping save time and make business processes efficient.
- **Accuracy:** Smart contracts reduce errors by automating processes, removing the need for manual form filling *(CFI Team, n.d.)*.

Disadvantages of Smart Contracts:

- **Difficult to Change:** Changing or modifying a smart contract is almost impossible after it has been launched. Even small coding mistakes can take a lot of time and money to correct.
- **Loopholes:** Smart contracts can have loopholes, and these usually come from coding mistakes or unclear terms that don't translate well into code. Unlike traditional contracts, which rely on trust and legal rules, smart contracts follow their code exactly as they are. This means that the final result might not always be what the parties originally intended.
- **Third Party:** Smart contracts can reduce the need for third parties, but they can't eliminate them completely. Instead, the roles of third parties change. For example, lawyers might not be needed to write contracts, but developers are still needed to turn the contract terms into code.
- **Unclear Terms:** Smart contracts can have difficulty handling unclear or poorly defined terms and conditions as they need precise instructions to work correctly *(CFI Team, n.d.)*.




NFT

3.1 INTRODUCTION TO NFTS

3.1.1 What are NFTs?

A non-fungible token (NFT) is a digital certificate stored on a blockchain that proves ownership and authenticity. You can think of it as a certificate for a specific digital item. To understand NFTs better, we can break it down into two. “Non-fungible”, which means it can’t be replaced or divided like money, and “token”, which means the digital representation on a blockchain.

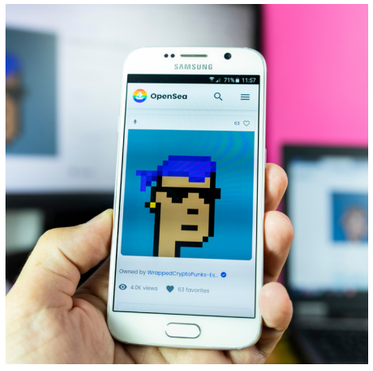
Non-Fungible
Fungibility is about how easily something can be replaced with another identical one. For example, money is fungible because any 20$ bill can be exchanged for another 20$ bill, and both keep the same value.

On the other hand, non-fungible items are different because they are unique and they can not be replaced in the same way. Each one has their own unique features that make it special. For example, if someone borrows a car, the expectation is to return the same car, not a different one, even if it is the same brand and the same model *(“What Is Fungibility,” 2022)*.

Tokens
Tokens are like digital items that can be traded and they represent ownership of an asset (coins or NFTs). There are two main types of token: fungible tokens, like Bitcoin or Ethereum, where each unit is the same and interchangeable, and non-fungible tokens (NFTs), which are unique and cannot be exchanged in the same way.

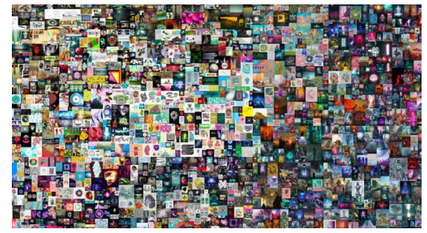
Tokenization is the process of converting an asset, whether it’s physical or digital, into a token that can be bought, sold, or traded. This is done using blockchain technology, which provides a secure and immutable system to track and store ownership in a transparent and permanent way. Once an asset is tokenized, ownership can be transferred quickly and easily. Tokenization removes the need for physical exchanges, making asset management secure, quicker, and efficient.

3.1.2 A Short History of NFTs

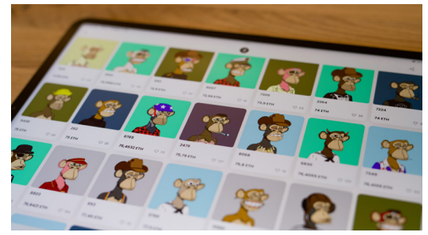


NFTs first appeared in 2014. They combined art and technology in a new and creative way. They were mainly developed to help artists and creators protect their work by using blockchain to prove ownership and authenticity. NFTs gained significant attention in 2017 with the success of two projects, CryptoPunks and CryptoKitties. CryptoPunks, a collection of pixelated portraits, were sold for free, and early resale value ranged between $1 and $30. Over time, their value increased, with some of them selling over $1 million each. Similarly, CryptoKitties introduced a fun and interactive way to digital ownership. Users were able to buy, collect, breed, and trade unique digital cats. These examples showed how NFTs can create value and engagement in exciting and creative ways through digital assets *(Baker et al., 2022)*.

These projects have played an important role in shaping the digital art movement by showing creators new ways to earn money from their works. A very important example that showed how artists can monetize their work is also seen with Beeple’s digital art, Everyday: The First 5000 Days, which sold for over $69 million. This artwork, a mosaic of 5000 images created by the artist over many years, has become a powerful example that showed the transformative potential of NFTs in the art world *(Howell, 2023)*.


Winkelmann, M. (2021). Everydays: the First 5000 Days

In 2021, NFTs gained widespread attention, with the growth of the cryptocurrency market and their influence in pop culture. Speculation also played a critical role in their growth, as many investors tried to find alternative opportunities during uncertain economic conditions. As a result, NFTs became a major topic of discussion, with collections like the Bored Ape Yacht Club becoming cultural icons. Other collections, such as Azuki, Pudgy Penguins, Cool Cats, Mutant Ape Yacht Club, Doodles, and Moonbirds, contributed to the variety of the growing NFT world.



NFTs also extended beyond just art and collectibles. They touched on areas, like the Ethereum Name Service (ENS), which allowed people register unique .ETH domains as NFTs, and NBA Top Shot, a platform where basketball fans could collect and trade digital highlights. These different use cases of NFTs, combined with the growing interest in blockchain technology, brought NFTs into a leading position in the digital space.

3.2 MAIN CHARACTERISTICS OF NFTS

- **Uniqueness:**
  Every NFT includes metadata, which acts like a digital fingerprint. This metadata shows NFT's unique features, history, and defines its role in the digital space. Similar to a certificate of authenticity for physical art, the metadata confirms the NFT's identity and proves who owns it.

- **Authenticity:**
  One of the main advantages of NFTs is that they can prevent counterfeiting and fraud. By using blockchain technology, NFTs can assure buyers that what they are buying is authentic. This ensures that people can trust they are getting exactly what they paid for.

- **Indivisibility:**
  NFTs are indivisible, which means that they cannot be divided into smaller parts like cryptocurrencies, and they need to be bought as a whole to own them.

- **Rarity:**
  The rarity of NFTs is one of the aspects that makes them appealing to collectors. Creators can choose to create an unlimited number of items or make only a limited number and depending on what they decide, this can have an impact on the rarity, and as a result, it can increase their value and make NFTs popular among collectors.

- **Ownership:**
  Blockchain makes it easy to prove ownership of NFTs. It also simplifies transferring ownership, completing transactions in minutes.

- **Transferability:**
  NFTs can be bought and sold easily on specific marketplaces, which makes them appealing to collectors and investors.

- **Transparency and Trust:**
  Because NFT records and transactions are accessible to anyone, they provide transparency. This transparency helps build trust between buyers and sellers *(Shilina, 2022)*.

3.3 TECHNOLOGY AND STANDARDS

3.3.1 Technology

Blockchain:
Blockchain was first introduced in 2008 as the public transaction ledger for the cryptocurrency Bitcoin. It is a type of DLT that works as a decentralized system where data is stored in a series of connected blocks, organized in the order they are created. This technology allows a P2P network where users can interact with each other securely and transparently without the need for a central authority *(Shilina, 2022)*.

Smart Contracts:
Smart contracts are digital protocols designed to execute agreements automatically when specific conditions are met. They can simplify various processes, and verify and execute agreements without the need for a third party. By automating these processes, smart contracts reduce costs, minimize the risk of fraud, and ensure secure and reliable transactions. They are commonly used in areas like decentralized finance (DeFi), to make transactions more efficient and reliable *(Shilina, 2022)*.

3.3.2 NFTs Standards

A token standard defines the smart contract and the specific features that the token created by it has.

Ethereum:
Because it provides a clear and well organized token standard, Ethereum is one of the most used platforms for developing NFTs. The standards used in Ethereum are called ERCs (Ethereum Request for Comments), and they provide developers a set of rules to follow when creating tokens on the Ethereum blockchain.

The ERC-20 standard is used to create fungible tokens, which are tokens that are interchangeable, like cryptocurrencies. This standard offers a lot of flexibility and functionality, making it useful for representing assets like currencies, financial assets, or utility assets.

NFTs, on the other hand, use the ERC-721 standard. This standard is specifically designed to create tokens that are unique and cannot be replaced with the same one, making it perfect for representing digital assets. ERC-721 includes rules for ownership, security, and metadata, allowing NFTs to be bought, sold, and transferred safely. Today, ERC-721 is the most widely used standard for NFTs *(Shilina, 2022)*.

Flow:
Flow is a blockchain platform created to support the next generation of games, apps, and digital assets. It uses a unique structure called multi-role architecture, which helps the network work faster and handle more activity without sharding. At the same time, Flow is designed to be a developer friendly environment, making it easier to create and run new projects.

To understand Flow and why it is important, it is better to start with CryptoKitties, an NFT based game that launched in 2017. In this game, players were able to buy, sell, collect, and breed virtual cats. The game quickly became very popular because of its simple and fun concept. However, this popularity increased the number of users and this led to heavy congestion on the Ethereum blockchain. At its peak, CryptoKitties was responsible for about 25% of all activity on the Ethereum blockchain, showing the network's limitations.

Frustrated with the limitations of the Ethereum blockchain, the team behind CryptoKitties, Dapper Labs, decided to solve the technical challenges they faced. In the process, they created a new blockchain called Flow.

One of Flow's unique features is the way it handles smart contracts. Flow allows developers to launch their applications in the beta state using "Upgradeable Smart Contracts". This allows developers to release their apps while they are still working on them. Users are informed that the app is still being developed and can decide whether to try it right now or wait until it's completed. When the developers are satisfied, they can decide to launch the smart contract and make it a permanent and immutable part of the blockchain. This makes Flow more flexible and user friendly for early stage development, compared to other blockchain platforms *(Shilina, 2022)*.

BNB Chain:
BNB chain is a blockchain network that is designed to handle transactions faster and more economically, which has made it a popular choice for DeFi applications. It uses a unique consensus mechanism (Proof of Staked Authority (PoSA)) and includes an Ethereum Virtual Machine (EVM), allowing it to work smoothly with Ethereum based apps. Like Ethereum, BNB Chain has its own token standards, such as BEP-721. BEP-721 offers faster transactions and lower fees than Ethereum, making it a good option for creating and trading NFTs *(Shilina, 2022)*.

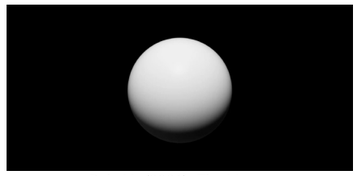
Other NFT Standards:
In addition to these standards, Cardano and Solana provide native tokens for NFTs, while Cosmos, NEAR, and Ceramic Network are developing their own non-Ethereum standards.

3.4 NFT USE CASES

Intellectual Property and Patents:
NFTs provide a unique way for users to establish their rights to content, exceeding the capabilities of traditional intellectual property protection tools like trademarks and copyrights. The ownership of an NFT is easily identifiable through timestamps recorded throughout its history on the blockchain. Even so it provides a useful tool, it is also important to note that owning an NFT doesn't automatically give the owner all intellectual property rights associated with the content. However this allows NFT owners to demonstrate their original authorship of a specific piece of work at any given time.

These advantages extend to patents as well. NFTs can serve as a reliable tool to protect and verify ownership of inventions. Furthermore, NFTs can provide the essential data for verification, establishing a public ledger that systematically documents and stores all transactions related to patents *(Shilina, 2022)*.

Visual Art:
NFTs, often linked with visual art, have received significant attention through notable digital artwork auctions. There have been several sales that reached millions of dollars. For example, In 2021, the most expensive NFT sold was "The Merge" by the digital artist Pak ($91.8 million).



Pak, M. (2021). The Merge

NFTs also had a significant impact on the digital art market because they provide a solution to two major issues in the space: copying other people's work and proving who owns the art. With the use of NFTs, which are based on blockchain technology, each piece of art is given a unique digital signature, which helps in proving if it is real, who owned it over time, and who is the creator. This makes it harder for people to steal someone else's work and sell it as their own.

NFTs also provide artists and creators with new ways to monetize their works. For example, artists can earn royalties from every secondary sale if they sell their artwork as an NFT. This was not possible before with the traditional methods *(Shilina, 2022)*.

Music:
Music NFTs provide a new way to own music digitally, similar to collecting a limited "first edition" record, but in a digital format. These NFTs are the proof of ownership of the unique audio file for the buyers, even if the files themselves are stored on platforms such as Bandcamp or IPFS.

In the traditional way, musicians usually lost half of their earnings to intermediaries, keeping only half of it for themselves. However, NFTs provide an equitable solution to artists: blockchain based streaming platforms and blockchain royalty tracking systems. On top of these, there are also specific marketplaces for music NFTs, like Audius, Catalog, and Sound.xyz, which make it easier for people to buy and sell these NFTs. Some marketplaces even focus on specific genres, like Groovetime, which focuses on dance music.

Also, the entrance of big names to the spaces like Snoop Dogg, Kings of Leon, and Warner Music Group, shows how NFTs can change the music industry *(Shilina, 2022)*.

Collectibles:
NFTs have introduced a new way of how collectibles work in the digital space, offering unique digital items that can be easily bought, sold, or traded. A good example that shows this aspect of NFTs is the NBA Top Shot collection. This collection introduced an entertaining and engaging way to use NFTs in the form of digital trading cards. These cards feature the NBA's greatest moments as highlights in an officially licensed way. Because they are backed by blockchain technology their authenticity is provable, which makes NFTs perfect for use in the collectible concept *(Shilina, 2022)*.

NBA, & Dapper Labs. (2021). NBA Top Shot

Games:
NFTs and blockchain are introducing a new experience to gaming by offering the possibility of true ownership of in game items. This means that players can trade, sell, or profit from their items if their value increases, creating dynamic in game economies. Additionally, game developers benefit from this by earning royalties from every in game transaction, making it an equally beneficial system.

There is also another blockchain based gaming trend, called "play-to-earn". This allows players to earn NFTs or cryptocurrencies as they play, which they can then sell for real world profit. This model can also improve the gameplay. Axie Infinity is an example of this play-to-earn system, though some critics say that it focuses too much on earning and less on having fun *(Shilina, 2022)*.

Sports:
NFTs have also impacted the sports industry. The Golden State Warriors became the first U.S. sports team to release their own NFTs. NBA Top Shot allowed fans to buy, sell, and trade officially licensed basketball highlights as digital collectibles. Similarly, the NFT platform Autograph has partnered with top athletes like Tiger Woods, Naomi Osaka, and Simone Biles, among others *(Shilina, 2022)*.

Golden State Warriors. (2022). Golden State Warriors 2022 Playoff NFT

Fashion:
NFTs in fashion use blockchain technology to create and sell unique digital fashion items like virtual clothing, accessories, and fashion shows. These NFTs give designers a new way to share their creativity, offer exclusive designs, and create engaging virtual experiences.

One example of this is the CryptoKicks, created by RTFKT in collaboration with Nike. They designed virtual sneakers as NFTs. Collectors can own and trade these digital sneakers, with some selling for thousands of dollars *(Shilina, 2022)*.

RTFKT, & Nike. (2023). RTFKT x Nike Air Force 1 collection

Domain Names:
Domain NFTs are unique web domains that are sold as NFTs. The key advantage of domain NFTs is that unlike traditional Web2 domains that require annual renewal fees, domain NFTs are a one time purchase and they provide the full ownership to the user without any censorship or the possibility of being taken away by others.

Another special feature of domain NFTs is that they can also be used as cryptocurrency addresses. This makes it easier to send and receive cryptocurrencies without needing complicated id numbers. Platforms like Ethereum Name Service (ENS) have made this popular, turning complicated crypto addresses into simpler, user friendly domain names *(Shilina, 2022)*.

Metaverse:
The metaverse is a virtual space that combines technologies like augmented reality (AR), virtual reality (VR), and blockchain with social media ideas. It creates an interactive online space where people can connect, explore, work, and play using their personal avatars.

Additionally, the integration of blockchain technology and NFTs into the metaverse allows users to own digital items such as virtual outfits or virtual lands. These items can be traded across different platforms using crypto wallets, demonstrating its interoperability *(Shilina, 2022)*.

Supply Chain:
Blockchain technology can significantly improve the supply chain by making data transparent and immutable. This helps verify the authenticity and reliability of supply chain data. This is especially crucial in industries like food and commodities, as it is important to understand where items come from and how they reach consumers.

NFTs can also be very useful for managing supply chains, as they provide reliable digital records for physical items through the use of blockchain technology. Companies can use NFTs to digitally represent their physical products, which can help them track products, see where they came from, prove who owns them, and confirm any certifications related to them *(Shilina, 2022)*.

- ***Product Origin and Authentication:***
  NFTs help verify the authenticity of products, making the manufacturing process transparent and preventing counterfeits. For example, the luxury watch brand Breitling gives each watch a digital passport as an NFT, which confirms its authenticity and ownership and is connected to a warranty program to track repairs. Similarly, NFTs can be used to help verify that food products are real. Consumers can scan a QR code on a nutritional supplement to follow its journey from production to delivery, helping to identify false claims about its origin and sourcing *(Shilina, 2022)*.

- ***Traceability:***
  Blockchain and tokenization are being used in many industries to track products. In this system, NFTs are being used as unique digital twins that represent the physical product in the digital space. When NFTs are created for batches of products, they provide a secure and traceable link between the prouct's digital twin and the actual product. This link allows the tracking of the product's journey through the supply chain *(Shilina, 2022)*.

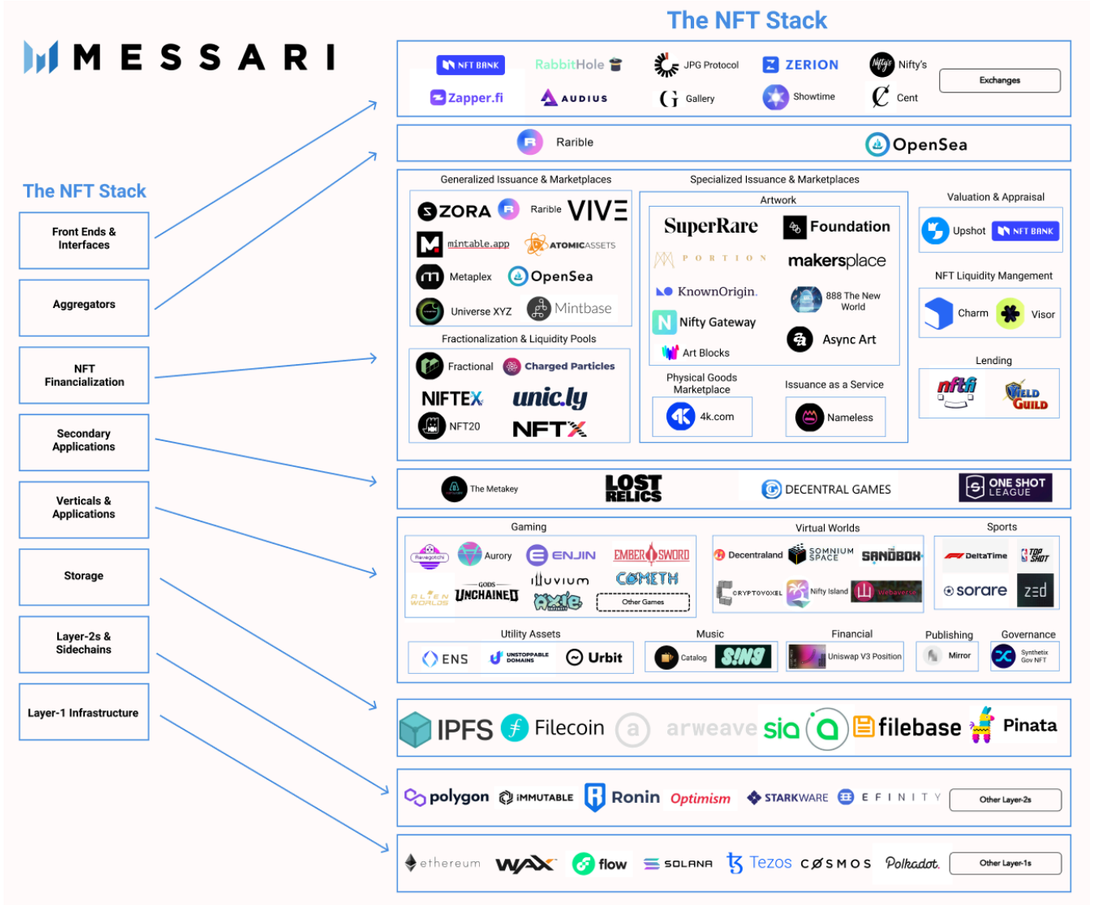
- ***Product Certifications:***
  Important business documents like certifications, invoices, and sales orders can each have a unique NFT to represent their digital identity. Certifications that prove a product is organic or fair trade are particularly important, as they can help increase sales by giving assurance to consumers. These certifications can be issued as NFTs on the blockchain by specific certifiers. After they are issued, they can be linked to the products through the supply chain, until they reach the final consumer. The consumer can then easily verify the authenticity of these certifications by scanning a QR code or through the use of an NFC tag *(Shilina, 2022)*.

3.5 THE NFT STACK

NFT space has grown from a small network with low activity and sales volume to a diverse, multi-chain ecosystem made up of several different layers. Each of these layers has its specific characteristics, goals, and functions, with many projects specializing in each area.

Layer 1: Layer-1s:
Currently, Ethereum is dominating the NFTs landscape, followed by Flow and to some extent, Wax. Even though Ethereum is dominating the NFT landscape, in time, many NFT projects might migrate to Layer-2 solutions or sidechains to improve scalability (faster and cheaper transactions). However, high-value digital art collections (blue chip collections) may still prefer Ethereum as their main network because of its stronger censorship resistance *(Nystrom, 2021)*.

Layer 2: Layer-2s and Sidechains:
Many consumer-centric NFT applications, such as gaming, sports, and virtual worlds, have had scalability issues on the Ethereum blockchain. Because of these limitations, games like Sorare initially used sidechains like Loom but had some reliability issues, while Axie Infinity developed its own sidechain, Ronin. There are also other sidechains such as Immutable X, Optimism, and Polygon, that are emerging to address and improve NFT scalability *(Nystrom, 2021)*.



Nystrom, M. (2021). The NFT Stack: Exploring The NFT Ecosystem

Layer 3: Storage:
Layer 1 blockchains have limited on-chain storage capacity. Because of this NFTs often require external storage solutions. IPFS (InterPlanetary File System) and Arweave offer permanent storage for NFTs, while Filecoin provides a cheaper option for real time storage. Also, services like Filebase or Pinata provide user-friendly interfaces and enterprise desired features such as S3 Compatible Object Storage (a common storage standard) and service-level agreements (SLAs), which address the need for companies to have formal and legal agreements when using IPFS or other storage layers *(Nystrom, 2021)*.

Layer 4: Applications:
While NFTs are mainly created and transferred at Layer 1 and Layer 2, the application layer serves as an important interface for the issuance of these tokens. For example, the growth of virtual worlds such as Decentraland and Cryptovoxels has shown a variety of activities such as conferences, art galleries, casinos, and future use cases.

Fantasy sport applications, such as Sorare, are also gaining a lot of attention as new users join the space, which shows the success of crypto based sports platforms. While there are still challenges with scalability, it is a growing space *(Nystrom, 2021)*.

Layer 5: Secondary Applications:
Composability allows developers to build new applications on top of existing ones. For example, virtual worlds like Decentraland include different applications, such as the online casino called Decentral Games. Similarly, Sorare, in partnership with Ubisoft, developed a fantasy league called One Shot League using Sorare's existing cards. The ability of this layer to combine and expand on existing systems creates more opportunities for developers and helps these platforms to grow *(Nystrom, 2021)*.

Layer 6: NFT Financialization:
For NFTs to grow, they need tools like lending, liquidity, and asset management, similar to assets in DeFi. While the important thing about NFTs is their uniqueness, improving their liquidity is also important for potential financial use cases.

To achieve NFT liquidity, protocols create liquidity pools where people can deposit NFTs from the same collection or fractionalized NFTs. Fractionalization is about dividing an NFT into smaller, fungible tokens to allow shared ownership and making it easier to trade or invest in these assets. By doing this, protocols can create markets with higher liquidity, expanding the financial possibilities of NFTs *(Nystrom, 2021)*.

Layer 7: Aggregators:
NFT marketplaces are platforms for buying and selling NFTs. OpenSea is the most used marketplace, along with LooksRare, both of which have the highest trade volume on Ethereum. Other well known marketplaces include Magic Eden, Solanart, and Blur, which also see significant monthly activity *(Nystrom, 2021)*.

Layer 8: Front Ends and Interfaces:
In the NFT space, many companies are competing with each other to create the best tool for interacting with NFTs. At first, efforts centered around collectibles and digital art, which led to the creation of galleries and platforms for displaying NFT collections.

Wallets like Coinbase Wallet and Rainbow, along with apps like Zapper and Zerion, make it easy for users to view and manage their NFTs.

Additionally, there have been platforms like NFT Bank that provide features such as investment analysis and price predictions. Other platforms like Nonfungible, CryptoSlam, and Nansen, also provide analytic tools, but they do not provide the option for viewing individual NFTs *(Nystrom, 2021)*.

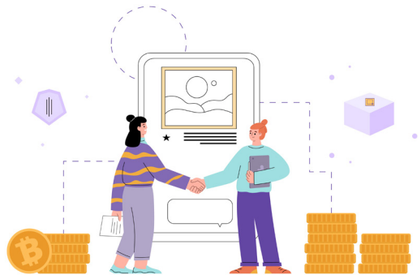
3.6 NFT MARKETPLACES

3.6.1 Understanding NFT Marketplaces

NFT marketplaces are platforms that allow the buying, selling, and creation of NFTs.

3.6.1.1 How Do NFT Marketplaces Work?

NFT marketplaces work similarly to other online marketplaces, with the only difference being that they only sell NFTs. These NFTs can be sold at predetermined prices or through auctions. From the customer's side, they work similar to traditional online marketplaces. However, since they are developed using blockchain technology, users must create a blockchain wallet that is compatible with the chosen marketplace and transfer cryptocurrency to this wallet. Additionally, these blockchain wallets are not only used for transactions but also to store the purchased NFTs *(What Is an NFT Marketplace?, 2023)*.



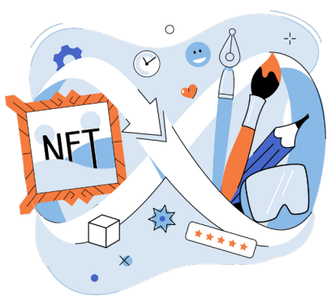
From the seller's side, the process starts with creating an account on the NFT marketplace. Once the seller is registered, they can list their digital assets by uploading them to these marketplaces and setting a price. Many marketplaces also give the option to mint new NFTs directly on the platform, which is a process commonly known as the release of a new NFT collection for presale at a predetermined price *(What Is an NFT Marketplace?, 2023)*.

It is also important to note that NFT marketplaces operate using smart contracts and blockchain technology, which securely store information related to NFT transactions, connect buyers and sellers, and provide details about each transaction.

3.6.1.2 Blockchain's Role in NFT Marketplaces

The Ethereum blockchain is the most widely used blockchain for NFT transactions today, mainly because of its ability to execute smart contracts more efficiently. It facilitates secure transactions, cryptocurrency trading, the buying and selling of NFTs, and the development of decentralized applications and games.

NFT marketplaces, built on blockchain technology, allows the trading and management of NFTs. As a distributed database, blockchain records all transactions that are happening in these marketplaces, securely storing important information such as the creator of the NFT, the buyer, transaction date, and the transaction price *(What Is an NFT Marketplace?, 2023)*.



3.6.2 Primary vs. Secondary Marketplaces

There are two types of NFT marketplaces: primary and secondary. Even if they sound similar and both have the same purpose which is the buying and selling of NFTs, there are also significant differences between them.

3.6.2.1 What is an NFT Primary Marketplace?

A primary NFT marketplace is where NFTs are sold for the first time, usually through a process called "minting". These marketplaces can either be the official website of NFT projects or platforms created by the artists themselves.

Many NFT creators use primary marketplaces to launch and sell their collections. Buyers can connect their crypto wallets to these platforms, allowing them to easily purchase NFTs using cryptocurrency *(Mrig P, 2023)*.

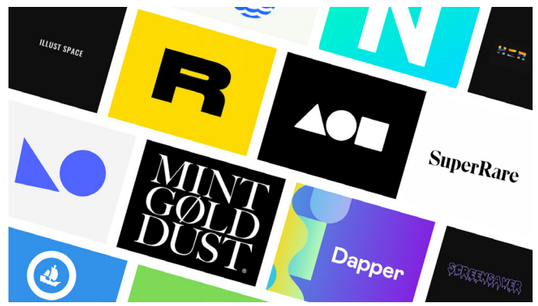
3.6.2.2 Benefits of Primary NFT Marketplaces:

- **Excitement of NFT Reveal:** In generative NFTs, collectors often have no idea how their NFT will look until it is revealed. This element of surprise creates excitement and builds anticipation. This uncertainty makes the process of buying a new NFT more interesting and appealing, which also adds a fun aspect to the whole process.
- **Simplicity of Buying Multiple NFTs:** Minting makes it easy to buy multiple NFTs at once in a single transaction. This simplifies the process and helps reduce gas fees as buyers can pay one single transaction fee.
- **Early Access Benefits:** NFT projects often reward their first supporters with special perks. These can include free or discounted mints for future NFTs, exclusive membership in the projects DAO's, or a special role in the Discord community.
- **Potential for Increase in Value:** Minting an NFT gives buyers the opportunity of getting a rare and possibly more valuable item from a collection, which they could later sell for a higher price if they want to. However, there is also a chance that the value of the NFT could decrease over time *(Mrig P, 2023)*.

3.6.2.3 What is an NFT Secondary Marketplace?

An NFT secondary marketplace is where people buy and sell NFTs that have already been minted on a primary marketplace. These marketplaces include a variety of different NFT collections from different creators and companies.

Some of the most popular secondary marketplaces are OpenSea, Rarible, and LooksRare. Other notable marketplaces in this category are Blur, Magic Eden, Solanart, and Axie Marketplace *(Mrig P, 2023)*.



3.6.2.4 Benefits of Secondary NFT Marketplaces:

- **Better Security:** Secondary marketplaces are generally safer for buying NFTs because the NFTs listed on these platforms have already been minted. These platforms also provide buyers a better idea about the value of the NFT's, which helps reduce uncertainty.

- **Lower Transactions Costs:** When minting on a primary marketplace, many people often compete to buy a limited number of tokens, causing gas fees to increase and sometimes reach hundreds of dollars per transaction. On the other hand, secondary marketplaces give buyers more flexibility to choose when to make their purchase. By buying during times of lower network activity, buyers can reduce gas fees significantly.

- **No Failed Transactions:** In a primary marketplace, there is a risk that NFTs may sell out before a transaction is completed. This can result in the loss of the gas fee for the failed transaction. On the other hand, these issues are very rare in secondary marketplaces, as buyers usually do not purchase the same NFT at the same time.

- **Fewer Technical Issues:** During an NFT mint, the creator's website can sometimes crash, causing transactions to fail and buyers to lose the transaction fees they paid. While this is usually a small inconvenience, it can still be a financial risk for buyers. On the other hand, secondary marketplaces are more reliable and less likely to face technical issues during transactions *(Mrig P, 2023)*.

3.7 INVESTING IN NFT

3.7.1 Why Do People Buy NFTs

People buy NFTs for different reasons, with the two main reasons being investment opportunities and the joy of collecting.

For many, NFTs are seen as a financial opportunity. Some buyers "flip" NFTs, which means buying and selling them quickly for a profit, and some buyers hold onto them for long term investment.

For some others, buying NFTs is a passion for collecting. These buyers enjoy supporting their favorite artists or creators. In the gaming industry, NFTs can also open up new possibilities as they can unlock new gameplay features or improve the overall gaming experience in blockchain based games.

Additionally, most NFT projects now offer appealing perks such as utility, community benefits, and merchandise. These features make NFTs not just an investment or a collectible but also an engaging and rewarding experience *(Why Do People Buy NFTs? - Everything You Need to Know, n.d.)*.

3.7.2 Advantages and Disadvantages

3.7.2.1 Advantages of Investing in NFTs:

- **Allowing Anyone to Invest:** NFTs can be accessed by people all over the world, creating a potentially limitless market and demand.

- **Creating Verifiable Contracts:** NFTs can digitally represent ownership of any item, providing benefits in documenting ownership. The ability to quickly create, verify, and transfer electronic contracts reduces the time and costs related with managing physical contracts, reducing reliance on traditional legal services.

- **Strengthening Legal Evidence:** NFTs are created and stored using blockchain technology, which is tamper-proof. This makes it easier to prove ownership of an asset and harder to challenge in a court of law.

- **Fractionalizing Ownership:** Dividing ownership of expensive assets into smaller parts can be a useful way to raise funds. These smaller parts can be traded in secondary markets by hundreds, thousands, or even millions of people. This increases liquidity and makes it easier to buy and sell these shares and raise money. In simple terms, it allows expensive assets to be divided into smaller, more affordable parts that can be easily bought and sold, giving companies a way to raise funds and investors an opportunity to get involved *(Garnett, 2024)*.

3.7.2.2 Disadvantages of Investing in NFTs:

- **Lack of Regulations:** NFTs are mostly unregulated, with minimal laws and limited consumer protections. This lack of regulation can lead to issues like market manipulation, often caused by misinformation and speculative hype. These factors can cause NFT prices to change quickly, increasing the risk of scams like pump and dump.

- **Fraud and Scams:** Because it is relatively easy to set up a marketplace and make transactions online, the NFT space is often targeted by fraud and scams. This makes it possible for people to make false claims about NFTs and take advantage of buyers or sellers. This lack of rules and oversight also gives scammers more chance to operate without getting caught.

- **Limited Legal Rights:** NFTs can prove ownership and help resolve disputes, but they don't stop the tokenized asset from being copied or pirated. NFTs don't provide legal rights like patents, trademarks, or copyrights. This means that others could challenge ownership, make copies of the asset, or sell fake versions of the asset without needing permission.

- **Securing NFTs:** Keeping NFTs safe is a responsibility that users have to manage on their own. It can be difficult and time consuming to keep the public and private keys of an NFT wallet safe, and error could result in losing access, either because of technical difficulties or hacking. Additionally, since blockchain transactions are transparent, NFTs don't offer much privacy and can sometimes be exposed to malware risks.

- **Weighing a Dual Investment Structure:** When investing in NFTs and the assets that they represent, it is important to note that while the NFT's value is connected to the asset, they are not the same thing. To make informed decisions, investors should make research and understand both the value of the asset and how the NFT works financially. It is also important to note that digital items like NFTs often have less real value compared to physical items *(Garnett, 2024)*.

WEB 3.0

4.1 INTRODUCTION TO WEB 3.0

4.1.1 What is Web 3.0?

Web 3.0 introduces a new era for the World Wide Web, built on the concept of decentralization. At the core of Web 3.0, blockchain technology is expected to play an important role, ensuring security and transparency. Additionally, artificial intelligence (AI) and machine learning (ML) will bring enhanced intelligence and adaptability to the internet *(Essex et al., 2023)*.

4.1.2 Evolution of Web 3.0

Web 1.0:
Web 1.0 is the first version of the web, developed by Tim Berners-Lee in 1989 and lasted until 2004. Often called the "read only web", it was made up of static web pages connected by hyperlinks. This early web didn't have interactive elements or complex designs. Even email was very basic, limited to plain text without the ability to send image attachments. Most websites were personal pages hosted by free hosting platforms or internet service providers (ISPs). The main goal of Web 1.0 was to serve as a content delivery network (CDN), where users could browse and read content without being able to interact, post comments, or leave reviews.

Web 2.0
Web 2.0 started around 2004 and introduced the "read-write web". This allowed users to actively participate and interact online. It was a significant improvement from the one way communication of Web 1.0.

With Web 2.0, social media platforms such as Facebook, Twitter, and YouTube became very popular, as they provided users with the opportunity to connect with others, share content, and leave reviews. Smartphones also had a big impact in this period, helping apps like Instagram and WhatsApp become widely used around the world.

Additionally, Web 2.0 transformed the internet to a platform for apps and online shopping (e-commerce). It created the foundation for numerous web services, with billions of users generating a massive amount of content.

Web 3.0
Web 3.0 is the next step in the evolution of the internet and it can bring changes as impactful as Web 2.0. Focused on the concept of decentralization, transparency, and greater user utility, it aims to transform the internet into a more user centric ecosystem.

Berners-Lee discussed some of the key concepts back in the 1990s, as outlined below:

- ***Decentralization:*** No permission is needed from a central authority to post anything on the web; there is no central controlling node, and thus, no single point of failure. This setup eliminates the existence of a "kill switch" and ensures freedom from indiscriminate censorship and surveillance.

- ***Bottom-up Design:*** Rather than code being written and controlled by a small group of experts, it was developed openly for everyone to see, encouraging maximum participation and experimentation.

In 2001, Tim Berners-Lee imagined a "Semantic Web" where computers would understand the meaning of online information and provide users with more personalized experiences. However, doing this was very difficult at that time. Teaching computers human language elements required significant time and resources. Additionally, the web's evolution, especially the rise of social media and user generated content, has created a Web 3.0 that is different from Berners-Lee's original idea *(The Investopedia Team, 2024)*.

4.2 KEY FEATURES OF WEB 3.0

- **Ubiquitous Connectivity and IoT Support:**
  Ubiquitous connectivity and IoT support distinguish Web 3.0 from its earlier versions. The use of semantic metadata ensures that data and information are interconnected and more accessible. IoT further improves this by allowing users to access data across multiple applications anytime and anywhere, creating deeper engagement and interaction *(BasuMallick, 2022)*.

- **Decentralization:**
  One of the most important features of Web 3.0 is decentralization. It uses distributed networks to allow data exchange and transactions without relying on intermediaries. This approach helps protect user privacy and ensures ownership of their data *(Nasar, 2023)*.

- **Blockchain and Smart Contracts:**
  Web 3.0 and blockchain work well together because they both focus on decentralization, better connectivity, and compatibility across different platforms. A key feature of this system is also smart contracts, which automate tasks such as processing transactions. Together, these technologies simplify processes, enhance security, and transform businesses by improving productivity and transparency.

- **Decentralized Data Storage:**
  Decentralized data storage is not a key feature of Web 3.0, but adding it improves security and reliability compared to centralized systems. In Web 2.0, there is an unspoken agreement between users and platforms, where platforms own the user data, and users get access to the platform's services. This led to the creation of "data islands" between different platforms, which made it harder to move or share information across them.

As more people understand the importance of owning their data, it becomes very important to address issues like reducing the cost of data storage and ensuring that the benefits of data ownership are distributed more fairly. To implement decentralized data storage, researchers have made notable contributions such as:

IPFS: IPFS, or the InterPlanetary File System, holds the potential to transform how we navigate the internet. Unlike the current HTTP and HTTPS protocols that power the World Wide Web, IPFS aims to create a decentralized file system connecting all devices.

HTTP works on a request-response model, where users connect to servers based on their geographical location. For example, when someone from the US visits a website hosted on an Amazon server, that person's browser gets the content from Amazon Web Services. However, this centralized model creates risks, as downtime in servers like AWS can affect a significant portion of the internet.

In contrast, IPFS offers a solution by allowing the creation and sharing of permanent, distributed web content. It gives priority to content over servers, ensuring that data remains accessible even if individual servers go offline. This approach provides numerous advantages, such as enhanced data integrity, resistance to censorship, and reduced operational costs *(McKay, 2022)*.

- **Semantic Web:**
  Web 3.0 is expected to be a "semantic web" because it organizes data in a way that machines can easily understand and use. This allows for more advanced search capabilities and helps automate tasks and decision making processes *(Nasar, 2023)*.

- **Artificial Intelligence and Machine Learning:**
  Computers will be able to understand and process information similarly to humans in Web 3.0. This will be achieved using technologies based on Semantic Web principles and natural language processing. It will also include machine learning, a type of artificial intelligence that uses data and algorithms to learn and improve over time, becoming more accurate as it processes more information *(The Investopedia Team, 2024)*.

- **Data Ownership:**
  With Web 3.0, users can sell or share their data through decentralized networks while keeping full control over it. This data will be created by different devices, such as smartphones, personal computers, appliances, cars, and sensors.

Web 3.0 will store information in multiple locations at the same time, decentralizing it and organizing it based on content rather than physical location. This change will give users more power by reducing the massive data control currently held by companies like Google and Meta *(BasuMallick, 2022)*.

4.3 WEB 3.0 USE CASES AND APPLICATIONS

Web 3.0 will use AI powered tools to improve the online experience, customizing online content to meet individual user needs and preferences. Unlike Web 2.0, users will have control over their personal data, deciding how their data is used. A large portion of this content will be automatically generated, making Web 3.0 more efficient by saving both time and money *(Essex et al., 2023)*.

Built on blockchain technology, Web 3.0 will also support new applications and services based on existing blockchain technologies like:

- **Cryptocurrency:** Cryptocurrencies, like Bitcoin, are digital currencies built on blockchain technology. They use cryptography to secure the creation of monetary units, transaction processes, and verification of ownership changes.

- **Metaverse:** The metaverse is a virtual world where people can interact as avatars. Based on Web 3.0 principles, it aims to create immersive experiences while keeping decentralization. It also supports creator driven economies, giving users more freedom and control over their online activities.

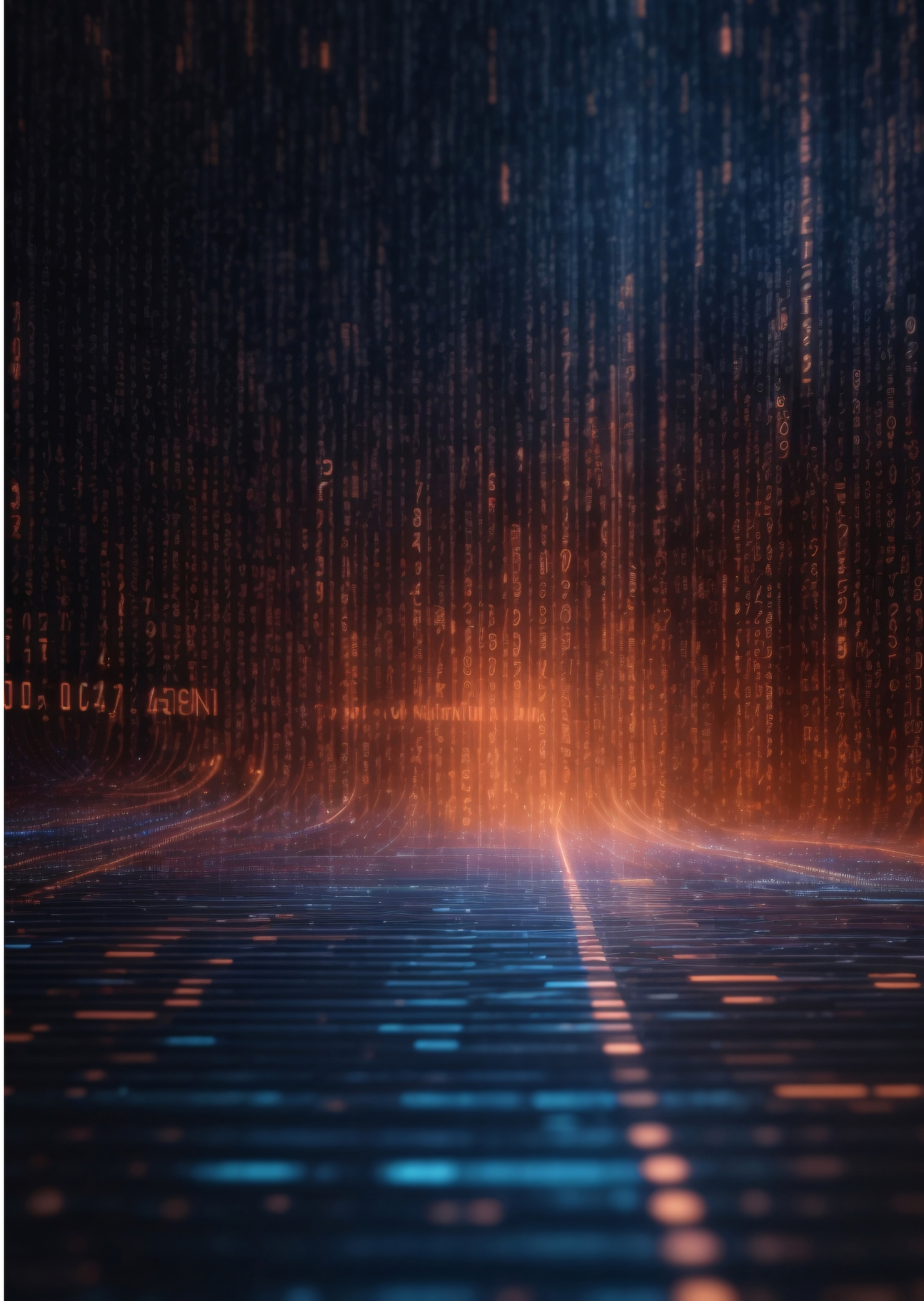
- **Decentralized Applications (DApps):** DApps are open source softwares developed on decentralized blockchain platforms. They can be improved by others, and any modifications are recorded on the blockchain's distributed ledger.

- **NFTs:** NFTs are unique digital assets that use cryptography to verify ownership. They are expected to play an important role in how valuable items are created and traded in Web 3.0.

- **Decentralized Autonomous Organization (DAO):** DAOs play an important role in supporting decentralized Web 3.0 services. They provide the structure and governance needed to make decentralized systems work efficiently and effectively.

- **Cross-Chain Bridges:** In Web 3.0, where many blockchains will work together, cross-chain bridges are very important for creating interoperability. These bridges will help assets and data to move seamlessly between different blockchain networks.

- **Decentralized Finance (DeFi):** DeFi is a growing blockchain technology that could become the foundation of financial services in Web 3.0 *(Essex et al., 2023)*.



4.4 ADVANTAGES AND DISADVANTAGES OF WEB 3.0

Advantages of Web 3.0:

- **Transparency:** Users can view the source code of the platforms they use and track their own data thanks to the decentralized web. This means everyone involved can see the value and transactions they are part of, without needing intermediaries to provide access to this information *(Shaikh, 2023)*.

- **Fewer Intermediaries:** Web 3.0 will allow businesses to connect directly with customers, reducing the need for central authorities that currently take a share of transaction earnings. While regulations will still be necessary to ensure fairness, the focus will move toward trustless and decentralized networks, reducing reliance on centralized systems *(Shaikh, 2023)*.

- **Data Ownership:** Users will have full control over their data. They will have the power to choose what data to share with businesses and even profit from it. Additionally, Web 3.0 will not be controlled by any single authority, allowing dApps to work without censorship or restrictions *(Shaikh, 2023)*.

- **Democratized Access for All:** The goal of Web 3.0 is to provide equal access to digital platforms for everyone. No matter the location, social status, beliefs, gender, or income, everyone can participate in digital services equally, thanks to its decentralized approach *(ProofEasy, 2023)*.

- **Increased Reliability:** Web 3.0's decentralized architecture removes the possibility of a single point of failure, making it more reliable *(BasuMallick, 2022)*.

- **Personalization:** With websites getting better at understanding and adapting to each user's preferences, Web 3.0 will provide a more customized online experience *(Shaikh, 2023)*.

- **Better Creator Economy:** Web 3.0 creates a better environment for content creators by helping them address challenges in earning the full value of their work. Intermediaries often restrict access to audiences in the current system, which limits the opportunities and income available to creators. Web 3.0 gives creators more control and allows them to profit directly from their works through features like tokenization *(ProofEasy, 2023)*.

Disadvantages of Web 3.0:

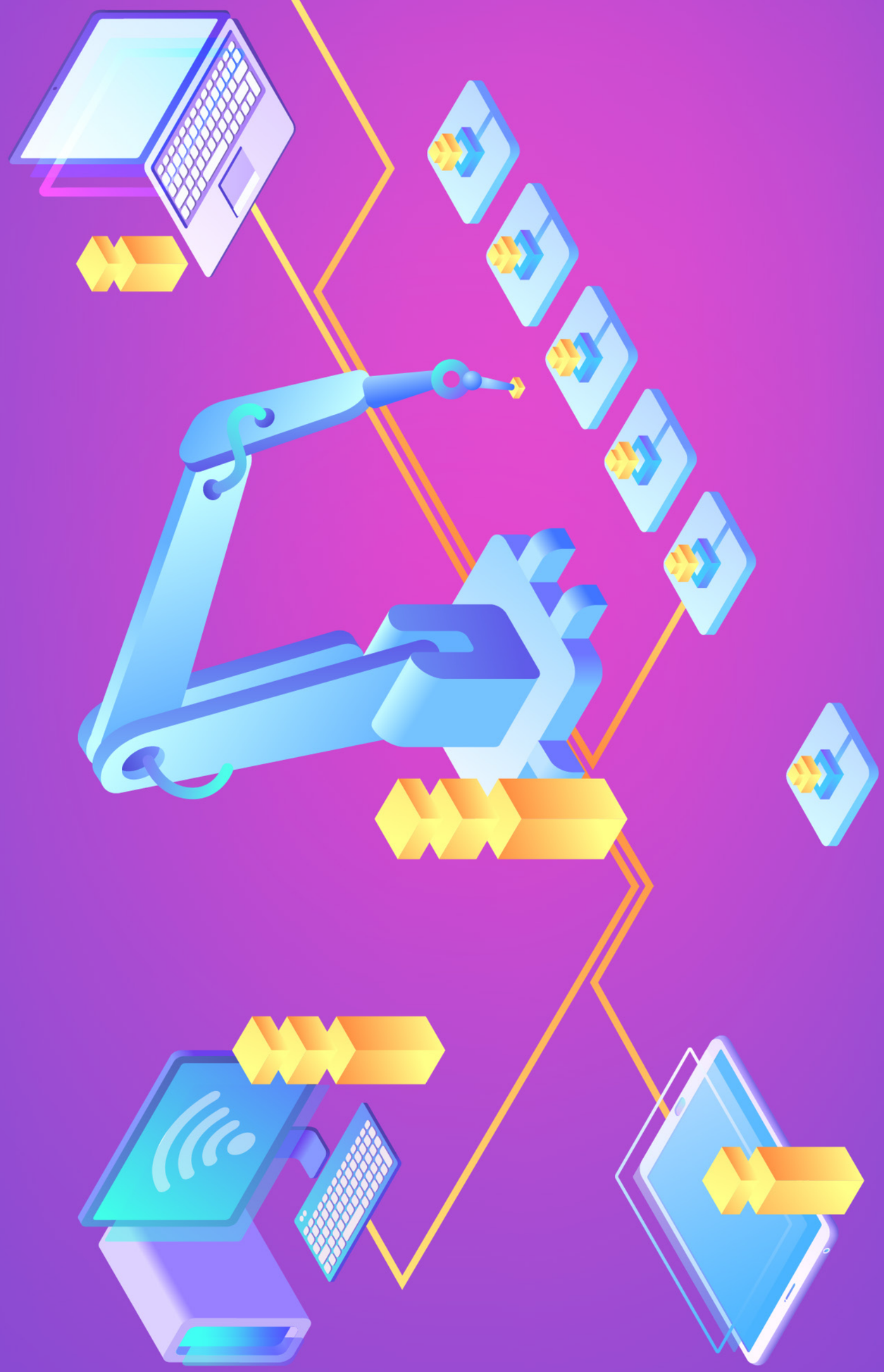
- **Complicated for Beginners:** One of the main challenges of Web 3.0 is that the technology can be hard for beginners to understand *(MetaSpace, 2023)*.

- **Technological Requirements and Carbon Footprint:** One of the main drawbacks of Web 3.0 is its technical requirements and the associated environmental impact. Because Web 3.0 relies on blockchain technology, it often uses systems that require a lot of energy, which significantly increases its carbon footprint *(MetaSpace, 2023)*.

- **Scalability:** calability is a big challenge for Web 3.0 because it uses P2P networks. As more people join the network and traffic increases, managing the growth can be difficult, which might slow its development and adoption *(MetaSpace, 2023)*.

- **Security:** Security is a very important aspect of Web 3.0 that needs significant attention. There have been breaches on blockchains and cryptocurrency exchanges, as well as hacks of smart contracts, which are commonly reported problems. Developing secure systems is very important to build trust in the space.

- **Regulatory Concerns:** The decentralized nature of Web 3.0 can also present significant regulatory challenges. As there is no centralized authority, and as a result, no significant regulations, users' online activities may become less secure, potentially leaving them with fewer legal protections. Additionally, the lack of clear regulation increases the risk of fraud, as there is no significant way to punish bad actors in the space.



INDUSTRY 4.0

5.1 INTRODUCTION TO INDUSTRY 4.0

By combining technologies like cloud connectivity, AI, ML, and the industrial internet of things (IIOT), Industry 4.0 is changing the way manufacturing is done. The combination of these technologies allows the creation of smarter and more connected products, industries, and systems.

Automation of repetitive tasks improves productivity by providing a collaborative environment between humans and technology. This collaboration allows teams to focus on more creative and challenging tasks, thereby increasing efficiency and creativity *(Industry 4.0: The Future of Manufacturing, n.d.)*.

5.1.1 What is Industry 4.0?

Industry 4.0 is about the use of innovative technologies to transform manufacturing and industrial operations. These technologies include robotics, automation, big data analytics, AI, ML, and the IIoT. With the integration of these technologies, Industry 4.0 allows the creation of smart factories and smart manufacturing, improving flexibility, efficiency, and productivity. It also encourages customization and intelligent decision making in supply chain and manufacturing processes *(Industry 4.0: The Future of Manufacturing, n.d.)*.

5.1.2 The Evolution of Industry 4.0

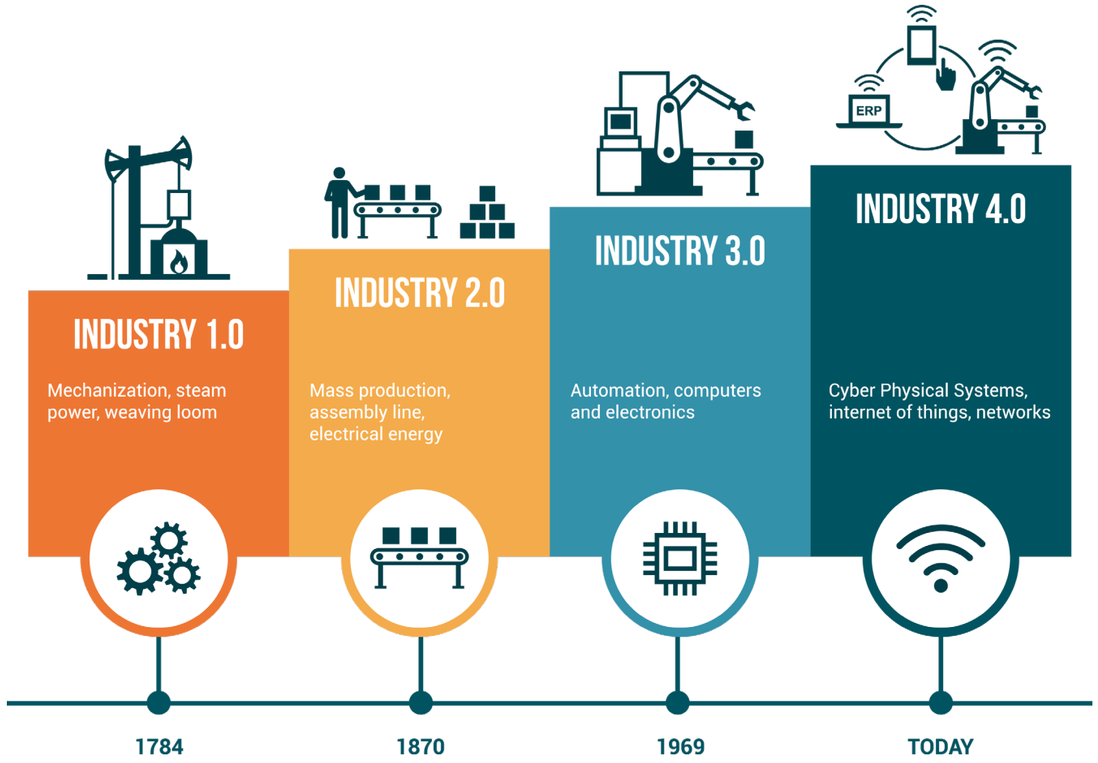
- **First Industrial Revolution**
  The First Industrial Revolution began in the late 18th century and continued until the middle of the 19th century. During this time manufacturing went through a significant change from manual labor to mechanized production powered by steam and water. It started in Great Britain and then quickly spread to Europe and the United States. This period also witnessed the growth of the global economy, the development of factories, and improvements in productivity and efficiency *(Hyseni, 2023)*.

- **Second Industrial Revolution**
  The Second Industrial Revolution took place between the late 19th century and early 20th century. During this time, new industries developed, electric power became widely used, assembly lines were introduced, and railroads and steamships were added to the transportation infrastructure *(Hyseni, 2023)*.

- **Third Industrial Revolution**
  The Third Industrial Revolution started in the 1960s and continued until the end of the 20th century. It brought significant changes to the world, such as the introduction of new communication systems, information technology, electronics, the internet, and new energy sources. Computer aided design and manufacturing (CAD/CAM) systems and computer controlled machinery were also introduced *(Hyseni, 2023)*.

- **Fourth Industrial Revolution**
  The Fourth Industrial Revolution (Industry 4.0) started in the early 21st century. It is characterized by digitalization, innovation, and modern technologies that improve automation, streamline production, and enable the creation of new products and services.

This period also brought significant changes to the economy and society, including greater connectivity, easier access to information, the growth of the sharing economy, and new forms of working. However, it also created some problems, such as cybersecurity, privacy issues, and the effect of automation on employment *(Hyseni, 2023)*.



5.2 TECHNOLOGIES OF INDUSTRY 4.0

Industry 4.0 uses technologies that connect the digital and physical worlds, which allows the development of intelligent and autonomous systems. Some of these technologies are already in use by many businesses and supply chains, but their full potential can only be achieved when they are used together.

Blockchain:
Blockchain is a distributed and decentralized digital ledger that allows secure, transparent, and immutable recording of digital transactions. It impacts Industry 4.0 by contributing to it in several ways:

- ***Supply Chain Management:*** Blockchain allows the tracking of goods and transactions in real time, which improves the efficiency, security, and transparency of the supply chain.
- ***Decentralized Manufacturing:*** Blockchain can be used to develop decentralized manufacturing systems that allow machines to communicate with each other and execute transactions automatically.
- ***Data Security:*** As it uses cryptographic techniques, blockchain can provide a secure way of storing and sharing data. By limiting access to information for those who have the permission, it helps protect sensitive information and reduces the possibility of data breaches.
- ***Digital Identity:*** Blockchain can be used in identity systems to provide secure access to a variety of resources and services. These systems give people a more secure way to verify identity and reduce the risk of fraud and identity theft *(Hyseni, 2023)*.

Artificial Intelligence and Machine Learning:
Industry 4.0 uses AI and ML to automatically analyze data and improve communication. While ML learns from past data to make processes more accurate and efficient over time, AI uses advanced algorithms to imitate human thinking and decision making *(Hyseni, 2023)*.

Augmented Reality (AR):
AR combines digital content with the physical world. People can look at actual products while also viewing real-time IoT data, detailed repair instructions, training materials, and more using smart glasses or mobile devices. AR is especially useful for tasks like maintenance, quality assurance, technician training, safety, and improving overall service in Industry 4.0 *(Industry 4.0: The Future of Manufacturing, n.d.)*.

Cloud Computing:
Cloud computing is an important technology of Industry 4.0 as it provides a scalable and effective way of managing, storing, and analyzing the vast amounts of data collected from sensors and machines.

Common use cases of cloud computing include the management and storage of data, the use of analytics and machine learning models, remote monitoring and control, and collaboration and communication *(Hyseni, 2023)*.

Industrial Internet of Things (IIoT):
The Internet of Things (IoT) connects devices that share data over the internet, creating a network of smart devices that work together.

In a similar way, the Industrial Internet of Things (IIoT) connects devices in factories, warehouses, and shipping operations. These devices, which are equipped with sensors, collect important data that helps businesses in daily operations. Manufacturers can use this data in their systems to improve the planning of production, predict delays, and manage maintenance *(Industry 4.0: The Future of Manufacturing, n.d.)*.

Additive Manufacturing & 3D Printing:
Additive manufacturing, also known as 3D printing, started as a method for quick prototyping but in time expanded to include a wide range of additional applications. It provides a way for businesses to create parts on-demand from digital designs, enabling the production of customized items. In this way, companies can reduce the costs and minimize the need for traditional off-site production. Additionally, over time, the materials used in 3D printing has expanded to include metals, polymers, ceramics, and biomaterials *(Industry 4.0: The Future of Manufacturing, n.d.)*.

Autonomous Robots:
Autonomous robots are an important component of Industry 4.0, as they are made to work with little or no human involvement. As these robots are designed for specific tasks and purposes, they come in different sizes. To perform complicated tasks, these robots include AI, advanced software, sensors, and machine vision. These technologies allow them to understand the environment they are in, process information, and make decisions based on the data they collect *(Industry 4.0: The Future of Manufacturing, n.d.)*.

Digital Twins:
Digital twins are virtual representations of real world products, processes, or systems created from the data collected by IoT sensors. They are very important for Industry 4.0 as they allow businesses to better understand their systems and products. Businesses that are using digital twins can monitor the performance of their products, predict when maintenance is needed, and solve potential issues before they occur, ensuring operations work without any problems *(Industry 4.0: The Future of Manufacturing, n.d.)*.

Cybersecurity:
Cybersecurity is a critical component of Industry 4.0 because of the increased connectivity and the use of Big Data. Companies can use a Zero Trust approach, detecting, preventing, and responding to risks automatically using technologies such as machine learning and blockchain. This reduces the risk of potential data breaches and prevents delays in production across their systems *(Industry 4.0: The Future of Manufacturing, n.d.)*.

5.3 BENEFITS OF INDUSTRY 4.0

Industry 4.0 includes more than just technological improvements. By connecting teams and operations across the manufacturing sector, it creates transparency and integrated business processes that can help the entire organization.

It significantly improves the efficiency of operations by helping businesses better manage resources, reduce downtime, and increase productivity. These improvements also support sustainability efforts, as smart systems and data analytics optimize energy usage, reduce waste, and allow the designing of more environment friendly products throughout their lifecycle.

Industry 4.0 also gives businesses the ability to collect and analyze vast amounts of data in real-time. This ability provides important information to businesses that helps them make accurate and secure decisions. It also helps businesses adapt to changing client needs by providing customized products and personalized solutions.

In summary, Industry 4.0 technologies not only increase efficiency and production, but also give businesses a competitive advantage by allowing them to predict trends and stay ahead of competitors through continuous advancements *(Industry 4.0: The Future of Manufacturing, n.d.)*.

5.4 SMART MANUFACTURING

Smart manufacturing uses real-time data and technologies like AI and the IIoT to adapt quickly to changes in customer and business needs. By collecting data from machines and sensors, it helps improve the efficiency of production, increase product quality, and keep equipment working properly.

Also, smart manufacturing connects data from across the supply chain to predict potential problems, address issues early, and ensure the company can meet its promises to customers *(What Is Smart Manufacturing?, 2022)*.

5.4.1 What is Smart Manufacturing?

According to the National Institute of Standards and Technology (NIST), smart manufacturing is “fully-integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs”.

Smart manufacturing combines human creativity, connected machines, and AI powered systems and analytics through the use of cloud connectivity. By using AI and smart technologies, it becomes more adaptable and improves the ability to quickly change production based on real-time data. Smart manufacturing, which focuses on visibility, adaptability, and resilience, is also very important in creating more effective supply chains and improving overall business operations *(What Is Smart Manufacturing?, 2022)*.

5.4.2 Benefits of Smart Manufacturing

- **Efficiency and Productivity:** Businesses can work faster, smarter, and safer thanks to automation, real-time data analysis, and connected manufacturing systems. Machines connected through IoT can execute operations automatically and predict when maintenance is needed. This allows businesses to save time, reduce errors, and deliver outcomes that are consistent and efficient.

- **Adaptability:** Data analysis and smart manufacturing systems allow businesses to react quickly to changes in the market at every stage of the manufacturing process. With this flexibility, it becomes easier to change production processes and customize products quickly and accurately to meet customer demands.

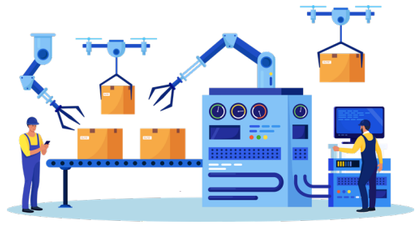
- **Reducing Costs and Risks:** Digital systems that connect the entire supply chain help businesses improve their predictions, manage inventory, and find smarter logistics solutions. This helps reduce risks and lower costs

- **Sustainability:** Smart manufacturing technologies collect data that can help businesses create better plans to improve operations and reduce energy use. From creating eco-friendly products to using environmentally friendly logistics and transportation strategies, these technologies can help with sustainability efforts in different ways.

- **Improved Quality Control:** To make sure that quality standards are visible, easy to verify, and met at every step, smart manufacturing technologies can be used in the supply chain and production processes *(What Is Smart Manufacturing?, 2022)*.

5.5 SMART FACTORIES

Smart factories are advanced facilities where machines, communication systems, and computers work together to create an interconnected network. These factories use technologies such as AI and ML to analyze data, automate tasks, and continuously improve their operations *(Smart Factory: The Future of Manufacturing, n.d.)*.



5.5.1 How Does a Smart Factory Work?

A smart factory brings together machines, people, and big data into one connected digital system. It not only analyzes data but also learns from its experiences. By analyzing information and learning patterns, it can create better workflows, suggest ways to improve operations, and automate tasks. With a focus on continuous improvement, a smart factory can self correct and optimize its operations, making itself more efficient, productive, and safer over time *(Smart Factory: The Future of Manufacturing, n.d.)*.

5.5.2 The Structure of a Smart Factory

- **Data Collection:** Businesses can now more easily collect and organize important data from their operations, supply chains, and global networks thanks to modern database technologies and AI. Data is directly sent to IIoT systems from connected machines equipped with sensors. By collecting data from various sources, such as performance metrics, market trends, logistics, and other relevant information from various channels, AI powered technologies can improve the overall process.

- **Data Analysis:** In smart factories, data analysis uses ML and intelligent business systems, with advanced analytics and modern data management tools to analyze the various data collected. IIoT sensors play an important role, as they notify when machines require repairs or maintenance. Also, market and operational data are analyzed to understand risks and opportunities. Workflow efficiency is regularly studied to improve performance and make automatic adjustments when needed. With access to a wide range of data, smart factories can optimize processes and improve supply chain forecasting.

- **Intelligent Factory Automation:** Following data collection and data analysis, workflows are created, and instructions are sent to the machinery and devices within the system. These devices can be inside the factory or located at different logistics or manufacturing points in the supply chain. Smart workflows and processes are continuously monitored and improved. For example, if a news article reports a rise in demand for a specific product, workflows for 3D printers can be adjusted to prioritize that products production. Similarly, if a shipment of a raw material is delayed, inventory reserves can be used to avoid disruptions *(Smart Factory: The Future of Manufacturing, n.d.)*.

5.5.3 Benefits of a Smart Factory

- **Productivity and Efficiency:** The goal of smart factory technologies is to reduce the need for reactive methods and improve the reliability and adaptability of supply chain management. By using tools such as predictive analytics and big data analysis, operations can be improved and managed with greater efficiency. This helps the creation of improved inventory control, better demand forecasting, and faster product delivery.

- **Sustainability and Safety:** Consumers today are willing to pay more for products that are made in socially and environmentally responsible ways. Smart factory technologies provide a solution to this by helping businesses find and use greener, safer, and more ethical manufacturing methods. Furthermore, smart factory managers can track the quality and origin of supplies and materials, even from the most distant links in the supply chain, by integrating technologies like blockchain.

- **Product Quality and Customer Experience:** Smart factories use cloud connectivity and real-time monitoring to track every step of the manufacturing process. This gives them instant information about the entire process and the ability to make quick changes if needed. The ability to adapt and customize products allows businesses to meet customer preferences and keep up with trends. Companies can also find areas for improvement by analyzing data, which can lead to the creation of better products, happier consumers, and fewer problems like returns or recalls. This also helps businesses remain competitive in the market *(Smart Factory: The Future of Manufacturing, n.d.)*.

DESIGN

6.1 INTRODUCTION TO DESIGN

Design plays a very important role in our daily life. Every day, people engage with products, systems, and services that have been carefully created by designers. They design the apps on our phones, develop wayfinding systems for highways, prototype furniture, and create blueprints for service processes. Designing involves envisioning, planning, and improving the physical or virtual structures that shape our lives.

Even if design is everywhere, it often goes unnoticed until it fails to meet expectations. Its impact becomes clear only when an app crashes, furniture is hard to put together, or a road sign is unreadable. As typographer John D. Berry said, “Only when design fails does it draw attention to itself; when it succeeds, it’s invisible” *(Huppatz, 2019)*.

6.1.1 What is Design?

The word “design” has different origins. One is the Latin word “designare”, which means to mark out, define, or designate. Another is the Italian word “disegno”, which means drawing, pattern, or plan. These origins have created two meanings for design, which are the process of creating something and the final product. At its core, design is about creating something better than what currently exists.

Design is a broad term, and its meaning varies depending on the user and the context. Fields such as communication design, industrial design, interior design, interaction design, architecture, and engineering each understand and engage with design from their own perspectives.

At its core, design is about conceiving a purpose, planning actions, and generating possibilities for achieving a specific outcome. It involves both reflecting on the present situation and projecting into the future. Unlike just any action or outcome, design is specifically focused on improving the human experience.

Miedinger, M. (1957). Helvetica

For example, in 1956, Max Miedinger designed the typeface Helvetica, which quickly gained worldwide popularity. Its clean and efficient design transformed clear and effective communication across various platforms.

However, not all designs meet their intended purposes. For example, the AK-47, designed by Mikhail Kalashnikov in 1947, initially intended for Soviet defense, became widely used in violence, leading its creator to regret its impact on the world.

Design is also a continuous process of improvement, aimed at creating something better than what currently exists. It’s a powerful tool that can shape the world in both positive and negative ways, requiring responsible and ethical use.

In conclusion, designers have significant impact through their work, shaping how we interact, communicate, and live. It is very important for designers to consider the wider impact of their creations and aim to produce positive outcomes while minimizing potential negative effects *(Huppatz, 2019)*.

6.1.2 Design’s History

Design’s history is characterized by two distinct periods: Industrial Modernization (1750–1945) and Accelerated Modernization (1945–2000).

During the era of Industrial Modernization, significant technological advancements like steam powered machines, imperial expansion, urbanization, mass communication, and new transportation methods transformed the world. Designers worked to apply these innovations to improve people’s quality of life. For example, they developed efficient machinery for factories, improved transportation systems, and designed urban infrastructure to support growing populations.

Following the Second World War, design continued its evolution fueled by innovations in materials such as reinforced concrete, metallic alloys, plastics, and synthetic fibers. The rapid growth of communication and transportation networks, such as television, automobiles, and jet travel, also opened up new possibilities for design.

Today, design is evolving from the creation of physical products to the development of services and experiences that use available resources. Instead of designing a new bicycle for mass production, designers are focusing on developing bicycle sharing services that are accessible through an app. This approach shows the importance of resource sharing and the principles of sustainability.

Moreover, the virtual realm has become increasingly important, combining the physical and digital worlds. Designers now connect interaction, service, and experience design, effectively integrating both realms. Even physical products, such as bicycles, require supporting elements like websites, branding, and advertising to reach a wider audience.

Design in the digital age brings both challenges and opportunities. Designers must adapt to instant communication, vast information resources, 3D printing, and robotic manufacturing while maintaining a human centered approach.

While design cannot solve all the world’s problems, it remains a potent force for creating positive change. Whether led by professional designers or individuals developing their design skills, the evolution of design continues to shape our world *(Huppatz, 2019)*.

6.2 DESIGN THINKING

6.2.1 What is Design Thinking?

Design thinking is a human-centered innovation method that focuses on understanding and meeting the needs of end-users. It uses creative problem solving methods traditionally used by designers and applies them to business processes. By focusing on empathy, ideation, prototyping, and testing, design thinking tries to create innovative solutions that connect with customers and support business success. This approach can be used to address a wide range of challenges, whether they involve products, services, or entire business models.

The features of design thinking can be summarized as follows:

- Design thinking is a problem solving method that looks at both the issue itself and the factors around it. It combines careful analysis with a broader approach to finding solutions, creating a process that ties everything together. People from different areas work closely together through the process.

  To enhance creativity, design thinking focuses on three main areas: People (keeping the human side in mind), Process (using a structured way to solve problems), and Place (creating an optimal working environment that encourages creativity). Also, collaboration is important for creating ideas, as it usually requires contributions and efforts from multiple stakeholders to turn concepts into reality *(Müller-Roterberg, 2018)*.

- In design thinking, people are the starting point. Customers should have direct influence on key decisions throughout the process. Traditional market research approaches often fall short when seeking new products or services *(Müller-Roterberg, 2018)*.

- Design thinking begins with understanding the customer. By empathizing with the customer's perspective and setting aside preconceptions, designers can better understand their problems and needs. This customer-centric approach helps create solutions that truly meet their expectations and supports making better decisions about which ideas to develop further *(Müller-Roterberg, 2018)*.

- Design thinking focuses on making ideas concrete as early as possible, even for services. By creating rapid prototypes, designers can test individual features and gather feedback from customers before investing heavily in development. The key is to keep prototypes simple and clear, yet detailed enough to gather meaningful insights. For example, instead of developing a complete app, designers can create a paper mock or key screens to assess user navigation *(Müller-Roterberg, 2018)*.

- Design thinking involves continuous revisiting of various design stages. This iterative process is not a mistake but an important part of learning. Failure is embraced as a crucial component of this approach, following the idea that "failing early leads to faster success *(Müller-Roterberg, 2018)*.

6.2.2 The Process of Design Thinking

The design thinking process involves six steps: understanding, observing, defining problems, brainstorming solutions, prototyping, and testing. The first three steps focus on exploring the problem and identifying its nature and main causes. The last three steps focus on finding solutions and working on how to put them into action *(Müller-Roterberg, 2018)*.

- **Step 1: Understand:** Start by understanding the problem or the requirement at hand. Identify the main stakeholders and the technical knowledge required. Clearly define the question to accurately frame the problem or need.

- **Step 2: Observe:** Detailed research and on site observations is very important for understanding customers needs and problems. This step includes activities such as interviews, surveys, and documenting observations with photos or videos. These methods help to understand the context, defining target groups, and gaining a deep understanding of customer needs and behaviors.

- **Step 3: Define the Problem:** Use the data collected from observations to create a clear picture of a representative user and the specific challenge they are facing. Frame this challenge as a clear, actionable question.

- **Step 4: Ideate:** Begin by brainstorming to generate a wide range of potential solutions. Then, analyze these ideas from the customers perspective to identify any weaknesses. Finally, evaluate and select the most promising ideas based on their potential to meet customer needs.

- **Step 5: Prototype:** Prototyping brings ideas to life by turning them into physical or digital forms, like sketches, models, or simulations. This step allows test ideas quickly at a low cost, before investing heavily in a final product or service.

- **Step 6: Test:** The last step is testing the ideas. This step includes doing experiments and collecting feedback from customers to improve the concepts. This step also helps answer important questions about development, production, and the market *(Müller-Roterberg, 2018)*.

6.3 COLLABORATIVE DESIGN

6.3.1 What is Collaborative Design?

Collaborative design brings together professionals from different fields to work as a team from the start of a project. To give a clear understanding of collaborative design, we can think of a scenario where a software developer, a UX expert, and a graphic designer are working together to create a mobile app interface. This collaboration guarantees that the final project is visually appealing, functional, and accessible to all users. This collaborative method works well because each professional brings their unique skills to the table, providing to the team a better understanding of the entire process. Creating clear communication and working together from the beginning helps prevent misunderstandings and increases the chances of success.

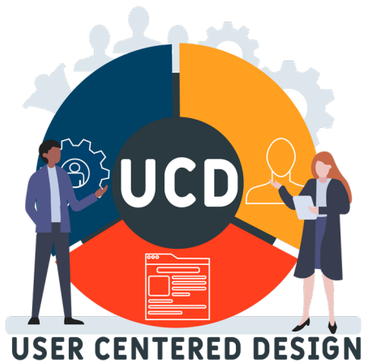
Collaborative design changes the focus from “working for” others to “working with” them. It encourages shared responsibility and uses the strengths of each team member to shape the project’s goals and outcomes *(Van Welie, 2022)*.

6.3.2 Benefits of Collaborative Design

- **Creativity:** When designers collaborate and work together, they create an energetic and creative environment. This collaboration brings together different skills and ideas, often resulting in the development of original and new solutions.
- **Different Perspectives:** Collaborative design brings together designers with different skills, experience, and backgrounds, encouraging new ideas. Every designer in the process provides their own perspective, questioning existing ideas and bringing in new ideas to the table.
- **Efficiency:** Designers share the workload, take on different tasks, and work together at the same time, which allows products to be completed more quickly and efficiently.
- **Adaptability to Change:** Collaboration helps designers become more flexible and open to change. It teaches them how to adapt to shifts in directions, explore new ideas, and adjust their designs to meet the changing needs of a project.
- **Complete Solutions:** By working with experts from different areas, they can design balanced and complete ideas that look at the problem from multiple perspectives.
- **Learning New Skills:** In a collaborative design environment, designers can share their knowledge, learn from each other, and try new things, which helps them improve their skills.
- **Improved Problem Solving:** Collaborative design makes problem solving a team effort. By combining their skills and knowledge, designers can create a strong foundation for solving problems. Each designer brings their own expertise, helping to look at problems from different perspectives and find practical solutions.
- **Reducing Risks:** By collaborating and sharing knowledge, designers can predict and fix problems before they happen, saving time, effort, and money while avoiding costly mistakes.
- **User Centricity:** Collaboration in design keeps users at the center of the process, making sure that their feedback and needs shape the project. With multiple designers working together, teams can better understand and connect with users, creating designs that exactly meet their expectations and needs, and provide better experiences.
- **Better Communication:** In collaborative design, designers learn to share their ideas clearly, listen to others, and have productive discussions. This improves teamwork, reduces misunderstandings, and keeps everyone focused on the same objective.
- **Contimuous Improvements:** Collaboration allows designs to improve through ongoing feedback and changes. Designers can present their concepts and ideas as they progress, get input from the team, and make changes based on collective feedback. This type of collaboration leads to open communication, valuable suggestions, and the possibility to develop new ideas *(Aftab, 2024)*.

6.4 USER-CENTERED DESIGN

6.4.1 What is User-Centered Design?



User-Centered Design (UCD) is an approach that focuses on putting users needs throughout the entire design process. It aims to understand users behaviors, values, and expectations to develop solutions that effectively meet those needs.

In UCD, every design choice is made with the user in mind, how it gives value to the users and does it help users reach their objectives. This approach shows the importance of incremental development, where user feedback is regularly integrated and considered to improve the design *(Browne, 2021)*.

There are five main principles that define UCD:

- Including users in the early phases of the design process to involve them as active participants in shaping the design.
- Understanding how and why people will use the product while balancing their needs with business goals.
- Regularly collecting and analyzing user feedback to refine the design at every stage.
- Centering the development process around users to ensure that their needs guide how products are created and delivered.
- Using a continuous cycle of testing, feedback, and improvement to improve the product experienceprocess *(Browne, 2021)*.

6.4.2 How Does User-Centered Design Work?

The UCD process includes four steps:

- Understanding the user and the context in which they will use the product.
- Defining user needs and business objectives.
- Developing design solutions.
- Determining the effectiveness of design.

Step One: Understand the User and the Context in Which it Will be Used:
In this step, designers try to understand the characteristics of their users, the challenges they face, and the factors that shape how they use the product. Designers identify what attracts users to the product and the ways in which they engage with it *(Browne, 2021)*.

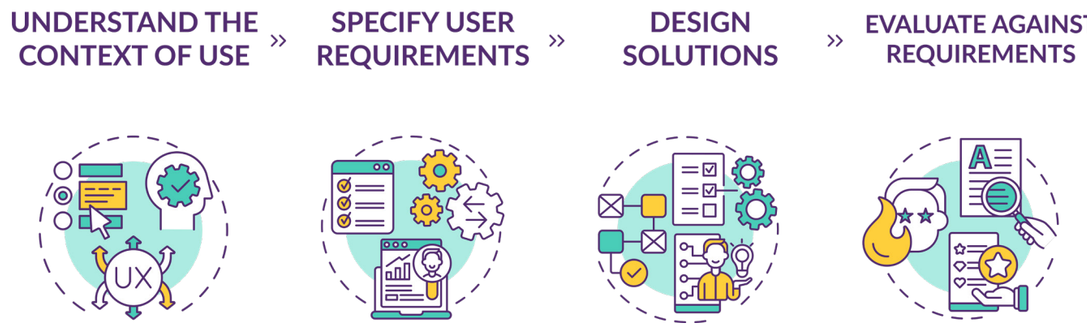
Step Two: Defining User Needs and Business Objectives:
In this step, designers identify how the design will benefit both the user and the business, as well as the problems the design addresses. During this step, designers and stakeholders also determine the metrics for measuring business success and define what success means for the user *(Browne, 2021)*.

Step Three: Creation of Design Solutions:
In this step designers work on creating storyboards, mapping user journeys, building wireframes, designing mockups, and planning user flows. They also test different user interface elements and establish an effective information architecture *(Browne, 2021)*.

Step Four: Determining the Effectiveness of Design:
After the design team has come up with potential solutions, they evaluate how well these solutions meet user and business needs. At this step, usability testing with actual users becomes crucial as it helps to understand how the design performs.

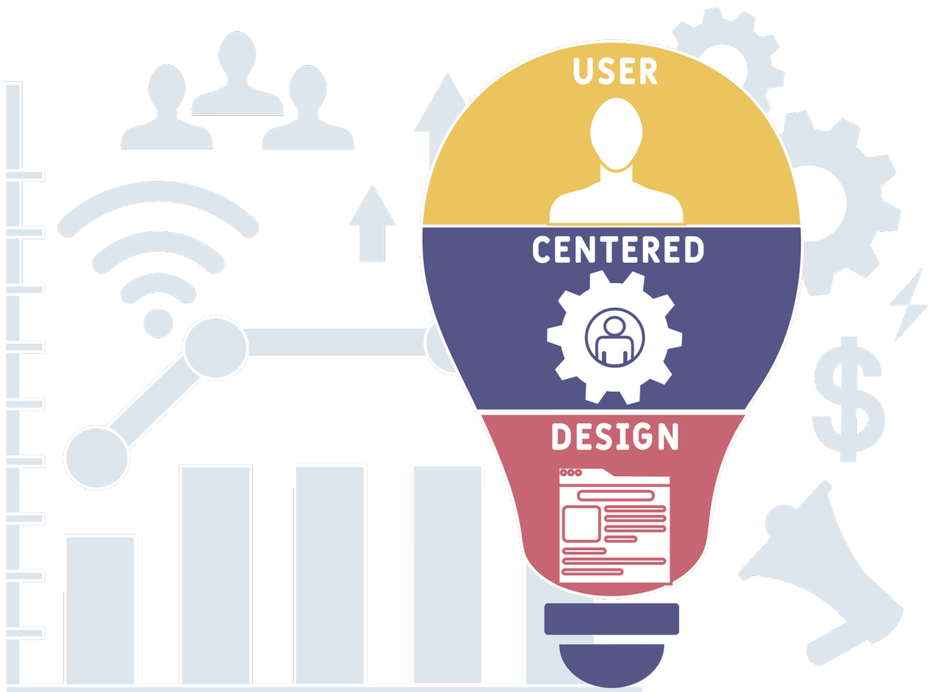
Important questions to ask during this step include: What worked? What didn't? How did users respond? What can we improve?

It is rare for a design to meet all its goals on the first try. Typically, it requires several iterations of the UCD process to create a version that works well for both users and the business. This iterative process shows the value of UCD. After completing this step, the team uses what they have learned to return to the first step and start a new design cycle *(Browne, 2021)*.



6.4.3 Benefits of User-Centered Design

- **Reducing Costs and Risks:** Involving users early in the design process helps companies create products that are easy to use and meet user needs. This approach lowers the chances of making costly design mistakes and minimizes the need for extensive customer support to explain how the product works.
- **Deeper Sense of Empathy:** By following the UCD process, businesses can better understand their users which can lead to the creation of products that are ethical, accessible and inclusive.
- **Higher Customer Satisfaction:** The UCD process pushes companies to focus on their users need and wants during product development. This customer focused approach not only increases satisfaction but also improves the user engagement, which can result in higher sales and revenue.
- **Increased Productivity:** UCD actively involves users throughout the entire design process, which reduces the need for designers to make guesses or spending time on features that are not necessary.
- **Involves All Team Members:** Using the UCD process ensures that everyone in the company is on the same page and provides stakeholders with a transparent view of how the project is progressing. Also bringing together a team with diverse skills and backgrounds can lead to the development of more effective and user friendly products *(Browne, 2021)*.



6.5 INNOVATIONS IN DESIGN

6.5.1 Artificial Intelligence

AI is technology that enables computers and machines to simulate human intelligence and problem solving abilities. Whether operating on its own or combined with other technologies, AI can execute tasks usually requiring human involvement or intelligence. Examples include digital assistants, GPS navigation systems, autonomous vehicles, and generative AI tools like ChatGPT.

6.5.1.1 How Does AI Work?

AI systems work by analyzing a large amount of labeled data to find patterns and connections. These patterns and connections are then used to make predictions or decisions. For example, a chatbot trained on text data can have realistic conversations with people, while an image recognition tool can identify objects in pictures after examining millions of examples. Moreover, with the development of generative AI, creating text, images, music, and other forms of media becomes easier than ever *(Anand, 2024)*.

In AI programming focuses on capabilities that include the following:

- **Learning:** Learning is a key part of AI programming. It involves collecting data and creating rules that help transform these data into actionable information. These rules are called algorithms, and they give computers clear instructions on how to perform specific tasks.
- **Reasoning:** Reasoning is about choosing the best algorithm to reach a specific outcome. This ensures that AI can make the right decisions.
- **Self-Correction:** Self correction allows AI systems to improve their performance over time. This process is very important as it helps algorithms correct and improve themselves, making them more accurate and reliable.
- **Creativity:** For better creativity, AI uses methods like neural networks and rule based systems to create new ideas, including the generation of text, music, images, and other types of content *(Anand, 2024)*.

6.5.1.2 Why is AI Important?

- AI is a very important tool in today's world. It is transforming how we live, work, and interact. It is also being used in businesses to automate tasks that were normally done by humans, such as customer service, fraud detection, and quality control. AI is also very useful at completing repetitive and detail oriented tasks. It can perform these types of repetitive tasks quicker and with few errors *(Anand, 2024)*.

Another key benefit of AI is its ability to effectively analyze large amounts of data, which helps businesses to get a better understanding of their operations that might otherwise go unnoticed. Additionally the increase in generative AI tools is opening the way for innovations in fields like education, marketing, and product design *(Anand, 2024)*.

Today, AI has become a very important tool for some of the world's biggest companies, such as Apple, Microsoft, and Meta. These companies use AI to improve their operations and maintain a competitive advantage in the marketplace.

6.5.1.3 Advantages and Disadvantages of AI

AI technologies are quickly evolving because they can process large amounts of data much faster and more accurately than humans. While the large volume of data generated daily would be really difficult for a human researcher to handle, AI applications using machine learning can quickly analyze and transform this data into actionable information.

However, a primary disadvantage of AI is the high cost of processing the large amounts of data it requires. Additionally, as AI techniques are integrated into more products and services, businesses must be very careful about AI's potential to create unfair and discriminatory systems whether intentionally or unintentionally *(Craig et al., 2024)*.

Advantages of AI:

- **Good at Detailed-Oriented Tasks:** AI is very good at handling detail oriented tasks. It can spot small patterns and connections in data that people might miss, making it a valuable tool for tasks that require full concentration.
- **Consistent Results:** Modern analytics tools use AI and ML to analyze large datasets consistently, while also maintaining the capacity to adapt to new data through ongoing learning.
- **Customization and Personalization:** AI can improve user experience by personalizing interactions and content delivery on digital platforms for individual users needs.
- **Reduced Time for Data-Heavy Tasks:** AI significantly reduces the time needed for data processing, and industries such as banking, insurance, pharmaceuticals, and finance are using this capability of AI to analyze large volumes of data more efficiently and quickly.
- **Time Savings and Productivity Improvements:** The use of AI and robotics can save time and increase the overall productivity by automating tasks while also creating a safer workplace. For example, AI powered robots are usually used for dangerous and repetitive tasks. This helps create a safer working environment and increases the overall efficiency *(Craig et al., 2024)*.

Disadvantages of AI:

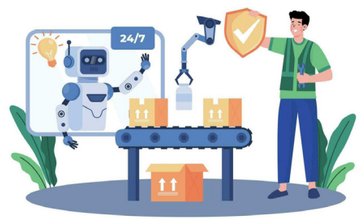
- **Expensive.**
- **Requires technical expertise.**
- **In most cases, it shows the patterns of its training data.**
- **It is unable to use what it has learned from one task to another.**
- **In some cases it might cause job losses, increasing the possibility of unemployment.**

6.5.1.4 Impact of AI on the Design Industry

In today's fast changing world, AI is a very important tool that reshapes industries and changes our approach to creativity. This is particularly noticeable in design, where humans can collaborate with AI to create fresh ideas with great aesthetics.

- **Augmented Creativity:**
  AI plays an important role in increasing creativity in design by analyzing large data sets and identifying patterns that might be missed. It provides valuable tools for designers to get inspiration, such as suggesting color palettes, generating concepts, or creating sketches based on past design trends. By helping in the creative process, AI allows designers to explore new possibilities and push the boundaries of their creativity, all while reducing the challenges of time constraints and information overload.

- **Efficiency and Iteration:**
  AI can make the design process much more efficient. Tasks that once took weeks can now be completed in just days. With the use of machine learning, designers can quickly analyze user feedback and preferences to adjust and improve the design. This fast cycle saves time and also helps create a product that better meets user needs.



- **Personalization and User Experience:**
  AI helps designers to understand user behavior, preferences, and demographics, allowing them to create designs that fit to individual needs. From personalized interfaces to user experiences, AI guarantees that the final product meets the customers expectations and tastes

- **Challenges of Creativity:**
  While AI increases creativity, it also brings challenges to traditional ideas of creativity and authorship. There are discussions around the authenticity of AI generated art and design, questioning the role of humans in a world that is increasingly influenced by AI and algorithms. Finding a balance between the efficiency of AI and the unique intuition of human designers is essential for maintaining the true spirit of creativity in the design field.
- **Collaboration and Co-Creation:**
  In the design industry, designers are starting to use AI more often, collaborating with it to improve their ideas and skills.

- **Ethical Considerations:**
  As AI is being used in the design process more often, ethical considerations are becoming more important. Issues such as algorithm bias, data privacy, and the responsible use of AI generated content require careful attention. Designers have to address these challenges thoughtfully, making sure AI is used to benefit people while maintaining strong ethical practices *(Artificial Intelligence and Humans: Impact on the Design Industry, 2024)*.

6.5.2 Digital Design Tools

6.5.2.1 What is Digital Design?

Digital design is about creating visual content for digital platforms, such as websites, mobile apps, digital advertisements, and social media graphics. It includes areas like UI/UX design, digital illustration, and immersive experiences. Digital design brings together elements from different design fields to create digital products that are not only visually appealing but also functional. Clear communication and user friendly interaction is also very important in digital design *(Chervinska, 2023)*.

It uses different tools and software, from programs like Adobe Creative Suite to specific software for 3D modeling, animation, and more.

6.5.2.2 Types of Digital Design:

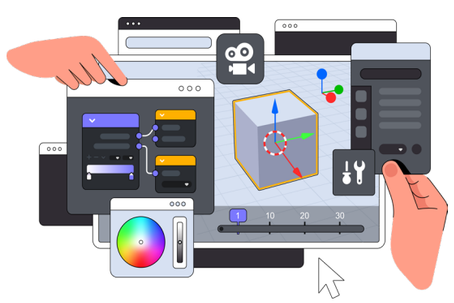
- **Web Design:** Web design is about creating the layout, look, and functionality of websites. It comes with its own challenges and requires a good understanding of digital design basics like grid systems, color use, and typography, as well as some basic coding knowledge.

- **UI/UX Design:** UI/UX design is important for any digital product that involves user interaction, such as apps, websites, or software. UI focuses on the visual components of the product, while UX focuses on the experience, making sure that it's smooth, intuitive, and user friendly.

- **Motion Graphics:** Motion graphics is about designing animated or digital video content. It's often used in ads, video games, and promotional videos to make visuals more engaging.

- **Digital Illustration:** Digital illustration is about creating images using digital tools and software. It is generally used in areas like graphic novels, video games, and advertising. One of the main benefits of digital illustration is its flexibility, which allows artists to edit their work and include multimedia elements.

- **3D Modeling:** 3D design is about creating and rendering models in a three dimensional environment. Compared to 2D design, it provides a more immersive experience, allowing designers to create realistic and engaging visuals.



- **Interaction Design:** Interaction design is about how users will interact with products. The aim is to create digital design components that are easy to understand and enjoyable to use, improving both usability and the overall experience.

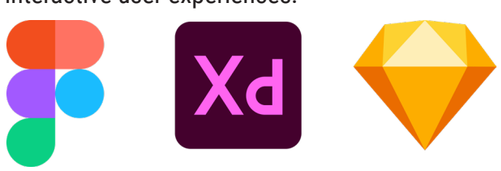
- **AR/VR Design:** AR adds digital features into the real world using devices like smartphones or AR glasses. On the other hand, VR provides a fully digital environment where users can interact with their surroundings.

- **Data Visualization:** Data visualization is the process of turning data into visual formats, like charts, graphs, or maps, to make complex information easier to understand *(Chervinska, 2023)*.

6.5.2.3 Different Categories of Digital Design Tools

- **3D Design and Modeling:** Blender, Maya, and ZBrush are leading tools in the 3D design and modeling. Blender is open source software that provides a comprehensive set of tools for 3D work, including modeling, sculpting, and animation. Maya is widely used in film, animation, and gaming industries for its advanced features, making it perfect for creating detailed animations and environments. ZBrush is specialized software that focuses on sculpting, allowing artists to create realistic characters and creatures.

- **UI/UX Design Software:** Some of the most popular tools for UI/UX design includes Figma, Sketch, and Adobe XD. Figma allows designers to collaborate in real time, making teamwork more efficient. Sketch is known for user-friendly interface and strong vector design features. Adobe XD combines UI design with prototyping, allowing designers to easily create and test interactive user experiences.



- **Graphic Design Tools:** Adobe Photoshop, Illustrator, and InDesign are some of the most widely used tools in graphic design. Photoshop allows artists to turn real images into creative works of art. Illustrator, which focuses on vector graphics, is perfect for creating scalable designs like logos and icons. InDesign brings these elements together, making it perfect for designing layouts for magazines, brochures, and digital content.

- **Motion Graphics and Video Editing:** Adobe After Effects, Premier Pro, and DaVinci Resolve are the most widely used tools for creating motion graphics and editing videos. After Effects adds life to designs with eye catching animations and visual effects. Premiere Pro is great for cutting and editing video footage to create polished films. DaVinci Resolve offers a complete solution for filmmakers, combining editing, color correction, and audio work in one platform.

6.5.3 The Future of Design

In the fast changing world of design, staying updated with new trends is very important. Advancements in technology and innovations are changing the design field, opening up new possibilities and expanding the limits of creativity.

- **Artificial Intelligence and Machine Learning:**
  AI and ML have a significant impact on the design field. These technologies can process large quantities of data efficiently and quickly, providing useful information about user behaviors and preferences. AI also helps designers by completing repetitive tasks, giving them more time to focus on creative tasks. From creating design examples to predicting user interactions, AI is becoming a key component of the design workflow.

- **Augmented and Virtual Reality:**
  AR and VR are being increasingly used in the design process. AR puts digital elements onto the real world, helping designers see and understand how their designs interact with the physical environment. On the other hand, VR provides completely immersive experiences, allowing designers to control and modify their work in real time. Together, these technologies provide designers new ways to prototype and present their ideas.

- **Generative Design:**
  Generative design uses algorithms to create different design solutions based on specific outcomes and limitations defined by designers. Designers provide the necessary information such as materials, budget, and performance requirements, and the system creates different options to choose from. This method makes the design process a lot quicker and creates opportunities to discover new ideas that may have not been possible with traditional methods.

- **Responsive and Adaptive Design:**
  The idea behind this design method is to provide a smooth and consistent user experience across different devices, and screen sizes. As wearable technology and IoT continue to grow, designers need to think about how their work will perform on different devices. Creating designs that easily adapt across different devices will be a key focus for the future.

DESIGN AND NFT

7.1 GUIDELINES FOR NFTS AND BLOCKCHAIN IN DESIGN

7.1.1 Understanding Core Concepts of NFTs and Blockchain

7.1.1.1 NFTs

- **Definition:** NFTs stand for non-fungible tokens, something which is unique in the digital world. It can be completely digital, such as a 3D file, but also physical, like a product. Thanks to blockchain technology, it cannot be tampered with, and the ownership can be traced back and verified very easily. Each NFT contains a metadata that confirms its uniqueness and their ownership rights.

- **Value for Designers and Artists:** NFTs improve the traceability and authenticity of both physical and digital products. This feature of NFTs allows designers to secure their intellectual property while also creating exclusive and verifiable products. By tokenizing a product into an NFT, a designer confirms ownership of the product they created. While tokenizing as an NFT might not prevent unauthorized copying or reproduction, since there are no strict rules yet, it effectively shows the verified product and reduces the possibility of scams.

- **Potential Use in Product Design:** NFTs can shape product design in new and innovative ways beyond exclusive digital benefits and resale opportunities. If NFTs continue to influence the design industry, designers may need to consider both the physical and digital aspects together as one. This two sided approach could influence the choices of material and technology, since the product might need to connect across two different but connected worlds. Depending on the product, design options could include personalization, which may require modular or adaptive design elements. While physical personalization might create a few challenges, the more flexible digital aspects could provide long term engagement and allow the product to change with the user over time.

7.1.1.2 Blockchain Technology

- **Definition:** Blockchain is a decentralized and distributed ledger that records transactions and data across multiple computers. It ensures that information such as ownership or transaction history remains secure, immutable, and transparent once recorded. This feature of blockchain is very important as it helps build trust in the digital world.

- **Smart Contracts for Automations:** Blockchain technology enables the use of smart contracts, which are self executing agreements written as code and integrated into the blockchain. These digital contracts can automatically execute terms and conditions when specified conditions are met, such as paying royalties to designers and artists if their works are being resold. This automation streamlines transaction processes, helps designers keep ownership rights, and improves both protection and the ability to earn money. Additionally, smart contracts can be coded to execute and handle a wide range of different tasks other than just automating transactions and payments. As long as the contract is set up correctly, it can automate a lot of different applications.

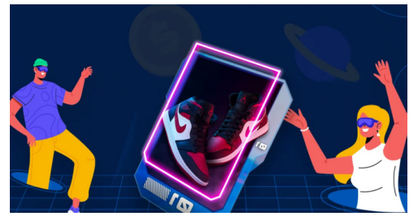
7.1.2 Exploring Applicable Use Cases for NFTs and Blockchain

7.1.2.1 Intellectual Property Protection and Patenting

- **NFTs and Intellectual Property Protection:**
NFTs are presenting a new method for documenting ownership of digital content, improving traditional intellectual property protections such as trademarks and copyrights. While NFTs themselves do not establish intellectual property rights, they verify original authorship of any digital work. More importantly, they provide a clear and secure record of when and by whom the work was created through a transparent and unalterable history recorded securely on the blockchain's immutable ledger. This helps create a digital provenance, but it needs to be integrated with existing intellectual property laws for full protection.

- **NFTs and Patent Documentation:**
While NFTs themselves cannot provide the same level of legal protection as a patent does for an inventor, they can be used to record the different stages of the development process of a product. A blockchain's public ledger, on which the NFT is based, will periodically record the transactions and relevant actions concerning the product, providing some kind of clear timeline that could be useful in a patent application or other forms of intellectual property claims. However, patents are still going to be given through a formal application and approval process set by governmental patent offices and NFTs and the recorded information will only serve as a supporting tool in the process.

7.1.2.2 Phygital Products



Phygital NFTs effectively bridge the gap between physical and digital realms, providing enjoyable, interactive, and dynamic experiences. Through the integration of tangible physical items with the digital functionalities provided by blockchain technology and smart contracts, these NFTs create new opportunities for creators and collectors. They provide new forms of ownership and interaction within the modern digital landscape.

For those who prefer physical items, Phygital NFTs give them an easily recognizable and tangible link. At the same time, they attract digital enthusiasts looking to blend modern technologies with traditional collecting methods. For example, collectors can display their physical items in their homes while also showcasing them digitally in virtual galleries or interactive displays. That unique combination easily bridges the gap between traditional collecting and modern digital experiences.

It is also important to note that this example focuses more on the visual and more artistic aspects of Phygital NFTs. However, with the use of right technologies, such as IoT sensors, proximity sensors, and smart contracts, the possibilities of Phygital NFTs can expand into more innovative and diverse areas.

7.1.2.3 Designing for the Metaverse

Designing for the Metaverse is very different compared to web and graphic design. It focuses on creating immersive and interactive experiences that combine physical and digital elements. This includes 3D environment design, the design of avatars and characters, and UI design for smooth navigation and interaction within virtual space.

Beside these factors, there are issues of inclusivity, in which designers must implement methods to ensure accessibility; monetization by using NFTs in ways that contribute to a sustainable business model; and the use of blockchain technology as a basis for secure, transparent transaction and interaction within virtual spaces.

At its core, the Metaverse is a place of interoperable digital platforms, virtual reality, and augmented reality combined with social engagement. The Metaverse is also more than just this shared digital environment, it is a place where people can connect, create, and collaborate, using NFTs where necessary to retain ownership and provenance of digital creations.

Designing for metaverse means integrating different design disciplines in such a way that one may interactively feel and believe in a virtual environment, with NFT and blockchain taking center stage in its economy and social fabric.

7.1.3 Enhancing Supply Chain Transparency and Sustainability with Blockchain

Blockchain can help create a clear and trustworthy system by contributing to greater transparency and accountability throughout the supply chain, especially for industries focused on responsible sourcing and sustainability. Using blockchain, every transaction and movement, from raw material collection to the final sale is permanently recorded on a distributed ledger, making all the information tamper-proof and trustworthy.

A very good example of this is the “Organic Cotton Traceability Pilot” in the fashion industry, which used blockchain technology to record every single stage of cotton production, from the growing of the plant to retail. In this way, it was possible to create a trusted, tamper-resistant ledger that enhances evidence for sustainability claims, like organic or fair trade.

To further improve the transparency, NFTs can be used to tag individual products or batches with a unique digital identity, enabling manufacturers to attach detailed, step-by-step information about a product’s journey directly to an NFT and to its associated metadata. While the core identity of the NFT itself does not change, the metadata that is associated with the NFT can change to show important updates, such as resale or repurposing. These features ensure that buyers and other stakeholders have the ability to check the latest and most relevant information. The ability to provide this detailed history through a QR code or an NFC-enabled tag supports an increasingly personalized and detailed view into the life cycle of the product. Also, the ability of NFTs to update the metadata when necessary creates a reliable and traceable history that helps the growth of a circular economy.

By leveraging blockchain and NFTs, businesses not only record and verify the sustainability claims of their products but also engage with consumers on a much deeper level by providing a transparent view of the journey each product has taken.

7.1.4 Embracing Dynamic Design

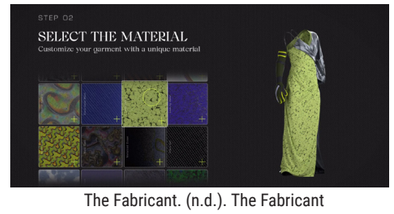
Dynamic design allows products to change or be customized even after they are created. This provides new opportunities for designers to create dynamic and engaging products in both the digital and physical worlds.

7.1.4.1 Customizable and Dynamic Products

- **Customizable Design Process:**
  NFTs and blockchain now give designers the possibility of creating customizable and modular products which consumers can purchase and modify. The most important and relevant example of this to date is the collaboration between Nike and RTFKT with their sneakers known as “CryptoKick”. When you purchase CryptoKicks, you will receive both a physical version of the shoes and a digital copy linked to an NFT that functions as a certificate of ownership and authenticity. The main features of personalization are accessible using the RTFKT app, where users can customize their digital sneakers by changing colors and patterns. The strong focus on digital personalization brings about a high level of individualism that is not possible with physical sneakers at this point, due to manufacturing and logistical limitations.

RTFKT, & Nike. (2022). RTFKT x Nike Cryptokicks iRL

- **Dynamic Design:**
  NFTs hold great promise for digital products that can change over time. The Fabricant is pioneering this innovation in the field of virtual wearables with its digital fashion house. Their NFTs are more than just digital certificates of ownership but they are unique digital clothes designed for virtual environments, gaming, and social media platforms.



The Fabricant. (n.d.). The Fabricant

Every digital fashion item that is purchased from the Fabricant gives the owner the right to use it in multiple different metaverse platforms. This means that owners can use their digital fashion items across a number of games and metaverses that adopt its integration, adding value for versatility and utility extending well beyond one single platform.

While the idea of evolving NFTs is quite interesting, Fabricant’s focus is more on creating a customizable and collaborative digital fashion experience. For example, most of their collections include such collaborations and co-creations with other brands to make sure that their digital outfits are always fresh and relevant with the trends. Additionally, users are given the ability to design their own outfits, turning creativity into opportunity by monetizing their custom clothes.

The Fabricant, & Tommy Hilfigar. (2021). TOMMY HILFIGER X THE FABRICANT

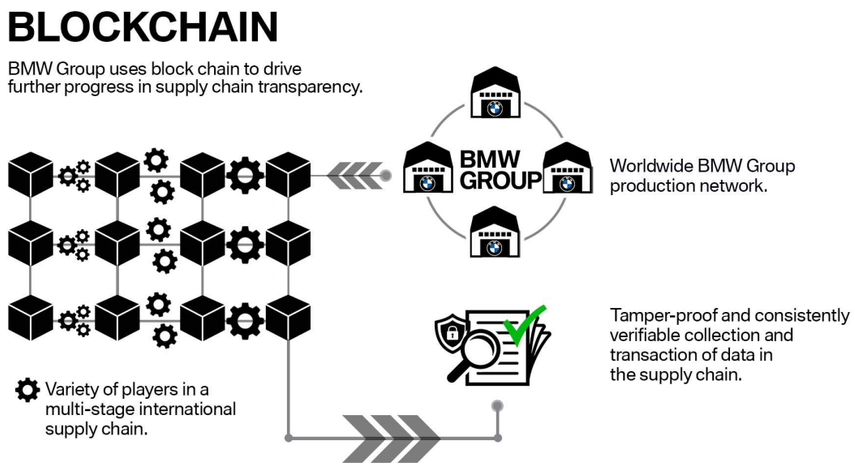
This gives digital products the ability to adapt to user preferences and market trends, thereby helping to create immersive and engaging experiences. Offering unique designs, interoperability, and frequent updates, platforms like the Fabricant keep consumers loyal to their digital belongings. These new opportunities in digital fashion could lay a foundation for NFTs that evolve over time, perhaps with seasonal updates, collaborative design efforts, or features that encourage personalization. Even

though Fabricant does not provide fully dynamic and evolving products yet, it provides a platform where users are constantly provided with new features, creating a sense of dynamic design and innovation for its users.

7.1.4.2 Digital Twins

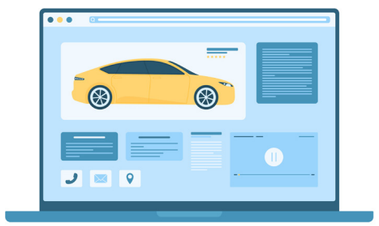
A digital twin is a virtual representation of a physical product, such as a building, a car, or any other object. They have the ability to dynamically show real-time changes and statues of the physical counterpart. In the automotive industry, companies like BMW have started to use digital twins in monitoring the performance of a car throughout its lifecycle, from production to real-time data monitoring during usage.

This can be further improved in security and transparency with the linking of digital twins to blockchain and NFTs. For example, blockchain is being used in the automotive industry by BMW. They have developed a system called the PartChain project, which allows tamper-proof data sharing, meaning that every vehicle part can be tracked and updated properly throughout the supply chain. If blockchain can be applied to digital twins, it can potentially secure all updates, repairs, and upgrades performed on the physical product. These changes would be visible in the digital twin and also immutably recorded on the blockchain's ledger.



BMW Group. (2020). BMW Group uses Blockchain to drive supply chain transparency

Additionally, if digital twins can be linked to NFTs, they can be used as a digital certificate of ownership for the vehicle. Any event like service, customization, or part changes, will be immutably recorded on the blockchain and, as a result, also in the metadata of the NFT that represents the digital twin. These will make the vehicles hold their resale value better, due to the fact that potential buyers can have full confidence in the permanent record, which verifies all details about service history, customization, and transfer of ownership *(The Power of NFT's and Their Use in the Automotive Industry, n.d.)*.



Theoretically, the integration of digital twins, blockchain, and NFTs would create a future where the owners of products and the manufacturers interact, monitor, and verify with maximum efficiency. While the use of NFTs is still in its theoretical stage, companies like BMW are leading in the integration of blockchain in the automotive industry.

7.1.5 Engaging with Communities Through NFTs

7.1.5.1 Collaborative Experience with NFTs

NFTs can change the way in which brands interact with their communities by changing the focus from a one time product release to creating continuous experiences. Rather than just selling digital or physical products, NFTs allow brands to participate in a shared journey with their audience, offering exclusive access, benefits, and potential developments. A good example of this can be seen in Adidas's "Into the Metaverse" project, which showed NFT's ability to provide long-term interaction between a brand and its community.

Adidas. (2022). Adidas Into the Metaverse

Adidas started this journey by selling NFTs that functioned as digital access keys. Holders of these NFTs did not have any kind of impact on the design of a product or an experience, but they were given exclusive access to both limited edition physical merchandise and digital wearables. This element of exclusivity created a closer relationship between a brand and the community around it.

More importantly, Adidas actually made these experiences continuous. The NFTs were not just one time product releases and they provided future benefits. Owners of the NFTs got early access to future collaborations, private events, and other experiences, thereby creating continued engagement with the brand's growth. These created the feeling of being a part of Adidas's journey in the metaverse and not just the purchase of a product.

Adidas also collaborated with several important Web 3.0 players, such as the Bored Ape Yacht Club and gmoney, leveraging the existing communities built around these NFTs. In this way, Adidas bridged the gap between traditional retail and the world of NFT while connecting with a customer base that is already passionate about NFTs and the metaverse. By collaborating with recognized Web 3.0 projects, Adidas also showed the importance of shared culture and the value of it with its audience, making the project feel more collaborative and community oriented.

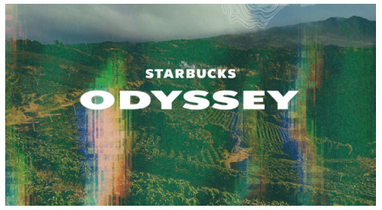
In summary, community driven NFTs are more focused on creating collective experiences that evolve over time. In these types of NFTs, the idea is not always about direct participation in design but rather about creating the feeling of belonging and continuous engagement to build a better relationship between brands and their communities. As a result, this creates stronger and long lasting relationships.

7.1.5.2 Improving Brand Engagenment Using NFTs

NFTs can provide new opportunities for brands to engage with customers, build loyalty and create value. They can represent anything from art to virtual real estate, as well as exclusive brand experiences. This flexibility helps brands to create new stories, connect in deeper ways with their audiences, and build a sense of community around them through a number of unique, interactive, and immersive ways.

- **Uniqueness and Exclusivity:**
  NFTs allow brands to create unique digital collectibles that provide users with a greater sense of exclusivity and perceived value. For example, Gucci collaborated with SuperRare on "The Next 100 Years of Gucci", a limited edition NFT collection that celebrates the brand's 100th anniversary, while Adidas's "Into the Metaverse" collection connects virtual wearables with physical products by giving NFT holders access to new exclusive merchandise and events, creating a smooth experience between the digital and physical worlds.

- **Better Engagement and Loyalty:**
  By incorporating NFTs into loyalty programs, brands can add a strong layer of customer engagement with exclusive content, assets, or special perks. A good example of this is the Starbucks “Starbucks Odyssey”. It’s an NFT-based initiative where holders will get experiences ranging from virtual classes in making espresso martinis to events at the Starbucks Reserve Roasteries and even trips to Starbucks Hacienda Alsacia coffee farm in Costa Rica. This approach creates a deeper emotional connection and builds a greater sense of community between the brand and its customers. However, Starbucks has announced that the Odyssey program will come to an end on March 31, 2024, as the company prepares for future plans.



Adidas. (2022). Adidas Into the Metaverse

- **New Revenue Streams:**
  Brands can generate additional income by selling digital assets, such as digital art pieces or collectibles as NFTs. An example of this is the “NBA Top Shot” collection. The collection was launched in partnership with Dapper Labs and it offered fans a special way to engage with the sport by owning digital highlights of iconic basketball moments. NBA Top Shot has not only created a deeper fan interaction but also generated a significant amount of revenue for the NBA, with some individual NFTs selling for hundreds of thousands of dollars. This example showed how digital collectibles can create a profitable revenue stream while strengthening the connection between brands and their audiences.

7.1.6 Monetization and New Business Models

7.1.6.1 Royalties, Resale Benefits, and Direct Sales

NFTs allow designers and artists to completely bypass traditional retail intermediaries, such as physical stores or distributors. In this way, designers can have more control over their products or brands and pricing strategies while establishing closer relationships with customers. Also, by using blockchain based marketplaces, designers now have the possibility to sell directly to consumers while keeping a larger share of the profits, which makes their products competitively priced.

Furthermore, NFTs have the ability to continuously generate income through royalties from subsequent transactions, made possible by the smart contracts. A part of the transaction value on every resale of an NFT automatically goes to the original creator. This way, creators are guaranteed to keep benefiting from their works in the long term through a sustainable economic model extending beyond the first transaction.

7.1.6.2 New Business Models

- **Crowdfunding Through NFTs:**
  NFTs open up new possibilities for creators to get early funding for their projects. Instead of finding investors or using websites like Kickstarter, designers and artists can sell NFTs before a project is finished. This type of NFTs serves as a “supporter token”, giving early supporters a way to invest in the project while gaining private access and perks as it develops.

  A very good example of this model is the Bored Ape Yacht Club (BAYC). While the initial idea wasn’t precisely crowdfunding, the sale of 10,000 unique BAYC NFTs generated initial funding to support further development. These tokens represented ownership of unique digital assets while also serving as “membership tokens”, which gave early supporters access to exclusive content and events, future NFT collections, and to a VIP community. This example showed the ability of NFTs to create community ties and create loyalty while bringing both short term and long term value to early supporters.

Bored Ape Yacht Club. (2021). Bored Ape Yacht Club

- **Virtual Real Estate and Experience:**
  With the development of new virtual worlds, there are new opportunities for artists and designers to create and sell virtual experiences and environments. For example, a designer can create a digital art gallery or an immersive environment that anyone in the world can visit virtually. These types of virtual experiences can be bought and sold as NFTs, which means the buyer has ownership rights over them. In addition, these places can be rented out for all sorts of events, exhibitions, or virtual performances, just like any physical properties. This allows creators to monetize their work in new ways, while offering unique, interactive experiences for a global audience.

  An example of this is the presence of Atari in Decentraland. The classic video game company bought several large plots of virtual land in order to create their own Atari themed world. This space involves interactive experiences, branded content, and even a virtual casino where users can play games and win digital rewards. This is how Atari used virtual land as a form of marketing and entertainment by developing an entirely branded and interactive environment in the metaverse, creating unique digital experiences for its users and earning them money through their virtual environment.

Decentraland, & Atari. (2021). DCL x ATARI

- **Membership and Access Tokens:**
  NFTs can also be used as digital tickets that give exclusive access to content, events, or communities. For example, an artist can create a number of NFTs that act as memberships and grant owners access to private events, either digital or physical. This concept thinks NFTs as a form of digital membership that allows artist to build a closer, more direct relationship with their supporters while giving them exclusive perks not available to the general public.

  One of the most clear examples of this is Kings of Leon’s use of NFTs in the music industry. When the band released their album “When You See Yourself”, they also announced an NFT collection that included 18 “gold tickets” as NFTs. Each of these golden tickets were lifetime front row seats to all current and future Kings of Leon concerts. Additionally, they provided VIP perks, such as backstage access and concierge service, along other premium experiences.

Kings of Leon. (2021). KINGS OF LEON x YELLOWHEART

7.2 INTRODUCTION TO PHYGITAL PRODUCTS

Phygital products combine the physical and digital, turning everyday objects into interactive and dynamic experiences. The term “phygital” represents a connection in which a tangible product is improved by digital features that provide extended functionality, traceability, and personalization for the customer. In addition to this, phygital products can use blockchain and NFTs to create a more secure and verifiable link between the physical product and its digital counterpart, continually proving ownership and authenticity via the blockchain.

At the core of phygital products is the seamless integration between physical objects and blockchain verified digital assets. NFTs mostly act as digital certificates of authenticity registered on the blockchain, allowing the easy and secure verification of ownership and the origin of the real physical object. Beyond just proof of ownership, NFTs can also unlock additional experiences through the use of smart contracts and related technologies, such as augmented reality features, personalized content, or interactive experiences that extend to both physical and digital worlds. Combined with blockchain, phygital products also bring new levels of transparency, allowing consumers to trace a product’s lifecycle right from its production to sale which improves the overall supply chain system.

In a more advanced application, the use of digital twins in phygital products will allow real time monitoring of a product’s condition, linking the physical and digital worlds. A digital twin would provide up-to-date information on how a product is operating and in what condition, securely recorded on the blockchain. While these technologies are still evolving, they offer significant opportunities, including greater personalization, transparency, and long term consumer engagement.

7.2.1 Improving Supply Chain Transparency with Blockchain

Blockchain technology improves the transparency of phygital products from manufacturing to distribution. Its immutable and decentralized nature allows businesses to provide consumers a transparent record of the journey that a product takes, from sourcing raw materials to final delivery. This creates trust by ensuring ethical and sustainable practices, which are very important for the modern consumers.

For example, blockchain has been used in the fashion industry in the “Organic Cotton Traceability Pilot” to track every step of cotton production. It created a reliable system that allowed the verification of sustainability claims, such as organic or fair trade, by checking and verifying every stage. In phygital products, blockchain allows consumers to access detailed records of a product’s lifecycle, with NFTs serving as verifiable certificates for each stage, providing deeper insight into the product’s origin and ethical credentials.

7.2.2 Digital Twins and Real Time Monitoring

Probably one of the most important aspects of phygital design is the use of digital twin technology. Digital twins are virtual replicas of physical products that would help in tracking the status, efficiency, and lifecycle of a product in real time, allowing much more transparency for both manufacturers and consumers. If this is further combined with blockchain, the data becomes immutable, securely recorded, and verifiable, improving the product’s long term value and integrity.

Industries such as automotive and manufacturing have started exploring how to integrate digital twins with blockchain. For example, BMW’s PartChain project uses blockchain to provide transparency in the origin and management of vehicle parts. Combining the secure data of PartChain with digital twins could allow BMW to create a system that not only verifies the origin of every part but also monitors its condition throughout the vehicle’s lifecycle. Together, this combination enables real time insight into the performance of every component, combining the digital twin to a reliable and transparent record throughout its entire lifecycle, from production to replacement.

IoT sensors combined with digital twins technologies working together will further improve real time monitoring across industries. Sensors installed in vehicles, for instance, can monitor conditions, performance, or repair history of a car while updating that data to the metadata of an NFT that represents the car, which is linked to a blockchain. In such a context, this would provide an immutable and more transparent record that would enhance transparency and user trust.

In conclusion, this technology not only improves transparency but also encourages designers to consider a product’s entire lifecycle, including its creation, maintenance, and repairs, thereby supporting greater sustainability and product longevity. With real time, verifiable data about a product’s condition, consumers can make better decisions, strengthening their connection with the product. Although the integration of IoT, blockchain, NFTs, and digital twins remains largely theoretical, this example shows how product design can be improved by focusing on transparency, better user experiences, and long lasting value.

7.2.3 Emotional Connection Through Phygital Products

Phygital products also offer different ways of establishing an emotional connection between consumers and brands. The difference of phygital items compared to traditional products is that they combine physical ownership with digital usage, creating multiple touch points for the consumers with their products. This dual interaction creates a stronger feeling of ownership and personal attachment, particularly because digital and physical components provide customizable features or exclusive content.

A good example of this in the NFT space is the digital sneakers created through the partnership between Nike and RTFKT, known as CryptoKicks. These sneakers were sold in both physical and digital forms. The owners received a digital version of the sneakers as an NFT and a physical shoe. The digital version was highly customizable using an app. Users were able to change colors or patterns of the digital version, which was used in the digital environment. While the possibilities for physical customization are, for now, limited due to logistical difficulties, the digital version provides another level of lasting interaction that improves the emotional connection.

RTFKT. (2022). RTFKT Cryptokicks iRL

This example shows how designers must carefully consider how consumers will interact with both the tangible and digital elements of a product. This requires careful consideration of the design of each of these settings so that they can be brought together in a harmonious way. By combining these digital and physical layers, phygital products allow consumers to develop a dynamic relationship with their purchases, extending beyond the act of buying and encouraging ongoing engagement with the brand.

7.2.4 Future Design Implications of Phygital Products

In the future the integration of blockchain technology, phygital products, IoT, and other relevant technologies can bring great power into the design field. Designers can look beyond the physicality of objects to explore how digital elements can improve the overall experience, from augmented reality engagements to virtual worlds and future product updates. These changes also force creative teams to think about crucial aspects beyond the present design possibilities, such as technical and logistical feasibility of implementing these technologies.

In addition to these, there are also sustainability issues to consider, such as ensuring energy efficient implementation of blockchain and sourcing materials responsibly in the case of physical components. Furthermore, the experiences created through these products should be user-friendly to fit different skill levels and preferences to assure that phygital products are usable and accessible for everyone.

Transparency enabled by blockchain and real time data provided by digital twin technology further allows designers to make more informed future iterations, while the user feedback helps create a truly responsive and data driven design approach. It allows better adaptability in the product's lifecycle and provides an iterative and adaptive process with which one can meet the evolving needs of the users.

Looking ahead, the combination of the physical and digital elements can continue to push the boundaries of design. Phygital products can represent the next stage in enabling dynamic, interactive experiences that connect with consumers and change the way how products are envisioned, designed, and used.

7.3 IMPROVING SUPPLY CHAIN WITH BLOCKCHAIN

One of the main reasons that blockchain can be integrated into phygital products is its ability to increase transparency in the supply chain. Phygital products, using the decentralized and tamper-proof capabilities of blockchain, can potentially provide verifiable proof at each stage of the production process. This kind of supply chain transparency is important for industries where ethics and sustainability are significant issues, since customers can clearly see how each product is made and what happens to it throughout its lifecycle.

In the case of phygital products, where physical objects are interconnected with digital records, blockchain ensures that this connection is traceable and trusted. Consumers can easily trace the origin and journey of the products they purchase in a transparent way. This transparency means that the consumers can now understand and see more precisely how the product they are going to purchase will align with their values, which helps build a higher level of trust in the brands. Also, at this level of transparency, brands can easily prove the claims on ethical production, while also giving consumers the power to make informed decisions based on confirmed data.

7.3.1 Improving Transparency and Trust in Supply Chain with Blockchain and NFTs

Every transaction and every stage within the supply chain can be recorded in the blockchain's distributed ledger in a secure, immutable, and transparent way. This can be very useful for businesses as it allows the recording of every stage of production, from the sourcing of raw materials to the final point of sale. It also provides consumers access to detailed information, helping to build trust and accountability between brands and their customers.

Phygital products can also be linked to NFTs, which serve as a secure digital certificate related with the product's lifecycle. These NFTs store metadata that contains the key information about a product's journey, such as where it was sourced, how it was made, and the conditions under which it was transported. One of the primary advantages of blockchain in this process is the immutability it provides once the data has been recorded. However, new data can always be added as the product moves through the supply chain. This means that while previous data cannot be changed, new information can always be added continuously, which allows for real time tracking of the product's lifecycle.

Consumers can easily access this information by scanning QR codes or NFC-enabled tags placed to the product to verify claims like sustainability certifications, ethical production practices, or fair trade origins. Although integration of NFTs and blockchain for supply chain transparency is still in its early stages, it is being explored across a range of industries, from fashion to food and electronics, where ethical sourcing and sustainability are becoming increasingly important.

By making the entire product lifecycle traceable and secure, brands can build stronger relationships with their customers. Blockchain and NFTs can ensure that claims about ethical sourcing and sustainability can be verified by consumers, which is an increasingly important aspect in design related sectors. As these technologies develop, they are showing great potential to address critical challenges like transparency, ethical sourcing, and sustainability.

7.3.2 Real World Example: Organic Cotton Traceability Pilot

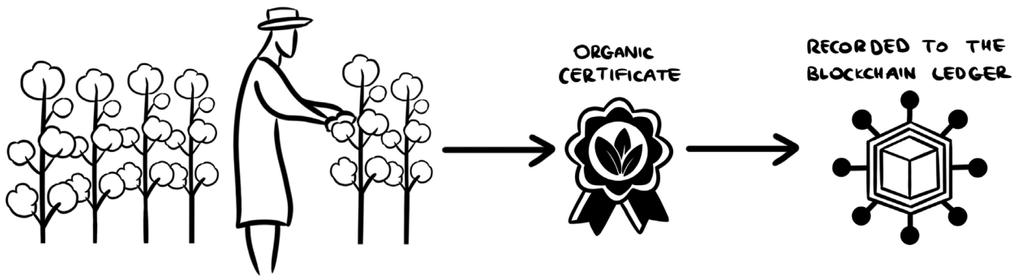
A good example of how blockchain can make supply chains more transparent is seen in the Organic Cotton Traceability Pilot in the fashion industry. In this pilot, blockchain technology allowed the tracking of organic cotton from farms to stores. At each step, farmers, textile producers, and retailers recorded information on a secure blockchain. This created a reliable and clear record of the cotton's journey through the supply chain, ensuring transparency and building trust.

Also, this pilot not only ensured the integrity of organic certifications but also authenticated claims about fair labor and environmentally responsible production. Even if there is no verifiable information about how to access this information, consumers could potentially access the products history through QR codes or NFC-enabled tags on the final product as an easy way to connect with the blockchain ledger and view the product's origins.

This pilot demonstrated that this kind of system works, but it was just the first step toward larger scale use. It showed how blockchain can bring complete transparency and traceability in supply chains, but more development and scaling up will be needed before it can be used widely across industries.

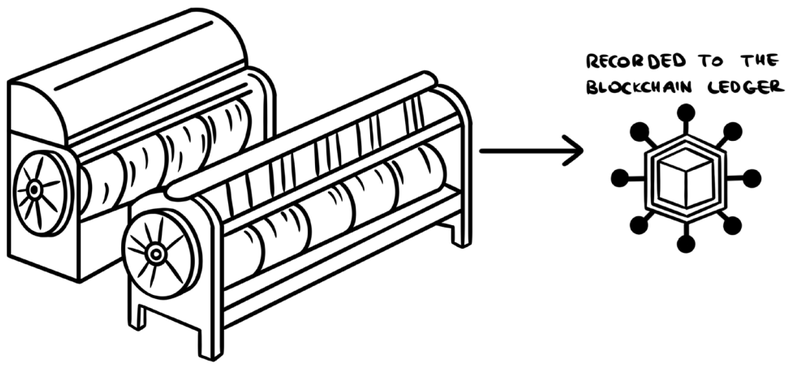
7.3.2.1 Steps of Organic Cotton Traceability Pilot

- **Step 1: Sourcing of Organic Material**



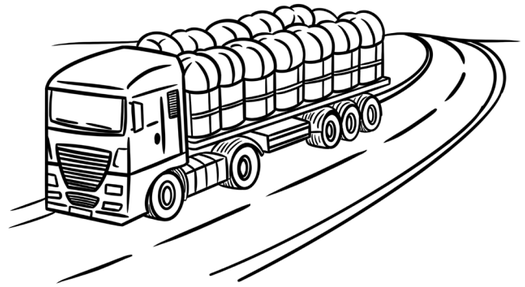
  - *Farmers collect raw material.*
  - *Data such as harvesting methods and organic certification are recorded to the blockchain.*

- **Step 2: Processing Recorded**



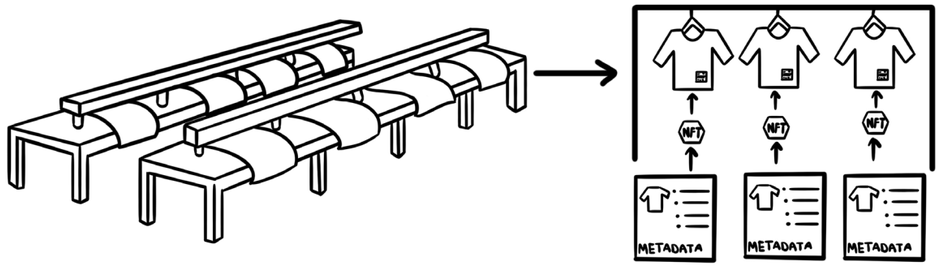
  - *The raw materials are processed and this is recorded to the blockchain.*

- **Step 3: Shipping Information Recorded to the Blockchain Ledger**



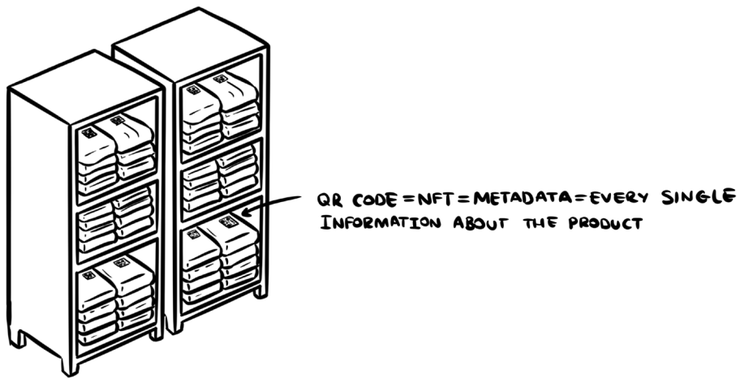
  - *Each transport stage, from the processing factory to the manufacturing facility, is recorded on the blockchain. This could include information on shipping methods and handling practices to verify ethical and ecor-friendly logistics.*

- **Step 4: Manufacturing Recorded**



  - *Information such as water usage, chemical treatments, and waste management practices are recorded to the blockchain.*
  - *A unique NFT is created for every single product, linking it to a digital identity. The metadata of each NFT contains previously recorded information.*

- **Step 5: Distribution to Retail**



  - *When the product arrives to retailers, the NFT metadata is updated for the final time with information such as, transportation, final assembly, packaging.*
  - *QR codes are also added to the physical product, allowing consumers to access the products complete blokchain backed history and its linked NFT.*

- **Step 6: Sale and Consumer Interaction**

- *When a consumer buys the product, the final sale is recorded to the blockchain.*
- *Consumers can scan the QR code to access the products NFT. Doing so, they can see records of every step, from origin to purchase.*

7.3.2.2. Applying Blockchain Transparency to Phygital Products

Blockchain-enabled transparency can provide significant advantages for phygital products. By recording the lifecycle of both the physical and digital components on a blockchain, businesses can provide customers with secure and reliable information about sourcing, production, and transportation. An NFT can also be created to act as a digital certificate, storing key information like sustainability certifications, shipping conditions, and whatever else may be relevant.

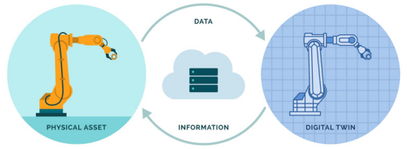
Integrating blockchain, NFTs, and phygital products allows consumers to track the journey of the product they want to purchase without needing any assistance. This also helps brands validate their claims about ethical sourcing and sustainability. Although still experimental, this approach has great potential to revolutionize supply chain transparency for phygital products, applying the same immutable principles used in projects like the Organic Cotton Traceability Pilot.

7.3.2.3. Other Examples of Blockchain in Supply Chain

Apart from the fashion industry, the use of blockchain technology is being explored for similar purposes in other industries. In 2018, for example, Carrefour integrated blockchain into its supply chain so that by scanning a QR code on a product, consumers were able to get information about its journey. In the case of BMW, its PartChain project integrated blockchain into its supply chain to track the lifecycle of vehicle components. This ensured the authenticity of the components and reduced the possibility of counterfeit parts entering the supply chain.

While these are still relatively new examples, they show the potential of blockchain in building trust and accountability across many different industries. As more consumers demand transparency and sustainability, blockchain provides a valuable tool for businesses by authenticating both physical and digital assets. This is particularly valuable in the case of phygital products, where combining physical and digital records is key to establishing consumer trust.

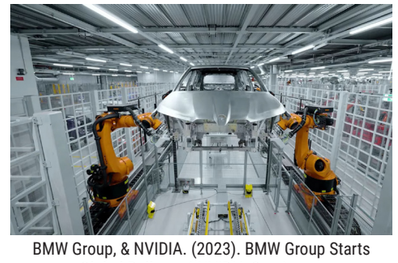
7.4 DIGITAL TWINS AND REAL TIME MONITORING



Digital Twins are advanced technologies that allow the creation of real time digital copies of physical products. These highly detailed virtual copies capture the entire lifecycle of a product, dynamically reflecting its real world status, performance and condition. When combined with blockchain technology and NFTs, digital twins provide exceptional transparency, traceability, and security in product design and management, creating a new field for phygital products. While still evolving in many industries, the combination of digital twins, blockchain, and NFTs holds significant potential to transform product design and management.

7.4.1 What are Digital Twins?

A digital twin is a direct virtual copy that represents the physical characteristics, behaviors, and conditions of a physical product. It provides data in real time with the integration of IoT sensors or other devices. This, as a result, gives a highly detailed view of the product's status from its creation to its final use, including how it is used, its wear and tear, and maintenance requirements throughout its entire life. Manufacturers, designers, and customers can view this data in real time, making digital twins very useful, precise, and efficient.



BMW Group, & NVIDIA. (2023). BMW Group Starts Global Rollout of NVIDIA Omniverse

Digital twin technology has already made significant impact in different industries such as automotive, aerospace, and manufacturing. A great example of a company that uses this technology is BMW. They use it to improve the performance and the manufacturing of their vehicles. By leveraging digital twins, they can track each vehicles conditions in real time, predict when it might need maintenance, and test numerous possible scenarios to ensure the car operates well throughout its entire life. As an example, this strategy allowed BMW to identify problems early on, improve the design of vehicles, and increase manufacturing efficiency.

7.4.2 Integrating Digital Twins with Blockchain and NFTs

If digital twins can be combined with blockchain, NFTs can act as digital twins, increasing transparency and accountability, as they are assets based on blockchain technology. Blockchain's decentralized and immutable nature ensures that any updates or changes made to the physical product are securely stored in its NFT based digital twin. As a result, the NFT not only works as a digital certificate of ownership, but it also stores the product's data and history, resulting in a clear, tamper proof record. This allows easy tracking of product changes while ensuring data security and accuracy.

In the automotive industry, BMW's PartChain project demonstrates how blockchain can securely track the production and lifecycle of vehicle components. By integrating this blockchain based system with digital twins and IoT devices, manufacturers can monitor the status of each component of a vehicle in real time. Repairs, updates, and ownership changes about a vehicle can be recorded on an immutable blockchain ledger.

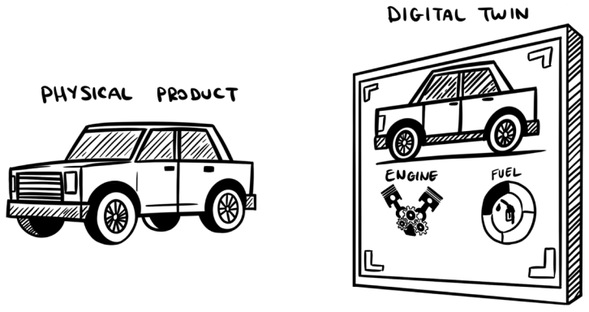
In this case, NFTs, as mentioned before, can act as digital twins that represent the vehicle itself. These NFTs can store important information, such as modifications, repair records, and ownership changes, securely and continuously updated on the blockchain. IoT devices, which are connected to the blockchain and through that to the NFT based digital twin, play an important role as they collect real time data from the physical vehicle, ensuring that the NFT based digital twin always has the most accurate data. If developed properly, this system can provide a clear and reliable way for consumers, manufacturers, and future owners to access important information about the vehicle and help them make better decisions.

Also, real time monitoring made possible by NFT based digital twins and IoT devices significantly improves the user experience, as they can inform owners about needed repairs or upgrades before problems occur. Blockchain automatically (thanks to the use of smart contracts) and securely records these warnings and if done, the repairs in an immutable way, while the NFT based digital twin acts as a reliable record of all the updates and repairs made. This gives users the information they need to make better decisions about their product and the products that they are going to purchase.

It is also important to note that, while these ideas are promising, they are still mostly theoretical. Projects like BMW's PartChain show some practical uses of blockchain in supply chain, but the integration of digital twins, blockchain, and NFTs in phygital products is still largely theoretical.

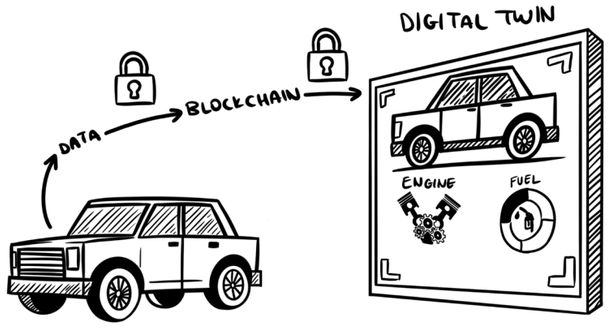
7.4.2.1. Steps of Integrating Digital Twins with Blockchain and NFTs

- **Step 1: Creating the Digital Twin**



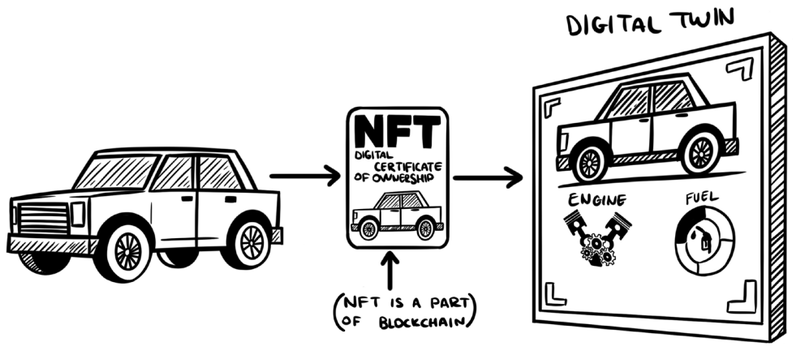
  - *Each physical product, in this case a car, has a digital twin, a virtual model that shows the cars real time stats and conditions.*

- **Step 2: Integrating Blockchain to this System**



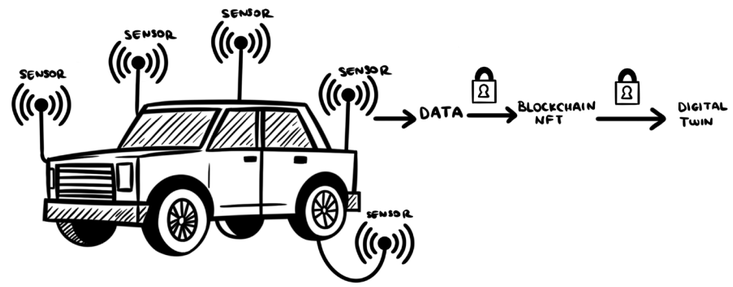
  - *Now the digital twin is connected to the blockchain. This ensures that all data related to the digital twin is securely recorded and cannot be changed. In this way it is possible to create a trusted source.*

- **Step 3: Assigning Ownership Using NFTs**



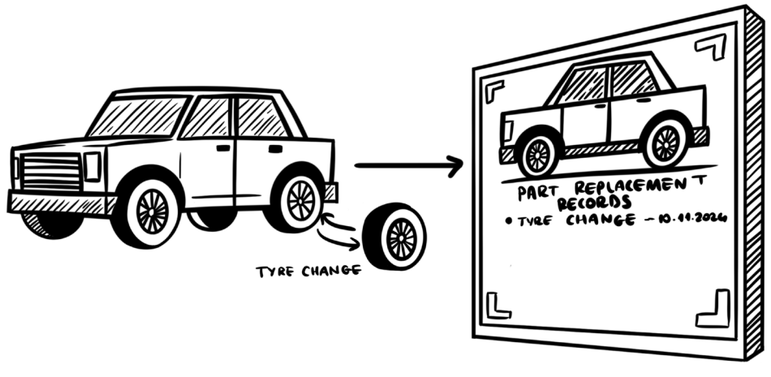
  - *An NFT that represents the car is created. This NFT serves as a unique digital certificate linked to both the physical product and its digital twin, representing ownership and creating a traceable, permanent history of the product.*

- **Step 4: Integrating IoT Sensors to Collect Data**



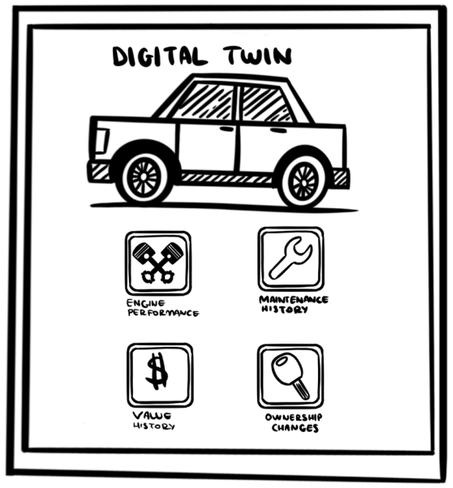
  - *IoT sensors on the physical product collect real time data such as performance data and maintenance needs. This data is continuosuly updated in the digital twin, making it an accurate representation of the product's condition.*

- **Step 5: Recording Updates on Blockchain**



  - *As the digital twin recieves updates (like maintenance records or part replacement), each update is recorded on the blockchain, secured against alteration*

- **Step 6: Providing a Comprehensive History**



  - *All modifications, ownership changes, and real time data information are recorded on the blockchain. The linked NFT holds metadata about the product's history, giving current and future owners a verifiable record of every event.*

7.4.3 Expanding Creative Possibilities with Digital Twins and Smart Contracts

Beyond tracking and monitoring, digital twins combined with IoT devices and blockchain through smart contracts can improve user engagement with phygital products in new and creative ways. IoT sensors like proximity sensors, heat detectors, or scanners allow a digital twin to understand the physical status of a product and create meaningful interactions between the digital and physical worlds based on these factors. This interactive connection allows the creation of experiences in which the physical and digital parts of a product can change in real-time, immersing users in both worlds at once.

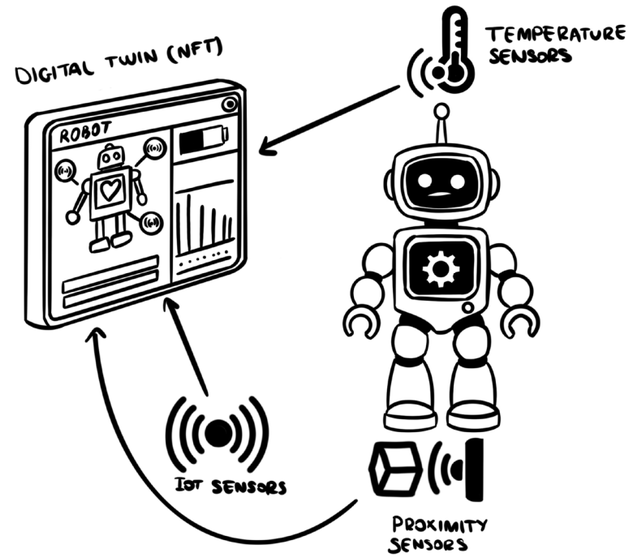
In this concept, smart contracts play an important role in automating interactions between IoT devices, blockchain, and NFTs to unlock new digital features or trigger actions based on specific situations within the digital twin or the physical product. For example, an NFT representing a phygital product can reach a milestone in a blockchain based digital world. As a result of this, a new feature can be unlocked or revealed in the physical product, such as a new sound effect (it is important to note that these kinds of features are limited by the capabilities of the physical product, such as its technological limitations). Similarly, a physical action with the phygital product that is linked to the NFT based digital twin could activate or unlock new features in the digital space that improves the user engagement in that space.

All these interactions are automated through smart contracts as they are digital agreements that execute automatically when specific conditions are met. This dynamic connection between the NFT (digital twin) and physical product can significantly improve the overall user experience.

In this case, phygital products integrated with digital twins, NFTs, IoT sensors, blockchain, and smart contracts allow for the creation of personalized, real time, interactive experiences that blur the lines between physical and digital realms. This kind of automation and interactivity enables designers to come up with products that are easily usable, enjoyable, and emotionally meaningful to users.

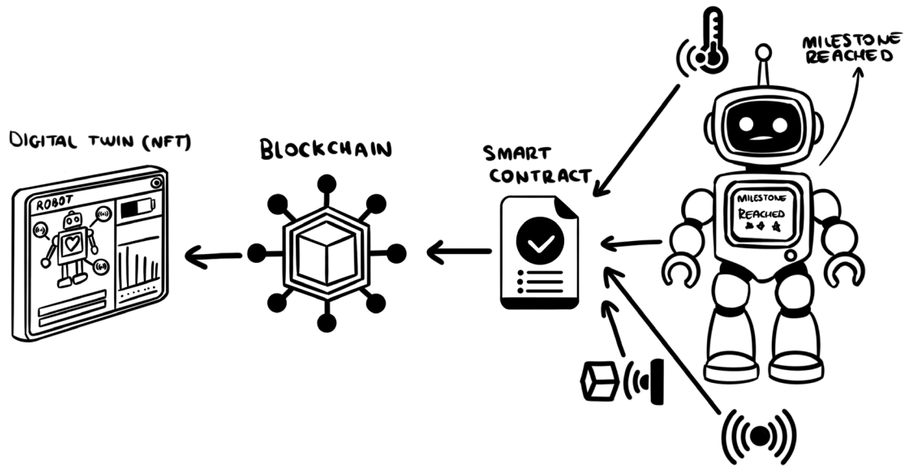
7.4.3.1 Example of an Engaging Phygital Product with Digital Twins and Smart Contracts

- **Step 1: Connecting Physical Products to Digital Twins with Sensors**



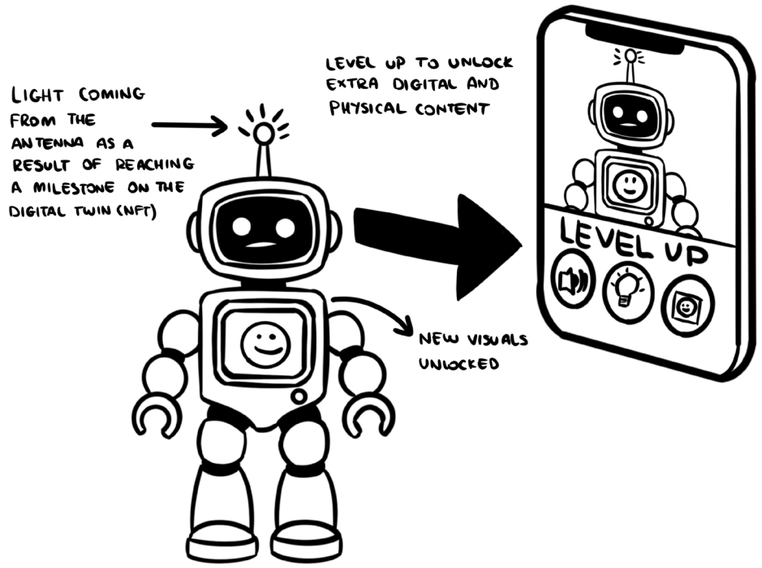
  - *The first step in this concept is adding sensors to link the physical product (in this example the toy robot) with its digital twin (the NFT). This connection created by sensors allows the toy to send information about specific events happening in real time.*

- **Step 2: Automating Actions with the Integration of Smart Contracts**



  - *The next step is about connecting these sensors to the blockchain and, through that, to the NFT based digital twin to automatically trigger predefined actions. In the blockchain and NFT space, transactions and events are automated using smart contracts, making them the best option for this concept. By defining actions at the beginning and integrating smart contracts to the system, events can be executed smoothly and automatically.*

- **Step 3: Creating Dynamic User Interaction**



- *After adding sensors and setting up a smart contract to connect the digital and physical product, the next step is to create dynamic user engagement. The idea in this concept is to create an interactive toy (robot) with both physical and digital versions, each offering unique features that make the experience more enjoyable. For example, the toy's sensors could understand specific colors, unlocking a new skin in the digital version. Additionally, reaching a milestone in the digital space, such as leveling up, could unlock a feature in the physical toy, like a sound effect or a new movement.*

7.5 EMOTIONAL CONNECTION WITH PHYGITAL PRODUCTS

Phygital products offer consumers more than just ownership; they create emotional connections and immersive experiences with the product. Combining physical products with digital aspects, phygital products engage with users in ways that traditional products cannot. While traditional products are just sold and the relationship ends there, phygital products take this relationship further. For example, a phygital wearable would have both a physical version and a digital counterpart, each with distinct features and use. In these phygital wearables, the physical version might be a default model with minimal customization options due to logistical and technological limitations. However, the digital version can be customized and can be worn in virtual environments, allowing for continued interaction even after the purchase. Additionally, the digital version can provide other kinds of benefits, such as acting as an entrance key to exclusive events, or free merchandise giveaways, as the idea behind these kinds of products is to provide an ongoing experience, which goes beyond the point of sale.

This approach meets modern consumer's desire for personalization, exclusivity, and engagement. It allows them to continue interacting with their product through digital updates, customization, or special experiences. It makes the product part of a greater story, part of an ongoing relationship between consumer and brand.

7.5.1 Creating Emotional Engagement through Customization

Probably one of the strongest ways in which phygital products can create an emotional connection with their customers is through personalization and customization. The ability to personalize a product, whether digital or physical, gives consumers the feeling of ownership and involvement beyond just buying the product. This kind of personalization creates an emotional connection by letting consumers express themselves and by allowing them to customize and interact with the product in their own way. As of now, personalization of phygital products mainly focuses on the digital aspects of the product, which can be changed as time progresses or customized by the consumer to keep them engaged with the product. The physical customization, on the other hand, is minimal due to the logistical and technological limitations.

RTFKT. (2022). RTFKT Cryptokicks iRL

A very good example of this is the collaboration between Nike and RTFKT with their line of CryptoKicks sneakers. When people bought CryptoKicks, they got a physical sneaker and a digital version of it, both linked to a single, verifiable NFT. The NFT not only acted as a certificate of authenticity and ownership, stored on the blockchain, but also as a key to future benefits, such as special digital or physical accessories exclusive to the holders, special upgrades, or access to exclusive events. As a result, instead of buying just a simple, static artwork, consumers bought an ongoing experience that kept them engaged in various ways. Additionally, with an app (CryptoKicks iRL) developed by RTFKT, users were able to change how their digital and physical sneakers looked, such as by changing the colors, patterns, and accessories virtually (they are also able to change the lights of the physical shoes through the app). These factors, all combined, created an ongoing experience, which kept the consumers engaged with the product and the brand. However, the logistical and technological limitations restricted the physical customization, but with the integration of digital features, the product went beyond the digital realm and created an ongoing experience in both the digital and physical worlds.

7.5.2 Ongoing Interaction Through Real World and Digital Experiences

Phygital products provide ongoing interaction through the combination of both digital and physical experiences, which go beyond traditional static products, creating a continuous relationship with the consumer. This change from traditional methods allows brands to deepen the engagement by offering exclusive access, rewards, and experiences that enhance both the digital and physical aspects of the product.

NFTs, in this concept, act as a bridge between the physical and digital worlds. For example, a phygital fashion item that is linked to an NFT could offer digital perks, such as accessories or seasonal features in the digital environment, while also providing access to real world events, such as entrance to exclusive events or product launches. This combination of digital elements and real world benefits helps build loyalty and a strong connection between the consumer and the brand.

Brands can also use NFTs as loyalty tokens, as a way to reward loyal customers with early access to upcoming products, exclusive events, or private gatherings. These potential experiences give consumers the possibility to interact with other community members and the brand, building a sense of exclusivity and belonging.

7.6 FUTURE DESIGN IMPLICATIONS OF PHYGITAL PRODUCTS

The phygital products, which combine the physical and digital elements, can have a big impact on the future of design. Designers will now have to consider not only the physical form and function of a product but also the digital layer that increases its value and user experience. This includes using blockchain, NFTs, smart contracts, IoT sensors, and other sorts of technological advancements to make products that are easier to track, personalize, and keep consumers engaged even after a good amount of use.

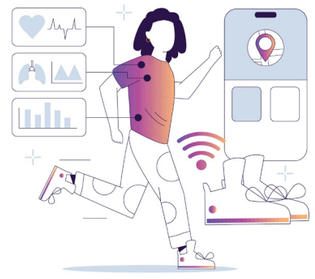
7.6.1 Building Long Term Consumer Relationships with Phygital Products

Phygital products are changing how products are designed and developed. They combine physical and digital elements, and this creates the need for a more connected and integrated approach to ideating, designing, and developing these products.

7.6.1.1 Designing Phygital Products with the User in Mind

- **Dual UX Expertise:** Designers need to have a good knowledge of both the physical and digital user experience in order to create successful phygital products. This means understanding how the user will interact with physical objects, focusing on areas like ergonomics, design, and usability. At the same time, they need to focus on developing smooth digital experiences, by creating easy to use digital interfaces that feel natural and intuitive. These two areas are very important in these products and they must be interconnected, as digital elements can shape what users expect from physical products, while physical products can make digital interfaces more usable. Designers can create a smooth and engaging experience through all dimensions of the product by combining these elements.

- **Seamless Integration:** Phygital products need to be integrated in such a way that they become one unified experience. Designers have to provide smooth transitions between the physical product and the digital aspects of it so that the function of the product remains consistent and the information flows smoothly as users move between digital and physical features of it. For example, we can think of a phygital wearable fitness product that uses augmented reality features and sensors to provide users personalized feedback in real time, based on their physical activity. This product can be linked to an NFT and, through the integration of smart contracts, it can provide rewards and perks automatically based on the users activity, such as unlocking unique content or giving special training plans as rewards for reaching a milestone. This kind of interaction adds a sense of progression and achievement, which can strengthen the connection between the product and the user. In some cases, the connection between the physical and digital features can be simpler, depending on the product's purpose.



- **Improved Functionality:** Adding digital elements to physical products makes them more intuitive and functional. For example, AR can be used to show step by step instructions, update the performance in real time, or create fun and game like experiences in the physical world improved by digital elements. NFTs can also be used in these products to improve the overall experience. They provide the feeling of ownership in the digital realm, which creates a stronger emotional connection between the user and the product. On top of this, they can also help provide special digital perks, like personalized digital

features or unique experiences for the customer. These perks are provided to the customer automatically thanks to the integration of smart contracts, which automate various tasks when specified conditions are met. This integration of digital and physical elements not only improves the overall functionality of the product but also creates a deeper connection and more personalized content for the user.

7.6.1.2 Blockchain's Role in Transforming Product Development and Consumer Engagement

Blockchain technology improves product development by providing transparency, traceability, and security throughout the entire system. It optimizes processes in production, starting from design to supply chain management. In prototyping, traceability provided by blockchain can be very helpful as it records every single change made to the design in chronological order and in a secure way. Its immutable records also improve quality control by storing reliable production data securely, which can be important for identifying and resolving issues if needed. This level of transparency in the supply chain creates accountability, benefiting both brands and consumers.

Blockchain also makes it possible to give brands the ability to use NFTs in deepening consumer engagement and offering personalized experiences. Linking physical products with NFTs can help a brand to understand more about their customers, such as what are their favorite features, customization options, and how often they engage with exclusive content. As consumers use NFTs and their platforms to claim rewards, join exclusive groups, or personalize digital items, the activity will generate valuable data about them. Brands can analyze this data to improve their products and provide a better experience for their users. Additionally, since blockchain is decentralized and secure, the collected data will be safe and reliable.

However, the consumer data that is collected through NFTs raises questions about trust and privacy. While blockchain technology provides a secure and reliable environment for users, it also makes the transaction history public and visible to everyone. This can potentially show details about users actions that might be private. For this reason, brands must focus on developing systems that keep user data private and follow privacy regulations.

While the adoption of blockchain is currently challenging, as it is a costly and complicated process, and traditional systems like proof-of-work use a lot of energy, the technology is improving. Most blockchains today are using less energy intensive methods like proof-of-stake. Over time, as the technology improves even more, blockchain could save costs significantly while improving the efficiency of various processes and consumer engagement.

7.6.2 Sustainability, Adaptability and Feasibility

While the potential of phygital products is huge, there are a number of critical factors that must be carefully considered before they can be implemented successfully and proven useful in the long term. There are three main factors that need to be looked at. The first one is sustainability, which focuses on the environmental impacts of using blockchain technology, which requires a lot of energy, as well as the materials and processes used to produce the physical product and how sustainably they can be made. The second one is adaptability, which focuses on creating products that are easy to understand and use for different people, no matter what their technical abilities are. The final one is feasibility, which is about understanding the technical and logistical requirements that are going to be needed to make sure that the physical and digital parts of the product work well together. If these issues are carefully taken into account, designers will be able to create phygital products that are creative, practical, and sustainable.

7.6.2.1 Environmental Sustainability

- **Energy Consumption:** One of the biggest issues about the sustainability of phygital products is the energy consumption level of blockchain technology. Especially blockchains that use proof-of-work (PoW) as their consensus mechanism, like Bitcoin, which require a lot of computational power to validate transactions and keep the network secure, resulting in a large carbon footprint. Bitcoin alone, for example, can use as much energy every year as a small country. This high energy usage also applies to NFTs created and traded on PoW blockchains, as the minting and transferring of these digital assets requires high energy usage.

  To solve the issue of high energy consumption in blockchains, there has been a shift towards the use of the proof-of-stake (PoS) consensus mechanism. Blockchains that use PoS consume less energy compared to those using PoW. A good example of this is Ethereum, whose energy use was significantly reduced after migrating to PoS. Other blockchains, such as Tezos and Solano, are also good options for creating and trading NFTs in an energy efficient way, which makes them suitable for phygital products. Furthermore, improving how transactions are processed and using renewable energy for blockchain activities are important for reducing the environmental effects of these technologies.

- **Sustainability of Physical Aspects:** Beyond blockchain, sustainability must also include the physical factors of phygital products. Using circular economy principles, such as using recycled materials, reducing packaging, and optimizing transportation methods, designers can reduce the environmental impact of the physical product. Also, considering the full lifetime of a product, such as durability, repairability, and recyclability is important in shaping a sustainable life cycle. By considering both digital and physical aspects of phygital products, designers can work toward creating products with less environmental impact.

7.6.2.2 Consumer Adaptability

To ensure that a wide range of users can easily adapt to phygital products, it is important to focus on adaptability. This means that these products should be easy to use (user-friendly) for people with different levels of technological knowledge. It should also include a clear explanation of benefits and making the technology easy to understand. By doing this, designers can make users feel more comfortable and interested in using phygital products, which can lead to more people accepting them.

User-Friendly Interfaces
In order for designers to make sure that a product is easy to use by anyone, regardless of their technological knowledge, they have to create interfaces that are both clear and simple to use. Here are ways in which they can do it:

- **Easy Navigation:** A clear and consistent navigation pattern, along with visual cues and a minimalist design, will help users understand and interact with the product easily even if they don't have any technical and technological knowledge.

- **Adaptable Interaction:** Providing different levels of interaction modes for different users can be useful because it allows the user to have the freedom to engage with the product at their own pace and comfort level. For beginners, a simple mode with basic features may be better, while more experienced users might prefer a more complex mode with extended functionalities.

- **Connecting the Physical and Digital:** The physical and digital parts of the product should work smoothly together to create an easy and enjoyable user experience. Transition between the physical product and its digital counterpart has to be effortless to increase the overall experience. This seamless connectivity can allow users to gain real benefits from digital features, thereby making the product even more engaging and immersive.

Education and Communication
Clear communication and education are important to help more people understand and use phygital products. Designers can achieve this by:

- **Targeted Communication:** It is important to communicate in ways that match different audience needs, so the information is clear and useful. This might include creating different levels of marketing materials, tutorials, and guides for beginners, intermediate users, and advanced users. It also includes using feedback from surveys or reviews to improve communication based on what real users need and experience.

- **Simplifying Complex Concepts:** Explaining complicated technologies like blockchain and NFTs in simple terms is important. As these technologies may seem complex, they can intimidate some users and, as a result, this might limit the widespread adoption of phygital products. Designers can use analogies, metaphors, and real world examples to explain such concepts. The onboarding process can also be simplified even more by using videos and tutorials, which can provide step by step instructions and make the technology seem more friendly and usable for a wider audience.

Building Trust and Transparency
To establish trust in phygital products, businesses need to be open about how they use blockchain and data. They should explain clearly that blockchain records every transaction publicly and what this means for consumer privacy. It is also important for businesses to explain how users can protect their digital assets using secure digital wallets.

Also, businesses need to be transparent about the data collected. They should explain what data they collect and how they use it, to make sure that users feel safe and confident that their privacy is being respected.

Moreover, businesses can provide privacy options that reduce exposure of personal information while still being transparent. By sharing all this information openly, businesses help users feel more in control over their digital assets and personal data. This builds up trust, loyalty, and improves the overall user experience, making users feel secure.

Community Building
Building a community around phygital products can provide an environment where users can support one another, stay engaged, and learn from each other. Online forums, social media platforms, and other interactive spaces can also be created to provide a space for product owners to connect. Only those who own the product (NFT) can have access to these platforms, creating an exclusive environment that deepens their sense of belonging. Additionally, there can be community feedback channels that might allow users to influence ongoing product development. This not only shows that ideas of the users are valued, but also improves the trust and loyalty as users can see that the product evolves based on their needs and feedback.

7.6.2.3 Technical and Logistical Feasibility

Developing phygital products has its own challenges in terms of both digital and physical feasibility. Businesses must carefully understand the technical requirements, such as infrastructure, data synchronization, and scalability of the system, and the logistical factors, such as inventory management, distribution, and product maintenance. To successfully combine the digital and physical aspects, businesses need to create a coordinated business model to make sure that the product works smoothly and is easy for consumers to use. Below, we will take a look at the key digital and physical aspects that need to be considered in the development of a phygital product:

Digital Aspects:

- **Cost Analysis:** When integrating blockchain and NFTs into product design, it is important to consider all the costs related to these technologies. These might include the cost of setting up blockchain, creating smart contracts, minting NFTs, and the transaction fees on the network. Businesses should look for economic solutions to minimize these expenses and create an economically sustainable business model. This can involve choosing an efficient and economic blockchain platform or optimizing smart contracts to be able to reduce the transaction costs (gas fees). It is also very important to keep the expenses as low as possible, since high expenses can affect the product's price and as a result reduce its accessibility. This means that a good cost analysis will help designers and businesses make the right decision for proper return on investment.

- **Infrastructure Requirements:** For phygital products to function smoothly, they need a strong digital infrastructure. This means that designers and businesses need to consider factors such as internet connectivity, cloud storage for digital files, and the efficiency and reliability of the blockchain so that they can provide a smooth product and a user experience for users. Additionally, keeping the users data secure is very important as it helps businesses to build trust in the digital space which is a crucial factor in the phygital products.

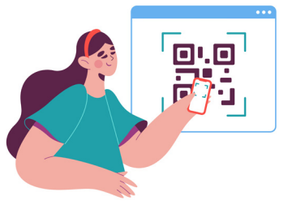
- **Scalability Challenges:** If phygital products become a reality in the future, designers and businesses need to handle challenges like processing large numbers of transactions at once, storing large amounts of digital data, and managing extensive user activity. To overcome these challenges, they need to focus more on scalability testing to identify potential issues before they become a bigger problem.

- **Collaboration and Research:** Collaboration and research are essential for staying informed about developments in blockchain, NFTs, and other technologies. Since these technologies are relatively new, there are always developments in the space, and continuous learning and active research are critical for businesses to remain competitive in the industry. For this reason, collaborating with blockchain developers and tech suppliers can be beneficial as they can help businesses stay competitive by updating them continuously. Furthermore, this collaboration can make it easier for businesses to adapt quickly to new technologies and changes in the industry.

Physical Aspects:

- **Combining Physical and Digital Parts:** To be able to create a true phygital experience, it is important to combine the physical product smoothly with its digital counterpart. This might include:

  - **Using NFC Tags or QR Codes:** These are affordable and practical ways to connect a physical product to its digital counterpart (in this case NFTs). Users can scan them to access information related to the product easily, prove the authenticity of the product, or unlock digital or physical features. Their simple nature and affordability make them a practical choice for improving user engagement and trust.



  - **Designing for Interactivity:** Integrating interactive elements into the physical products can significantly improve the phygital experience. By using responsive components such as motion sensors, sound sensors, or light sensors, designers can create an interconnected experience that connects the physical and digital worlds to create a dynamic, two sided experience. For example, we can think of an interactive toy that includes sensors to trigger actions such as new animations or sound effects in its digital counterpart or even unlock new digital features when specific actions are performed in the real world. For instance, reaching a milestone in the real world might reward the consumer with an NFT connected to their digital product, adding a surprise factor and deepening the engagement. At the same time, by integrating digital components into the physical product such as lights or screens, designers can introduce new features to the physical product over time, expanding the product's physical capabilities. This interactive way of designing creates a better connection between the user and the product by combining the physical and digital features to unlock new ways of play and engagement.

    There are also factors that need careful consideration to integrate these components, such as cost, durability, and if necessary, maintenance. While digital features can be added continuously through the use of NFTs and digital updates, the physical products may introduce challenges and limitations in terms of upgrades or modifications. To create a smooth two sided phygital experience, designers need to balance digital factors with the limitations of physical interactivity.

  - **Miniaturization and Durability:** For phygital products that include electronics, it is important to make them compact, visually appealing, and strong enough to handle regular use and environmental factors. However, some phygital products, such as limited edition collectibles or wearables linked to NFTs, may not require advanced technologies in the physical item. For these products, miniaturization and durability become less important, as their technological aspects are more focused on the digital elements.

- **Logistics and Distribution:** Phygital products combine both physical and digital parts, which makes delivering them more complicated than regular products. To get these products to customers smoothly, companies need to carefully plan for both the physical item (like shipping the product) and the digital part (like linking it to a digital feature or experience). In short, it's about making sure both the physical product and its digital counterpart are delivered and connected smoothly for the customer.

  - **Inventory Management:** Managing inventory for physical products and their digital versions, like NFTs, can be challenging as the demand can change unexpectedly depending on the hype around the product. To overcome these challenges, businesses can use systems powered by data analytics or AI for forecasting demand. These systems can analyze consumer buying patterns, seasonal trends, and transaction volumes on blockchain to be ready for changes in demand.

    From the digital side, NFTs can have a big role in the process. They are unique digital tokens linked to the physical products. They might help businesses track general information about the product, like its price, how many times the product has been sold, or the current location of the product (if the physical product includes IoT sensors or other technologies). Businesses leverage this information without invading consumer privacy. NFTs also confirm the authenticity of the digital assets and connect them to real physical products, ensuring both are genuine and unique.

    By combining NFTs with inventory management systems, businesses can manage their stock in a better way. For example, thanks to the integration of smart contracts with NFTs, they can update inventory systems automatically and reorder products when something is selling well. This makes it easier for businesses to adapt quickly to market changes and keep their physical and digital products in sync, creating a smoother experience for everyone.

  - **Global Reach:** Going into global markets comes with its own challenges for phygital products. Designers and businesses need to understand international shipping laws, customs procedures, and understand what consumers want across different regions. This not only applies to the physical aspects of the product but also the digital features which are equally important. Making changes to digital parts, like changing interfaces or content to fit local tastes, can really help improve how users in different places enjoy and interact with the product.

    Although blockchain and NFTs can operate without any geographical limitations, phygital products must also try to be equally accessible worldwide. Addressing the logistical challenges and working to localize content are critical steps for designers and businesses. This way they can try to close the gap between the limitless nature of digital assets and the physical limitations of real world products. By reducing these geographical barriers, both in the physical and digital worlds, designers can create phygital products that are more seamless and globally accessible.

CONCLUSION

This thesis explores how blockchain technology and NFTs can transform product design by connecting the physical and digital worlds. By using technologies like smart contracts, decentralized ledgers, digital tokens, and sensors, they improve transparency, security, and consumer engagement, while also opening up new opportunities for creativity and efficiency.

Technological Foundation

The first chapters of this thesis described how blockchain progressed from supporting cryptocurrencies to becoming a critical technology for decentralized networks. Blockchain's immutability, transparency, and decentralized nature make it a powerful tool for building trust and accountability in many industries such as manufacturing, healthcare, and product design. Furthermore, smart contracts simplify and automate complex tasks, while NFTs provide a secure way to represent and verify digital ownership. Additionally, if these technologies can be used together with Web 3.0 and Industry 4.0, it can create systems that increase autonomy, connectivity, and scalability.

Phygital Product Design

Blockchain and NFTs have created a solid foundation for phygital products, which combine physical and digital elements to create unique user experiences. Unlike traditional products, phygital products can leverage NFTs to use it as digital twins and tools to increase the value of the product by providing verified ownership, traceability, and exclusive features. These features might include unlocking special product functions, joining exclusive online communities, or participating in events linked to the product in the real world.

Blockchain technology provides transparency, verifying the authenticity of the products. Additionally, it also contains every transaction and action related to these products, which can verify details such as organic and ethical sourcing, previous owners, and the value change in time. In phygital products, smart contracts automate events and actions related to the product (when the specified conditions are met). These actions can be a surprise giveaway, a product function update, or a new feature.

Phygital products also strengthen the emotional connection between consumers and brands. However, creating a smooth connection between physical and digital elements requires careful consideration of user experience, sustainability, and logistics. By addressing these challenges, designers can develop practical and innovative products that truly connect with users.

Challenges and Considerations

While blockchain and NFTs have great potential for product design, they also come with their own challenges. Issues such as scalability, high energy usage, and unclear regulations can limit their adoption. Consumer trust is also another concern, especially around data privacy. Designers also need to find a balance between using advanced technologies and making products easy and accessible for all users.

Future Prospects

The future of blockchain and NFTs in product design also depends on their capabilities to advance with new technologies. Combining them with IoT, AI, and Industry 4.0 can lead to smarter digital twins, adapt-

able and dynamic products, and more sustainability in the process. As these technologies improve, they could reshape the interaction between consumers and the product. Collaboration between designers, engineers, and technology experts will also be very important for fully realizing their potential.

Final Thoughts

This thesis shows that blockchain and NFTs can be valuable tools for product design. They increase transparency, security, and the connection between physical and digital experiences, helping designers create meaningful products that align with modern consumers values. While there are technical, logistical, and ethical challenges to address, these technologies provide the potential for more engaging, sustainable, and impactful design in the future.

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