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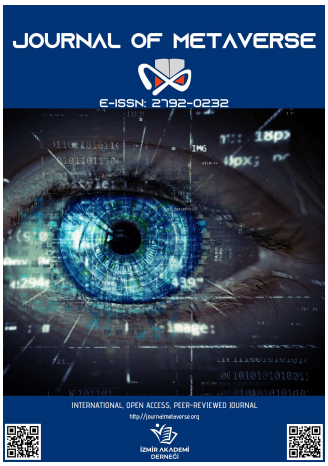

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A multi-criteria approach to rating Metaverse games

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***Abstract*— Non-Fungible Tokens (NFTs) took the already profitable gaming industry to a whole new level. Before that, people would pay to buy games, and there were also some in-game purchases. But now every item in games is an NFT, and different NFTs have different prices. A lot of users consider NFT metaverse games an investment opportunity. Therefore, it is vital to evaluate these metaverse games and rate them to find the most attractive investment opportunities. In this paper, we develop a framework for rating NFT metaverse games by considering their various risks and potential upsides through the PROMETHEE II method. Specially, we design a flip ratio that can take into account both the opportunity to flip another cryptocurrency and the risk of being flipped by another cryptocurrency. Our new flip ratio could be a very useful measure of risk-opportunity analysis. We also analyze the crash risk of NFT game tokens' prices through a non-parametric value at risk analysis, which is compatible with the volatile nature of cryptocurrency prices.**

Keywords*— *Non-Fungible Tokens, PROMETHEE II, Metaverse, Flip Ratio, Non-Parametric Value at Risk

I. INTRODUCTION

The global gaming market was valued at USD 173.70 billion in 2020, and it is expected to reach a value of USD 314.40 billion by 2026, registering a compound annual growth rate (CAGR) of 9.64% over 2021-2026. These platforms are attracting more than hundreds and thousands of new visitors in online traffic. Video gaming trends have experienced a massive surge in players and revenue recently. Companies like Microsoft, Nintendo, Twitch, and Activision have all reached new heights in player investment [1]. The emergence of e-commerce in the gaming world has become a natural thing with this rapid development of the game industry [2]. However, conventional gaming platforms are now faced with a new rival, NFT games. They may not be as much fun, but people can earn money from them. Instead of just paying to have fun NFT gamers are now playing to earn money (play-to-earn). Actually, conventional games like poker also provide the option of play-to-earn, and you can usually observe both extrinsically-motivated and intrinsically-motivated players in most conventional games [3]. However, NFT games' business plans are mainly concentrated on play-to-earn players. Therefore, in this paper, we are evaluating NFT games from the extrinsically-motivated players' point of view. Furthermore, our research is different from studies that are focused on categorizing players, as we are trying to suggest new evaluation tools for specific types of players. In other words, we are more concentrated on games' specifications than the players' specifications, which have been covered in previous studies [4, 3]. Lowry et. al. [4] extended the Hedonic-motivation systems (HMS) model to study players' motivations and Penttinen et. al. [3], through the use of such models, showed that there are very few differences between extrinsically-motivated and intrinsically-motivated players. Since play-to-earn players also have financial motivations, we believe that our findings would be useful to them.

We can define a Non-Fungible Token (NFT) as a cryptographically unique, indivisible, irreplaceable, and verifiable token that represents a given asset, be it digital, or physical, on a blockchain [5]. NFTs can represent objects like art, collectibles, and in-game items. In fact, people can attach private files or unlockable content to NFTs [6], which is very useful for providing online services (sending a file or a password to customers), but these are the lesser-known capabilities of NFTs, and most people know NFTs through their use in NFT games or collectibles [5]. The public attention toward NFTs has exploded in 2021 when their market experienced record sales, but little is known about their overall structure and evolution of them [7]. NFTs are widely used in NFT games and the metaverse. Metaverse and NFT games also overlap to some extent because metaverse can also be a place to play. However, it can cover more activities than just playing. For example, it can serve as a place for social experiments such as virtual concerts, meetings, and conferences. NFT-based metaverses can offer users new ways to play, invest, gather, and interact — and to earn from it all. Further, while development on the myriad singular metaverse platforms is highly noteworthy, it's the potential for the various metaverse games to interact and interoperate with one another that could drive the budding blockchain gaming ecosystem into a pillar of the global economy [8]. Metaverse technology is fairly specialized, and the industry is still in its early stages; once again we are like the internet in 1996. The term "metaverse" as a whole refers to any kind of activity that can be done in a virtual universe. It spans from social interactions to providing different services and playing games. In this paper, we focus on the metaverse games based on blockchain technology.

Since NFT games are a new phenomenon that provides a platform for both playing and earning money, it is crucial to evaluate and rate them to find the most attractive NFT games. However, to the best of the authors' knowledge, only a few studies have evaluated NFT games; therefore, providing a framework to do so can be very helpful. As Davis [9] mentioned, the harsh truth about NFT games (and the metaverse in general) is that they are not a good fit for most investors.

Although the adoption of NFTs in the gaming world comes with benefits, it also presents significant obstacles to overcome. Most notably, NFTs need to be made more appealing and intuitive to mainstream consumers who might not be technically oriented. And because NFTs possess intrinsic value, there's a risk that some will be used predominantly as speculative assets. This potentiality could

motivate players to purchase in-game assets with the hope of selling them for future profit, instead of using the assets within the gaming ecosystem as intended. Despite these challenges, the potential for profit within the gaming industry will motivate more non-blockchain-focused brands to experiment with NFTs, likely by forming partnerships with third-party blockchain projects that have the technical expertise needed to bring their vision to life. Simultaneously, the broader success of gaming Dapps will likely play a role in further catalyzing NFT infrastructure improvements and driving the development of innovative solutions that unlock mainstream adoption [10].

Since most of the blockchain projects' business models are more complicated than conventional firms', evaluating and rating these projects can provide a lot of valuable information to investors. However, at the time of performing this research, only a few analysts were evaluating and rating these projects, and most of them did not provide a reliable scientific analysis. Boreiko and Vidusso [11] reviewed the new ecosystem built around Initial Coin Offerings (ICOs) and studied the roles of the ICO aggregators, listing, and rating agencies. They found that rating data seemed to vary considerably across different rating websites and seemed not to be of great quality, so investors should treat such ratings with caution.

In this paper, we first take a look at the evolution of NFTs and NFT games and their specifications as Fintech. Then we explain our research methodology, which entails determining the proper criteria for evaluating NFT games and explaining the PROMETHEE II approach used to rate our sample NFT games. Next in the Data and Findings section of our paper, we provide the sample data and the output of our model, and finally, in the Conclusion section, we draw our conclusion about NFT games and how readers of this paper can use our methodology to rate other cryptocurrency projects and how they can interpret the results.

Non-fungible tokens (NFTs) differ from fungible tokens in two important aspects: Every NFT is unique and also it cannot be divided or merged. This new form of the token was first introduced with the ERC-721 standard in late 2017. ERC-721 variates significantly from the ERC-20 standard as it extends the common interface for tokens by additional functions to ensure that tokens based on it are distinctly non-fungible and thus unique. For practitioners, these distinct properties of NFTs enable a variety of new use cases. It particularly improves the tokenization of individual assets which is not feasible with fungible tokens, as they cannot digitally represent uniqueness. Thus, practitioners have conducted a multitude of experiments using NFTs to represent both digital goods such as virtual gaming assets, digital artwork, and software licenses as well as physical assets such as luxury goods and cars [12]. NFTs are powered by Smart Contracts. A smart contract is a self-executing contract or set of rules between two or more parties being directly written into the system and exists across the blockchain network [13]. NFTs are minted (i.e., created) through smart contracts that assign ownership and manage the transferability of the NFTs. When someone creates or mints an NFT, they execute code stored in smart contracts that conform to different standards, such as ERC-721. This information is added to the blockchain where the NFT is being managed [14]. ERC-998, which is an extension to the ERC-721 standard that adds the ability for NFTs to own other NFTs and tokens, was also introduced in 2018. Several extensions to ERC-721 have been developed in recent years and each one comes with special utilities (ERC-1155, ERC-223, ERC-827, ERC-777, ERC-1137, ERC-875, ERC-865). Since ERC-721 is based on Ethereum, Binance Smart Chain (BSC) has developed its own NFT standards. As the NFT markets grow, most smart chains are developing their own NFT standards. Moreover, to overcome Ethereum's currently high gas fee (minting and transaction fees) problem, OpenSea.io, which is one of the major NFT marketplaces, has collaborated with Polygon blockchain to enable minting NFTs with zero gas fees. Mintable.app has also started supporting Immutable X to provide zero gas fee minting. These types of blockchains that support zero gas fees are called layer-2 blockchains.

The first application based on NFTs to reach widespread adoption was a virtual online game called CryptoKitties. The game took up more than 70% of the transaction capacity of the Ethereum network at one point and the most expensive NFT that represents ownership of such a cat was sold for over USD 100,000 in late 2017. Over 100 similar digital collectibles such as virtual card games or unique original digital art have been created by the community in the past year and the number is expected to grow further [12].

As the popularity of the NFTs increased, so did their markets. Mukhopadhyay & Ghosh [15] reviewed the NFT marketplace from several aspects. They reported that the NFT marketplace can be categorized into two levels. One is at the project level and another is at the ownership level. At the project level, the NFT market can be segregated into 6 main segments - Art, Collectibles, Sports, Utility, Metaverse, and Games. At the ownership level, the NFT market is segmented into Primary and Secondary Market. Leading platforms like Opensea.io, Rarible.com, WazirX, Binance, and Mintable.app facilitate players to mint, trade, buy, and auction NFTs via Metamask wallet account that links the platform and cryptocurrency exchanges with fiat currency banking entities. Art and collectibles capture the major market segments because game NFTs are mostly traded at the games' internal marketplaces. Kireyev [16] also reported that an increasing trend in NFT prices may not be entirely attributed to an increase in the "value" of NFTs but could also be attributed to marketplace design improvements. According to Kireyev [16], NFT collections that are offered by two different marketplaces can exhibit significantly different market statistics because of differences in bidding costs rather than differences in inherent value. However, Kireyev [16] did not study NFT games and concentrated on NFT collections. Some NFT marketplaces such as the Mintable.app are now providing the ability to mint and trade NFTs with zero gas fees, however, purchasing Axi Infinity NFTs from its marketplace requires a gas fee. Some of the conventional games also have marketplaces to buy game items. Before the era of e-commerce, online gamers often relied on forums or even direct contact with the seller. Hence, fraudulent acts were

usually carried out by unscrupulous individuals. However, after the appearance of e-commerce in the gaming world, those problems began to vanish [2]. Now, NFTs have provided a secure way of selling and purchasing items in NFT games marketplaces.

Structurally, coins and tokens markets, as well as NFTs markets, can be classified into Decentralized Exchanges (DEX) and Centralized Exchanges (CEX). However, we can categorize games' NFT items markets as internal marketplaces that are managed exclusively within each game (e.g., https://market.decentraland.org/), or platform marketplaces that enable games developed on the same platform to trade their NFT items on a shared marketplace (e.g., https://enjinx.io/eth/marketplace).

Before we start with the evaluation of NFT games we discuss how these projects are closely related to financial technology so we could evaluate them from a financial point of view.

"Financial technology" or "Fintech" refers to the use of technology to deliver financial solutions. The term's origin can be traced to the early 1990s and referred to the "Financial Services Technology Consortium", a project initiated by Citigroup to facilitate technological cooperation efforts [17]. According to the Financial Stability Institute (FSI) of the Bank for International Settlements (BIS), fintech activities can be found in the following financial services categories: (i) deposits and lending; (ii) capital-raising and alternative sources of funding; (iii) asset management, trading, and related services; (iv) payments, clearing and settlement services; (v) insurance; and (vi) crypto-assets. Furthermore, FSI considered creating, distributing, storing, or exchanging crypto-assets, using them for investment or payment purposes, or as a reference in financial products as financial activities related to crypto-assets [18]. Although, FSI acknowledges that crypto-assets are part of Fintech activities they do not concentrate on particular types of crypto-assets and instead focus on the regulatory aspects of Fintech.

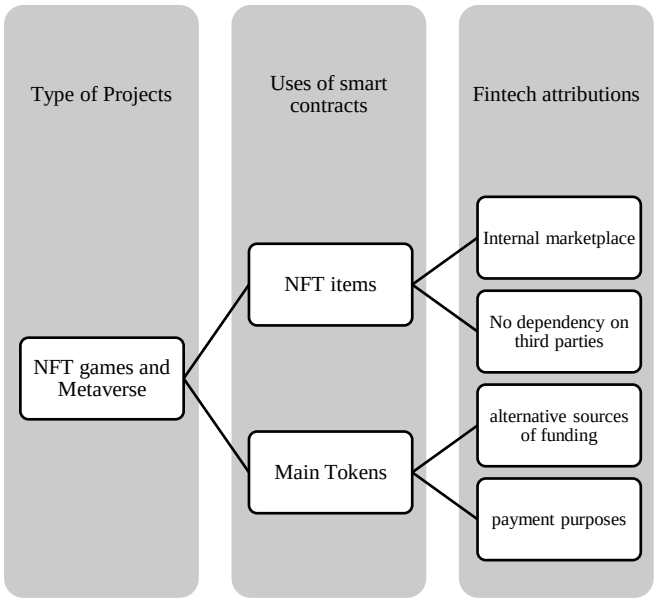
Moreover, The FSI report prepared by Ehrentraud et al. [18] mentioned that most crypto-assets could also be classified under the other categories of financial services, depending on their underlying economic function, rights attached and business model features, however, crypto-related services involve a range of unique approaches with quickly evolving use cases. This is also the case for NFT game projects because they also use utility tokens to cover the financial aspects of their business such as capital-raising and alternative sources of funding.

Lu [19] further studies how blockchain creates opportunities for Fintech: (1) utilizing the security, reliability, and immutability of the underlying infrastructure, and (2) implementing the functionalities of smart contracts. Although he discusses the importance and functionality of smart contracts in Fintech, he does not elaborate more on the different types of smart contracts or NFTs, and how they are used in Fintech. However, he suggests that in the near future we can expect the development of blockchain platforms to address the finance-specific needs of new marketplaces. Therefore, NFT games that provide an internal marketplace for their NFT items and use blockchain to address their finance-specific needs can be classified as Fintech. Other researchers such as Ali et al. [20] and Queiroza & Wamba [21] also emphasize the importance of smart contracts in empowering Fintech projects with new financial tools. Panisi [22] goes further and emphasizes the importance of smart contracts to fintech and electronic markets. According to him, blockchain and smart contracts aim at decreasing monitoring and enforcement costs. Thus, blockchain and smart contracts can free financial institutions from relying on post-trade financial market infrastructures and improve market efficiency in the clearing, settlement, and transaction management.

Among the researchers who have worked on this subject, Kong & Lin [23] state that NFTs serve as a novel investment vessel in this Fintech era. However, they concentrate on CryptoPunks collectible NFTs as one of the earliest and the most valuable NFT projects and do not consider other types of NFT projects such as NFT games.

As the literature review showed, researchers have identified smart contracts as examples of Fintech, but have not specifically focused on NFTs and NFT projects to precisely define their roles in the field of Fintech. As mentioned before, NFTs are used in several areas, the two main areas of which are collectibles and NFT games/ Metaverse. Most collectibles projects only sell their NFT collections and have no other connections with smart contracts. Yuga Lab, for example, which sells its CryptoPunks collection as NFTs, did not have a token until 2022, and then issued its token, ApeCoin, to finance its Metaverse project, not its collectibles project. However, NFT games and metaverses are more related to Fintech because they use smart contracts in two ways, for a variety of purposes that are defined by FSI as examples of Fintech. Fig. 1. shows what aspects of Fintech NFT games and metaverses cover:

Fig. 1. Metaverse characteristics that make them a type of Fintech



Source: Author's.

Analysts have used various methodologies to evaluate different cryptocurrency and blockchain projects. Cheah & Fry [24], through performing an econophysics methodology, reported that Bitcoin exhibits speculative bubbles and found empirical evidence that the fundamental price of Bitcoin is zero! which is a controversial opinion among market participants. They took into account the Bitcoin price and did not consider other characteristics of a cryptocurrency project; therefore, their methodology may not be suitable for a comprehensive evaluation of NFT projects. In another study, Urquhart [25] through a variety of robust tests reported that Bitcoin is an inefficient market but may be in the process of moving towards an efficient market. By performing the Ljung-Box autocorrelation of returns test, Runs and Bartels test of returns independency, and a variance ratio test they investigated if the Bitcoin price follows a random walk hypothesis. Similar to Cheah & Fry [24], Urquhart [25] also only concentrated on the price of Bitcoin. However, Blockchain projects are very diverse and even the NFT ecosystem is already extremely broad. Consequently, the due diligence process is necessarily different depending on the particular asset type [15]. Therefore, in this paper, we aim to provide a more in-depth analysis of NFT games.

Specifically, in the context of NFTs, Franceschet [26] adapted Kleinberg's authority/hub Hyperlink-Induced Topic Search (HITS) method to rate artists and collectors in a major crypto art marketplace. In his study, HITS method is developed to rate and rank artists and collectors in art systems. Artists create and sell artworks, they are the sources of art. Collectors buy and pull together artworks, they have some sense of where good art is. Franceschet [26] applied the proposed rating method to the marketplace of SuperRare, which is among the most important crypto art galleries by popularity and volume of exchanged artworks. His thesis in the art setting is: "A leading artist sells to leading collectors and a leading collector buys from leading artists." According to Franceschet [26] HITS method establishes a rating for artists coupled with a rating for collectors independently from the characteristics of NFT artworks, which can be hard to measure. However, in this paper, we aim to measure different characteristics of NFT game projects. Dowling [27] also performed a study on NFT pricing. His work is more concentrated on the pricing of NFT items within the games than pricing the games themselves. He tests the market efficiency of NFT Lands in Decentraland (a metaverse game that is also included in our study sample) which are traded as NFTs. To do so, he performs an automatic variance ratio (AVR) test, an automatic portmanteau (AP) test, and a Domínguez and Lobato (DL) consistent test. According to him, the NFT Lands market can be characterized as an inefficient market with a rapid rise in prices. He does not provide a framework for evaluating NFT Lands and determining their value in comparison to other virtual lands, rather, he investigates their market efficiency. Ante [28] who analyzed NFT markets on Ethereum smart chain through a (cointegrated) vector autoregression (VAR) model also reported that NFT markets are immature or even inefficient. Moreover, Ante [29] reported that (larger) cryptocurrency markets affect the growth and development of the (smaller) NFT market, but there is no reverse effect. In another study, Dowling [30] also tested if NFT pricing is related to cryptocurrency pricing. Through a wavelet coherence analysis that indicates co-movement between the two sets of markets, he reported that cryptocurrency pricing behaviors might be of some benefit in understanding NFT pricing patterns. He studied Decentraland, CryptoPunk, and Axie Infinity NFTs. Since both Decentraland and Axie Infinity are categorized as NFT games we have included them in our study too. CryptoPunk is not a game or metaverse, therefore, we did not include it in our study. Again, his study is focused on Decentraland and Axie Infinity's NFTs and not the whole projects, and also, he studies the crypto markets macrostructure and does not provide a framework for investment decision making. Since we intend to perform a comprehensive evaluation and fundamentally analyze NFT games our study is focused on different aspects of NFT games to be able to evaluate them from various aspects, and not just their NFTs. Moreover, instead of taking a macrostructure view and testing crypto markets' efficiency, we try to provide a framework for investment decision-making.

NFT games or generally all the blockchain-based projects are riskier than simple non-financial companies and they always have a tokenomics (economics of crypto tokens) aspect that has to be investigated thoroughly. Therefore, as explained in the previous subsection, it is safe to say that they can all be categorized as Fintech projects to some extent. As mentioned before, Kong & Lin [23] also considered NFTs as alternative investments in the Fintech era and reported that token scarceness and subjective judgments of aesthetics are crucial determinants for explaining a large portion of NFTs price premiums. Analysts use different multicriteria methodologies to rate conventional financial institutes. Some of the most commonly applied techniques include Data Envelopment Analysis (DEA), Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ELimination Et Choix Traduisant la REalité (ELECTRE), VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Preference Ranking Organization METHod for Enrichment of Evaluation II (PROMETHEE II) [31].

The PROMETHEE family of outranking methods include, among others, PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking). It is an outranking method for a finite set of alternative actions to be ranked and selected among conflicting criteria [32]. Various analysts have used PROMETHEE II for rating financial institutes and non-financial institutes. PROMETHEE II is also applied in cryptocurrency studies. Researchers such as Kądziołka [33] and Aljinović et al. [34] employed the PROMETHEE II methodology in the field of cryptocurrencies. Kądziołka [33] used the PROMETHEE II method to create a ranking of cryptocurrency exchanges. Cryptocurrency exchanges can surely be categorized as Fintech; however, their characteristics are very different than NFT projects. Therefore, while Kądziołka [33] shows that the PROMETHEE II method is appropriate for ranking cryptocurrency Fintech we have to develop special criteria to be able to use it for ranking NFT projects. Moreover, we go further than ranking projects and provide a framework for

rating them. Aljinović et al. [34] use PROMETHEE II for cryptocurrency portfolio selection and cite "incorporating criteria that, to the best of our knowledge, have never been used before in portfolio optimization" as one of their contributions to the existing literature. We also develop special criteria that, to the best of our knowledge, have never been used before in blockchain project evaluations. Aljinović et al. [34] study sample consists of nine cryptocurrencies: Bitcoin, Dash, Ethereum Classic, Ethereum, Litecoin, Monero, Neo, Stellar, and Ripple, which none of them are NFT game projects. Similar to Kądziołka [33], Aljinović et al. [34] study also does not provide a rating framework.

According to Ulengin et al. [35], the PROMETHEE II has at least 3 advantages: (i) being user-friendly, (ii) success in applications to real-life planning problems, and (iii) completeness of rankings. Also, Papathanasiou & Ploskas [36], who compared and modeled several Multiple Criteria Decision Aid (MCDA) methods including TOPSIS, VIKOR, PROMETHEE, SIR, AHP, and Goal Programming, state that PROMETHEE provides decision-makers with much richer information at the expense of a more complex preference modeling. They also mention that PROMETHEE has the GAIA visual descriptive model and also can be programmed in Python. Moreover, while PROMETHEE I only allows for partial ranking, PROMETHEE II allows for both partial and complete ranking of alternatives. Therefore, using PROMETHEE II can improve the usability, and flexibility of our research, to be applied to other types of cryptocurrencies, by professionals and also by less educated cryptocurrency investors.

II. RESEARCH METHOD

To produce a comprehensive analysis, we utilize a combination of generic cryptocurrency measurements, such as a token's market cap, alongside NFT games' unique criteria, such as the number of users, or the simplicity of entry to the game (free-to-play vs. pay-to-play). Below is a complete list of the selected criteria.

TABLE I. EVALUATION CRITERIA

Criteria		**Measuring method**	**Criteria Code**	**Preference**
Upside potential	White Paper	Most Recent Updated Date	WP	MIN
	Green Paper	1 if has a green paper, 0 if not	GP	MAX
	Scientific References	Number of citations to the project based on Google Scholar	SF	MAX
	Ease of Entrance	0 if free-to-play, 1 if pay-to-play	FREE	MIN
	Relative Market Value	The main token market cap, divided into the number of token holders	MATH	MIN
		The main token market cap, divided into the number of Twitter followers	MATW	MIN
Risks	CertiK Rank	CertiK's assigned rank, based on security score	CER	MAX
	Value at Risk	Non-Parametric 100-day Value at Risk	VaR	MIN
Hybrid	Flip Ratio	Distance from flipping the next higher-ranked coin compared to the distance from being flipped by a lower-ranked coin	FLIP	MIN

Source: Author's.

To perform a comprehensive evaluation, we tried to find a criterion that could measure both the upside potential of NFT games and their risks. Therefore, we put our criteria into two categories: upside potential and risks. We also designed a specific flip ratio that takes into account both the potential of flipping a higher-ranked token and the risk of being flipped by another token. That is why we put our special flip ratio in a hybrid category.

A. FLIP Ratio

Coin flipping, in a general sense, means flipping a coin to randomly determine the outcome of a binomial variable. In this sense, it is commonly used in statistics and probability studies. However, in cryptocurrency markets, flipping is a term that is commonly used to describe a situation where the market cap of a cryptocurrency exceeds the market cap of another one (usually a coin that used to have a higher market cap). In other words, flipping is when a cryptocurrency surpasses another cryptocurrency in market value. For example, if Ethereum ever beats Bitcoin to become the biggest cryptocurrency based on its market cap, we can say that Ethereum flipped Bitcoin; or from the opposite point of view, we can say Bitcoin got flipped by Ethereum. Since market dominance is an important measure of the weight of each cryptocurrency in the market, flipping is important to market participants. More dominant cryptocurrencies tend to have more influence on the market dynamics. Typically, the dominant coin becomes the market leader. Moreover, sometimes there is a competition between the holders of similar coins to surpass each other. For example, if Shiba Inu ever flips DogeCoin, it would be huge news for meme coins' holders.

As mentioned above, "The Flippening" is a special term in the cryptocurrency market that refers to "Market Dominance" [37, 38]. For example, one of Bitcoin's risks is to be flipped by Ethereum [39, 40], after which it may quickly lose its publicity and that would lead to a decrease in the number of Bitcoin holders. Therefore, being flipped pulls investors out of the cryptocurrency. The reverse is also true, a cryptocurrency, which gains more dominance by flipping other coins, also gains more market attention and a larger investor base. Flipping news is spread among the cryptocurrency community, and cryptocurrency project developers use this news for their marketing purposes.

"Market Dominance" is well documented in analyzing other, conventional, markets [41, 42, 43].

Thus, our FLIP ratio measures the potential for gaining more market dominance in proportion to the risk of losing market dominance. Our new flip ratio compares the chance of a coin flipping another coin to the chance of the same coin getting flipped by another coin. To the best of our knowledge, no similar ratio has been formulated in other studies or used by cryptocurrency market participants in their investment decisions. Although, there is a "Flippening Index" provided by https://www.blockchaincenter.net/en/flippening/ that plots the Ethereum market capitalization graph as a percentage of Bitcoin market capitalization.

We modeled our special flip ratio as follow:

$$FLIP = \frac{\#(N-1)\ coin's\ market\ Cap - \#(N) coin's\ market\ Cap}{\#(N) coin's\ market\ Cap - \#(N+1) coin's\ market\ Cap} \quad (1)$$

Where:

- #(N): coin's rank based on its market cap (e.g., Bitcoin is ranked as #1, Ethereum is ranked as #2, etc.)
- Market cap: coin's current market price multiplied by the number of coins in circulation as provided by websites like Coinmarketcap.com

B. Value at Risk

We use Value at Risk (VaR) as an important measure of the market risk of NFT games' main tokens. Unlike measures such as variance or CAPM Beta, non-parametric value at risk analysis is compatible with the volatile nature of cryptocurrencies and the large leptokurtosis of their price movements, which also shows that they do not follow a normal distribution. Cryptocurrencies' returns not only are more volatile and riskier than traditional currencies but also exhibit heavier tails behavior and violate the assumption of normality [44].

VaR can be calculated with different meths. There are three types of VaR: parametric VaR, simulated VaR, and non-parametric VaR. One significant advantage of non-parametric VaR is that we can calculate it based on the historical performance of cryptocurrencies rather than assuming a distribution probability. Therefore, we can work with actual scenarios that happened in the past. They may not happen again, but they are more realistic than other assumptions [45].

VaR calculates the maximum expected loss, over a given period and given a specified level of confidence. Generally, given $\alpha \in [0, 1]$, and a reference instrument r, the VaR_α at level α of the final net worth X with distribution P, is mathematically defined as [46]:

$$VaR_\alpha(X) = -inf\{x|P[X \leq x.r] > \alpha\} \quad (2)$$

In the historical non-parametric VaR approach, we calculate VaR directly from past returns. In this paper, we calculate VaR using 100 daily returns and set the level of confidence at 95%. Since we are using daily returns, we are finding the worst daily shocks in the past 100 days of a cryptocurrency's price movements.

C. White Paper and Green Paper

White papers and green papers are where a project explains its business and draws its road map. The white paper is more about what a project has achieved and is capable of doing now or in the near future. The green paper is more ambitious and focused on long-term developments. However, both of them should give a good explanation of the project and enlighten the readers about it. Since both of these papers do not have a very strict format, evaluating them is subjective. Therefore, we take their last updated date as a more objective criterion that shows how committed the project runners are to updating their white paper. Moreover, since many projects do not have green paper, we consider the existence of green paper as an advantage. To the knowledge of the authors, white paper and green paper specifications have not been used as factors in evaluating cryptocurrencies.

D. Scientific references

One other factor that we look into is the scientific importance of projects, and we measure it by the number of scientific references to the project, its white paper, and its green paper. It shows how innovative a project might be and how much it is covered by researchers. From an investor's perspective, whether a project has a scientific background can help to determine whether a team with a new idea is behind it, or whether the project, probably, is another copycat. This can at least help investors avoid projects that may be scams or rug pulls. Also, researchers usually study projects that at least have some data to review and are worth reviewing. Moreover, since there is no such thing as "analysts' coverage" for cryptocurrencies, "researchers' coverage" can be used instead. We use Google Scholar in this regard. Although relevant data are not summarized anywhere, Google Scholar's database is essentially a part of a popular WWW search engine, which means that there are no limits on the languages covered, keywords allowed per search, and list of covered journals, provided for the latter that an electronic edition exists [47]. To the knowledge of the authors, scientific references have not been studied in the process of evaluating cryptocurrencies.

E. Ease of Entrance

Playing most NFT games entails buying some NFTs to start with. We consider this a barrier to entry. However, some games offer the option of starting from scratch and playing to earn your first NFT item. We consider the free-to-play option an advantage. Although some studies reported that the free-to-play option may not be attractive because, inevitably, players have to pay to be able to play properly. People think it's unethical that some games give the illusion of a free-to-play option whereas if you want to practically play the game, you have to pay to unlock the game's main features. However, big, well-known games usually do not pursue this unethical path [48]. In general, the literature analysis revealed that the advantages of free-to-play over pay-to-play remain unproven, and each of these tactics has its own unique strengths and weaknesses [49].

F. Relative Market Value

Relative Market Value is a type of relative analysis that we use in our model to link the project's main token's market cap to one of its most important measures of performance, which is the number of players, or more comprehensively, its popularity. Generally, there are two types of cryptocurrencies: those meant to fund a specific project and those designed for general or non-specific uses [50]. In the present paper, by "project's main token" we mean the one that is meant to fund the NFT game project. Analysts and market participants sometimes call the first type of cryptocurrency "coins" and the second type of cryptocurrency "tokens" or, in our case, "utility tokens", which give their holders consumptive rights to access a product or service [51]. However, these categories may overlap now that cryptocurrencies can serve multiple purposes. Besides, since the market cap of all types of cryptocurrencies is calculated in the same way, we do not need to differentiate between coins and tokens when we are only using their market cap and may use both names interchangeably. Moreover, since most of the projects do not announce their exact number of players, we use two measures that together can be a good representative of a game's popularity. One measure is the number of the game's token holders, and the other measure is the game's official Twitter account followers. Almost all cryptocurrency companies are using social media as an advertising tool [52]. Therefore, Twitter followers can be used as a measure to determine the effectiveness of marketing costs in increasing games'

popularity. According to Park and Lee's [52] findings, measuring the social media presence of a cryptocurrency can lead to a more accurate evaluation. Li et al. [53] also state that the number of followers on Twitter and Reddit can reflect how many people support the cryptocurrency. Ong et al. [54] also used Twitter followers and market capitalization, among other measures, to provide an overall rank for alternative cryptocurrencies. They stated that a currency without users will not have any value and a strong indicator of a coin's strength is reflected in its community support. To measure community support, several metrics can be used as a proxy such as Twitter followers.

Regarding the number of token holders, other researchers have also used a similar measure to estimate game players. For example, in the Harris [55] study, games' user counts were determined by the number of unique wallets that showed any kind of interaction with a smart contract from the games. Our two relative market value ratios are defined as below:

$$MATH = \frac{token\ market\ cap}{Number\ of\ token\ holders} \quad (3)$$

$$MATW = \frac{token\ market\ cap}{number\ of\ Twitter\ followers} \quad (4)$$

The number of users can also be viewed as an indicator of the level of adoption of the game among people. In the cryptocurrency context, the level of adoption refers to how much a cryptocurrency is known to people or is used by people. The level of adoption shows how cryptocurrencies have found their way into ordinary people's lives. Shahzad, Xiu, Wang, & Shahbaz [56] discussed how gaming can be related to the adoption of bitcoin, although they didn't study the games themselves.

G. CertiK Rank

CertiK is a verification platform to examine smart contracts and blockchain ecosystems. CertiK checks if they are bug-free and hacker-resistant. Moreover, hybrid approaches to the verification of smart contracts are proposed and used in the CertiK project [57]. Here we use Certik's assigned ranks, if any, for NFT games to evaluate them based on their security. Certik mostly evaluates projects built on Binance Smart Chain and Polygon, but since there are a lot of different smart chains now, we couldn't find any security analysis agencies that would cover all of them. Moreover, CertiK is a pioneer in the area of cryptocurrency security evaluation.

Ratings are an important factor when analyzing stocks and bonds. In the field of company analysis, rating scores assigned by rating agencies refer to the companies' credit risk. If the rate of a company changes, it will have a huge effect on its stock price and its bond yields. However, since cryptocurrency projects are mainly not registered as companies, and their capital structure is not clear, they are not rated by rating agencies. Therefore, there are other agencies like CertiK that assign a security score to these projects. Hence, CertiK scores are about the operational risk of cryptocurrency projects rather than their credit risk. Security has always been a critical part of evaluating online games. The emergence of online games fundamentally changed the security requirement for computer games. In the new context, copy protection is not, at least not the only, security issue anymore. Though online games, on the other hand, are commonly regarded as one of the distributed E-Commerce applications, they have their own unique security challenges [58].

Regarding blockchain games, Min & Cai [59] assert that blockchain games are still suffering from security issues due to immature blockchain technologies and their unsophisticated developers.

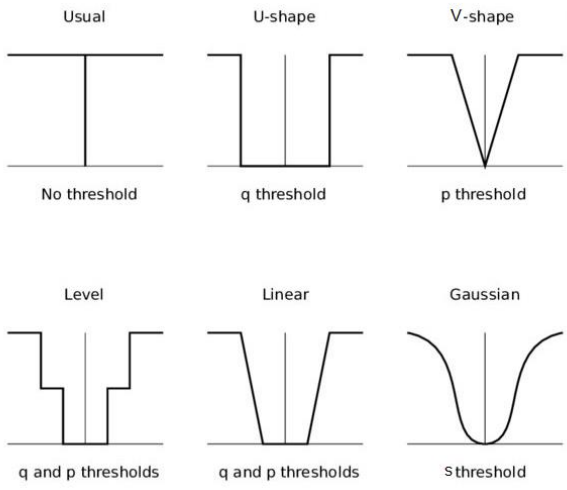
H. PROMETHEE II

As demonstrated in Table I, the specified criteria are conflicting; some of them are preferred to be higher while others are preferred to be lower. Therefore, after calculating these measures, we use the PROMETHEE II method to combine these conflicting criteria and rate NFT Games by comparing their strengths and weaknesses against each other. We follow the Doumpos & Zopounidis [60] approach in implementing the PROMETHEE II method for rating financial institutions. The evaluation of NFT games in the context of the PROMETHEE II method is based on pairwise comparisons. In particular, for each pair of games *(i,j)* the pairwise preference index $P(x_i,x_j)$ is computed, where $x_i=(x_{i1}, x_{i2}, ..., x_{in})$ is the vector with the description of the game *i* on *n* evaluation criteria. The $P(x_i,x_j)$ is defined as the weighted sum of pairwise partial preference indices $\pi_k(x_{ik}, x_{jk})$ as follows:

$$P(x_i, x_j) = \sum_{k=1}^{n} w_k \pi_k(x_{ik}, x_{jk}) \quad (5)$$

where w_k is the weight of criterion *k* and $\pi_k(x_{ik}, x_{jk})$ is the corresponding pairwise partial preference index. $\pi_k(x_{ik}, x_{jk})$ measures (on a scale of 0 to 1) the strength of the preference for the game *i* over game *j* on criterion *k*. It is a function of $x_{ik} - x_{jk}$ determining the comparative performances of the games on criterion *k*. Brans & Vincke [61], the developers of the PROMETHEE method, proposed six types of preference functions, namely: usual, U-shape, V-shape, Level, Linear, and Gaussian. Fig.2. depicts these functions and their required thresholds [62].

Fig. 2. PROMETHEE method six types of preference functions



Source: Binnekamp's.

A popular choice for quantitative data is the Gaussian function used by Doumpos & Zopounidis [60], Gökalp [63], and Paksoy & Traş [64] for rating financial institutions:

$$\pi_k(x_{ik}, x_{jk}) = \begin{cases} 0 & if\ x_{ik} \le x_{jk} \\ 1 - exp\left[-\frac{(x_{ik}-x_{jk})^2}{2\sigma_k^2}\right] & if\ x_{ik} > x_{jk} \end{cases} \quad (6)$$

where $\sigma_k > 0$, which has to be selected by the user, defines the inflection point of the preference function. The gaussian and Linear functions are more suitable if the criteria have a continuous numerical scale (such as FlIP, MATW, and MATH) and if we want to introduce an indifference threshold [65]. However, while the Linear function needs two thresholds, the Gaussian function only needs one, therefore, we are less dependent on the user's judgment.

Now, if we consider a set of M games for evaluation, the results of all the pairwise comparisons are aggregated into a net performance index $\emptyset(x_i)$ as follows:

$$\emptyset(x_i) = \frac{1}{M-1}[\emptyset^+(x_i) - \emptyset^-(x_i)] \quad (7)$$

$$\emptyset^+(x_i) = \sum_{j \ne i} P(x_i, x_j) \quad (8)$$

$$\emptyset^-(x_i) = \sum_{j \ne i} P(x_j, x_i) \quad (9)$$

Where Equation (8) represents the outranking character of the game *i* over all the other games and Equation (9) represents the outranking character of all games in the sample over game *i*. Thus, the net performance index $\emptyset(x_i)$ in Equation (7) combines the strengths and weaknesses of a game compared to its competitors in an overall evaluation measure. The net performance index $\emptyset(x_i)$ ranges from -1 to 1, with higher values associated with higher-performing NFT games.

To build a rating model, we can transform $\emptyset(x_i)$ into a 4-level rating scale via the following function:

$$V(x_i) = \begin{cases} 1 & if\ \emptyset(x_i) = \emptyset^M \\ 1 + 4\frac{\emptyset^M - \emptyset(x_i)}{\emptyset^M - \emptyset^L} & if\ \emptyset^L < \emptyset(x_i) < \emptyset^M \\ 5 & if\ \emptyset(x_i) = \emptyset^L \end{cases} \quad (10)$$

where $\emptyset^L = min\{\emptyset(x_i)\}$ and $\emptyset^M = max\{\emptyset(x_i)\}$.

With this transformation, the games' rates will range on a scale from 1 (best performance) to 5 (worst performance). Now, we can specify the associated ratings as follow:

TABLE II. TRANSFORMED NET PERFORMANCE INDEX INTERVALS AND THEIR ASSIGNED RATINGS

Overall score interval	Assigned rating
$\mathbf{1 \le V(x_i) \le 2}$	AAA
$\mathbf{2 < V(x_i) \le 3}$	AA
$\mathbf{3 < V(x_i) \le 4}$	A
$\mathbf{4 < V(x_i) \le 5}$	BBB

Source: Author's.

It is worth mentioning that our rating framework gives a good insight into the relative value of different projects. As cryptocurrencies have very complex structures, performing an absolute valuation and driving the intrinsic value of projects is a very sensitive subject and it is susceptible to a lot of considerations, even for very well-known cryptocurrencies like Bitcoin, therefore, most of the evaluations of cryptocurrencies are based on relative valuations. Furthermore, rating and ranking are considered as two different types of categorizations because ranking is based on sorting projects but rating assigns each project to a prespecified category

III. DATA AND FINDINGS

Our sample consists of NFT games on the top 100 cryptocurrencies ranked by their market capitalization, according to coinmarketcap.com (accessed on December 21, 2021). We selected projects that were tagged with "gaming" by coinmarketcap.com and provided at least one NFT game.

At the time of our study, there were 6 NFT games in the top 100 cryptocurrency projects. Some of these projects are games themselves, and some of them are platforms that developers can build their own games on them. We used their 100 days of historical prices up to Dec. 25 2021 to calculate their VaR and relative market value and Flip ratio. Table III describes the sample data.

TABLE III. SAMPLE DATA DESCRIPTION

Project	The Sandbox	Axie Infinity	Decentraland	Gala	Bora	Enjin
Main Token	SAND	AXS	MANA	GALA	BORA	ENJ
White Paper Latest Update	Aug-20	Dec-20	Aug-17	null	May-18	Sep-17
Google Scholar Results	22	53	241	0	0	46
Existence Of a Green Paper	No	No	No	No	No	No
CertiK Rank	1	null	14	null	null	null
Value At Risk	-0.10543	-0.08339	-0.11245	-0.1387	-0.1421	-0.0983
Main Token's Market Cap (million USD)	4,813	6,004	6,144	3,120	924	2,726
Higher Ranked Token's Market Cap (Million USD)	5,013	6,140	6,467	3,291	939	2,823
Lower Ranked Token's Market Cap (Million USD)	4,765	5,857	6,140	3,023	902	2,710
Free-To-Play	yes	NFT-Required	yes	yes	yes	yes
Number Of Token Holders	85,155	46,248	181,827	72,767	23,562	158,279
Twitter Followers	646,916	805,329	410,834	212,918	16,578	441,393

Sources: Author's, coinmarketcap.com, twitter.com, scholar.google.com, certik.com, decentraland.org, axieinfinity.com, sandbox.game, boraecosystem.com., enjin.io

"Null" in the "White Paper Latest Update" row of Table III means the project does not have a white paper, and in "CertiK Rank" row it means that the project has not been ranked by Certik.

As presented below, Table IV outlines the calculated criteria.

After calculating the criteria, we use Visual PROMETHEE Academic Edition software to rate NFT games. In calculating the Gaussian preference function, if we choose a low value for σ_k, it means that the preferences will be reinforced for small deviations. Now because determining the σ_k value is a subjective decision; we choose a small value to take into account the small deviations between projects in their ratings. Therefore, we set $\sigma_k = 0.5\%$ for all criteria. We also weigh all 9 criteria equally, however, in the "sensitivity

analysis" subsection we perform a sensitivity analysis and discuss how changing the criteria's weights and σ_k may change the results.

TABLE IV. CRITERIA DESCRIPTION

Criteria		Criteria Code	Preference	Minimum	Maximum	Average	Standard Deviation
Upside potential	White Paper	WP	MIN	391	1,603	1,073	579.62
	Green Paper	GP	MAX	0	0	0	0.00
	Scientific References	SF	MAX	0	241	63	101.74
	Ease of Entrance	FREE	MIN	0	1	0	0.41
	Relative Market Value	MATH	MIN	17,227	129,838	53,248	39641
		MATW	MIN	6,177	55,744	17,738	19011
Risks	CertiK Rank	CER	MAX	1	14	8	9.19
	Value at Risk	VaR	MIN	-0.1421	-0.0834	-0.1134	0.02
Hybrid	Flip Ratio	FLIP	MIN	0	1	1	0.23

Source: Author's.

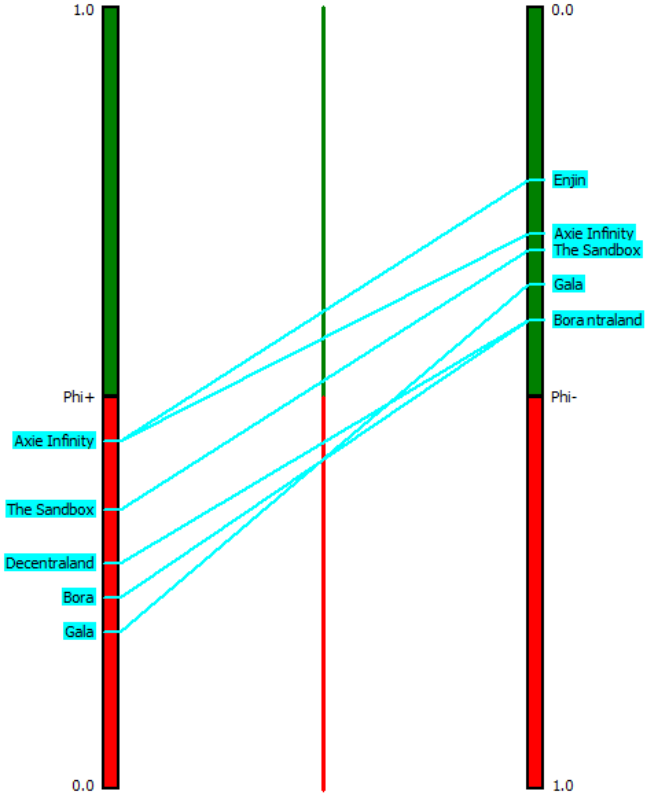
We calculated NFT games' partial performance scores and net performance index values, using Equations (8), (9), and then (7). Table V shows the partial performance scores and net performance index values.

TABLE V. PARTIAL PERFORMANCE SCORES AND NET PERFORMANCE INDEX VALUES

NFT games	$\emptyset(\mathbf{x_i})$	$\emptyset^+(\mathbf{x_i})$	$\emptyset^-(\mathbf{x_i})$
Enjin	0,2222	0,4444	0,2222
Axie Infinity	0,1538	0,4444	0,2906
The Sandbox	0,0462	0,3573	0,3111
Decentraland	-0,1111	0,2889	0,4000
Bora	-0,1556	0,2444	0,4000
Gala	-0,1556	0,2000	0,3556

Source: Author's.

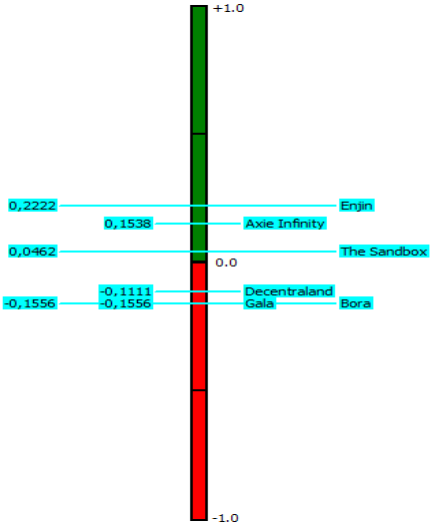
Fig. 3. PROMETHEE I partial preference ranking



Source: Author's, via Visual PROMETHEE Academic Edition software

Fig. 3., is useful to understand the partial preference ranking of games under consideration. The left column in Fig. 3. corresponds to the $\emptyset^+(x_i)$ values and the right column to the $\emptyset^-(x_i)$ values. If one game has the highest $\emptyset^+(x_i)$ and the lowest $\emptyset^-(x_i)$, as in our case, we can say it is the best game based on both $\emptyset^+(x_i)$ and $\emptyset^-(x_i)$; In our case, Enjin is ranked as the best performing game according to $\emptyset^+(x_i)$ values and $\emptyset^-(x_i)$ values. On the other hand, Gala is ranked as the worst-performing project according to $\emptyset^+(x_i)$ values, but according to $\emptyset^-(x_i)$ values, Bora and Decentraland are both the worst performing games. In this case, projects are incomparable based on their partial performance. Therefore, we have to look into their net performance.

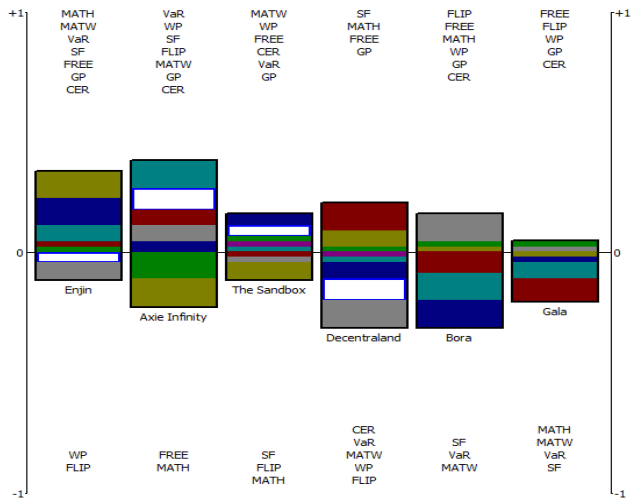
Fig. 4. PROMETHEE II complete ranking



Source: Author's, via Visual PROMETHEE Academic Edition software

Fig. 4. illustrates the PROMETHEE II complete ranking. In this figure, the game on the top (bottom) of the column has the highest (lowest) $\emptyset(\boldsymbol{x_i})$ value, so it is ranked as the best (worst) game. In PROMETHEE II complete ranking, all games are comparable. In our case, according to their $\emptyset(\boldsymbol{x_i})$, Enjin is ranked as the best performing game and Bora and Gala are both ranked as the worst-performing games. It is also worth mentioning that Enjin has its own NFT standard (ERC-1155) and therefore it has more potential to grow as a platform.

Fig. 5. Strengths and weaknesses



Source: Author's, via Visual PROMETHEE Academic Edition software

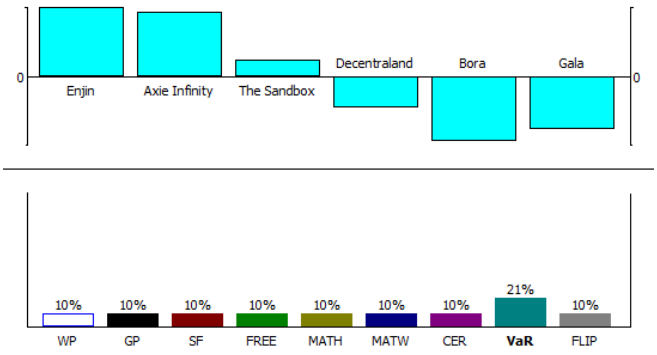
Fig. 5. shows the complete ranking in more detail. In Fig. 5., a bar is drawn for each game. The different slices of each bar are colored according to the criteria. Each slice is proportional to the contribution of a criterion to the $\emptyset(x_i)$ of the game. Positive (upward) slices correspond to good features while negative (downward) slices correspond to weaknesses. This way, the balance between positive and negative slices is equal to the $\emptyset(x_i)$. Games are ranked from left to right according to the PROMETHEE II Complete Ranking. In our case, all the games showed some weaknesses. Enjin weaknesses are based on its outdated white paper (WP) and high FLIP ratio. On the other hand, even though Axie Infinity performed well based on several criteria, its very high MATH ratio and the fact that it is not a free-to-play game prevented it from becoming the best NFT game.

A. Sensitivity analysis

In Aljinović et. al. [34] study, the weights of the chosen criteria were estimated using Saaty's AHP method. However, here we perform a set of sensitivity analyses to objectively investigate the importance of each criterion in ranking the NFT games. After that, we also perform a sensitivity analysis on σ_k.

Since value at risk is an important criterion that shows games token's price crash risk, we can double its weight and see how it would affect our ranking. As Fig. 6. depicts, in this case, Enjin would still remain the best NFT game.

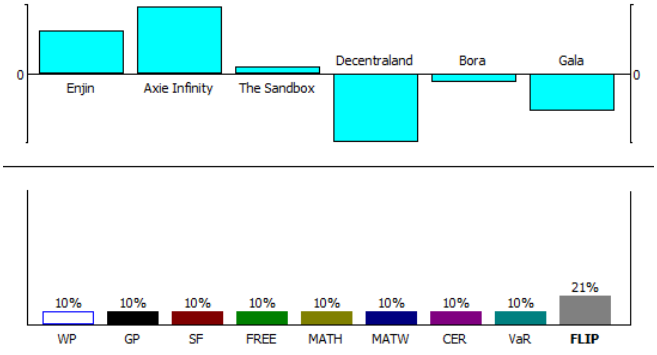
Fig. 6. Ranking, if we assign a higher weight to VaR



Source: Author's, via Visual PROMETHEE Academic Edition software

However, as Fig. 7. shows, if we double the weight of the FLIP ratio, Axie Infinity would surpass Enjin and become the best-performing game.

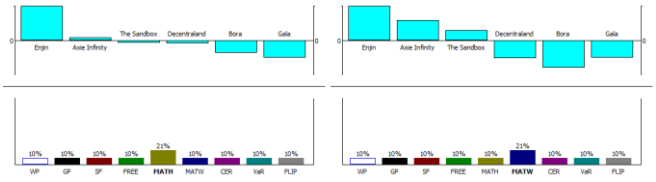
Fig. 7. Ranking, if we assign a higher weight to FLIP



Source: Author's, via Visual PROMETHEE Academic Edition software

From the relative market value point of view if we double the weight of MATH and MATW, in both cases Enjin would still remain the best-performing NFT game.

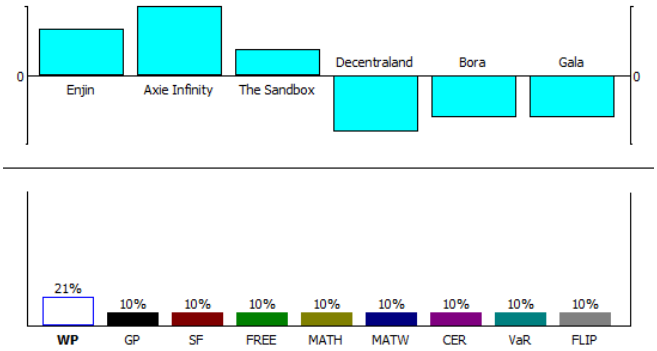
Fig. 8. Ranking, if we assign a higher weight to MATH or MATW



Source: Author's, via Visual PROMETHEE Academic Edition software

It is obvious that since none of the games had a green paper, this criterion does not affect the ranking. Based on our sensitivity analysis doubling the weight of SF, FREE and CER wouldn't change Enjin's rank as the best-performing game. Only if we double the weight of WP, it would make Axie Infinity the best game.

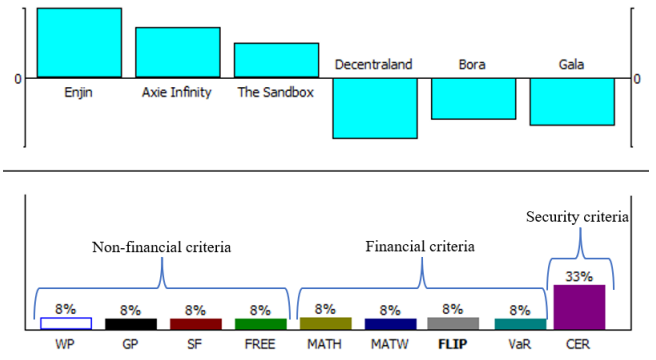
Fig. 9. Ranking, if we assign a higher weight to WP



Source: Author's, via Visual PROMETHEE Academic Edition software

We may also group our criteria into three equally weighted groups of non-financial, financial, and security criteria. We may consider WP, GP, SF, and FREE as non-financial criteria, MATH, MATW, VaR, and FLIP as financial criteria, and CER as security criteria. We also weigh the criteria in each group equally. Therefore, each group's weight would be around 33% and each criterion in each group would be weighted accordingly. Based on this scenario, Enjin would still remain the higher-ranked NFT game.

Fig.10. Ranking, if we group the criteria into three equally weighted categories



Source: Author's, via Visual PROMETHEE Academic Edition software

As we mentioned before, we chose a small inflection point for our Gaussian preference function. Now, to see the effect

of increasing σ_k on the results we rerun the model using $\sigma_k = 1\%$. If we compare the results depicted in Table VI with Table V, we can see that if we set $\sigma_k = 1\%$ the distance between projects net performance indexes values increases, however, their ranking will not change and Enjin will still remain the best performing game.

TABLE VI. NET PERFORMANCE INDEX VALUES IF $\boldsymbol{\sigma_k = 1\%}$

NFT games	$\emptyset(\mathbf{x_i})$
Enjin	0.2221
Axie Infinity	0.1551
The Sandbox	0.0449
Decentraland	-0.1080
Bora	-0.1532
Gala	-0.1609

Source: Author's.

Moreover, as Table VII shows, since we already chose a small inflection point, further decreasing σ_k will not change the ranking.

TABLE VII. NET PERFORMANCE INDEX VALUES IF $\boldsymbol{\sigma_k = 0.1\%}$

NFT games	$\emptyset(\mathbf{x_i})$
Enjin	0.2222
Axie Infinity	0.1363
The Sandbox	0.0637
Decentraland	-0.1111
Bora	-0.1556
Gala	-0.1556

Source: Author's.

B. The final rating

Finally, we transform the net performance values through Equation (10) and rate them according to our rating scale specified in Table II. The assigned ratings are as follows:

TABLE VIII. ASSIGNED RATINGS

NFT games	$\mathbf{V(x_i)}$	**Assigned ratings**
Enjin	1.00	AAA
Axie Infinity	1.72	AAA
The Sandbox	2.86	AA
Decentraland	4.53	BBB
Bora	5.00	BBB
Gala	5.00	BBB

Source: Author's.

As presented in Table VIII, 50% of the games are rated as BBB. Only one game is rated as AA and about 33% of the games under consideration are rated as AAA, which means they have a more attractive risk-potential profile than the others.

IV. CONCLUSION

The cryptocurrency market has grown significantly in recent years. One of the segments of this market, the NFT games market, has recently attracted a lot of attention with the popularity of NFTs as well as the development of metaverse. However, as mentioned in the literature review, many studies have reported that the NFT market cannot be categorized as an efficient market [28, 27]. Market efficiency has three main aspects: operational efficiency, informational efficiency, and allocation efficiency [66]. Although the use of blockchain technology has had a significant impact on improving the operational efficiency of the NFT games market, in terms of informational efficiency, NFT games market participants still face many ambiguities, due to the complexities of the NFT games projects. Poor information efficiency, in turn, has led to poor allocation efficiency. Therefore, to improve the efficiency of the NFT games market, we need to improve its informational efficiency, and consequently its allocation efficiency. Fundamental analysis, by refining data and turning it into information, helps market participants to comprehend this information and reflect it on prices, thus increasing market informational efficiency. Therefore, in this study, our focus is on selecting various data that is freely available to market participants. Then, by providing solutions to turn this data into decision criteria, we try to help investors make informed decisions. We also showed that most previous studies have focused on the games' NFT items themselves and also on market efficiency, rather than providing tools for evaluating and making investment decisions [28, 27, 30], whereas, we focus on the whole project from an investor perspective and provide a framework for comparative analysis and rating that could aid investors in their investment decisions.

Coins and tokens are often traded on Decentralized Exchanges (DEX) and Centralized Exchanges (CEX). Trading statistics of these markets are usually available. Similar to the coins and tokens markets, there are also NFT CEXs and DEXs that have grown significantly in recent years. However, in these markets, collectibles and other types of NFTs are mostly traded rather than games' NFT items. NFT games have internal marketplaces where their NFT items are traded, and each of these marketplaces has its own structure. Like tokens markets, market statistics for NFT CEXs and DEXs are also available, but due to the internal nature of NFT games marketplaces, not much information is published about them. However, games' main tokens are traded on CEXs and DEXs and can be compared. Accordingly, the focus of this study was on comparable data.

Since cryptocurrency projects have a very complex structure, are unregulated, and most importantly, do not publicize much information about their activities, evaluating them and determining which one is a more attractive investment opportunity is a difficult task.

After modeling the best criteria to evaluate and rate NFT games, we defined a 4-level rating scale (from AAA to BBB) to find the most attractive NFT games. Our findings show that 50% of the NFT games in the top-100 cryptocurrencies are rated as BBB, and investing in them needs rigorous due diligence. It is worth mentioning that we conducted a relative rating, so when we assert that a game rated as AAA performed well, we mean it performed well compared to the other games under consideration. Suppose we want to make an absolute rating. In that case, we should determine some thresholds for each criterion value, but determining these thresholds is a subjective matter, and we wanted to avoid making subjective judgments in our rating as much as possible.

Our research is different from other studies that are focused on players or the social and recreational aspects of games, as we are trying to evaluate and rate NFT games from an investment point of view.

Our comprehensive rating framework could be beneficial to cryptocurrency analysts and investors. In particular, the new FLIP ratio that we introduced could be a very constructive measure in all cryptocurrencies' ratio analyses. When performing ratio analysis, analysts try to use tailored

ratios that are suitable for the nature of each business. Unfortunately, up until now, there aren't many ratios that are modeled explicitly for cryptocurrency analysis. Therefore, we hope that introducing this new FLIP ratio can help other analysts develop a set of tailored ratios for cryptocurrency ratio analysis.

The non-parametric historical VaR that we used in this paper is also suitable for analyzing other types of cryptocurrencies. Also, we tried to take into account the adoption of games by considering Twitter followers.

Moreover, since we used free information that is available to all market participants, our proposed rating framework can also help evaluate various types of cryptocurrency projects. Analysts can modify our framework by choosing different criteria or changing the weights of each criterion and conducting their own customized cryptocurrency rating. They can also modify our framework and transform it into an absolute rating framework.

We suggest that analysts also add CVaR as another measure of risk for further research and define more ratios for relative analysis. Moreover, we considered the free-to-play option as a positive point for NFT games. However, the literature review has shown that the outcome of pursuing a free-to-play strategy over a pay-to-play scheme is not that straightforward and requires more research.

Our study contributes to the literature in three ways: First, we expand the studies on evaluating blockchain projects from a financial point of view by specifically concentrating on the NFT game and Metaverse. We add to the literature by providing evidence that NFT game projects and Metaverse can be categorized as Fintech. To the best of our knowledge, our paper is the first study that evaluates NFT game projects and Metaverse as types of Fintech, from a financial point of view.

Second, we add to the literature in the field of fundamental analysis by demonstrating the power of ratio analysis, which is an equity fundamental analysis method, in the evaluation of blockchain-based projects. For the first time, our study presents ratios that fit the characteristics of blockchain-based projects, especially NFT games and Metaverse.

Third, we add to the literature on the flexibility and applicability of the PROMETHEE II method in evaluating and ranking blockchain-based projects. We also show how to convert PROMETHEE II output into ratings.

The following limitations should be considered in interpreting and using the results of this study:

- The results of this study may change by changing the assumptions made to determine the weight of our criteria.
- Other information about NFT metaverse games may be available that may affect the results of the research.
- Apart from PROMETHEE II, there are other MCDA methods, which were also mentioned in the manuscript, and each has its own advantages and limitations, and using them may lead to different results.

According to our findings and also the mentioned limitations, we suggest that in future studies, methods such as the Delphi or AHP methods be used to determine the weight of the criteria. We also suggest that more data be used to evaluate projects. For example, the smart chains' gas fees can be considered one of the barriers to entering an NFT game.

Moreover, the time of establishment of metaverse projects can be taken into consideration, because older projects have more opportunities to attract the audience. In the present paper we performed a cross-sectional analysis, however, time analysis is also one of the approaches to analyzing financial ratios.

Finally, we suggest that the results of using other MCDA methods be compared with PROMETHEE II to determine whether a change in the method can make a significant difference to the results

REFERENCES

[1] M. Intelligence, "GAMING MARKET - GROWTH, TRENDS, COVID-19 IMPACT, AND FORECASTS (2021 - 2026)," Mordor Intelligence, 2020.

[2] R. Rachmadi, R. Chairullah, V. Levina, M. R. Pambudi, H. L. H. S. Warnars and T. Matsuo, "Online Game Marketplace for Online Game Virtual Item Transaction," in 8th International Congress on Advanced Applied Informatics (IIAI-AAI), 2019.

[3] E. Penttinen, M. Halme, P. Malo, T. Saarinen and V.-M. Vilén, "Playing for fun or for profit: how extrinsically-motivated and intrinsically-motivated players make the choice between competing dual-purposed gaming platforms," Electronic markets, vol. 29, no. 3, pp. 337-358, 2019.

[4] P. B. Lowry, J. Gaskin, N. Twyman, B. Hammer and T. Roberts, "Taking 'fun and games' seriously: Proposing the hedonic-motivation system adoption model (HMSAM)," Journal of the association for information systems, vol. 14, no. 11, pp. 617-671, 2012.

[5] F. Valeonti, A. Bikakis, M. Terras, C. Speed, A. Hudson-Smith and K. Chalkias, "Crypto Collectibles, Museum Funding and OpenGLAM: Challenges, Opportunities and the Potential of Non-Fungible Tokens (NFTs)," Applied Sciences, vol. 11, no. 21, p. 5, 2021.

[6] Q. Terry and M. Fortnow, The NFT Handbook: How to Create, Sell and Buy Non-fungible Tokens, Wiley, 2021, pp. 39-41.

[7] M. Nadini, L. Alessandretti, F. Di Giacinto, M. Martino, L. M. Aiello and A. Baronchelli, "Mapping the NFT revolution: market trends, trade networks and visual features," arXiv preprint arXiv:2106.00647, 1 June 2021.

[8] C. Staff, "What Is a Crypto Metaverse?," Cryptopedia, 2021.

[9] W. J. Davis, Metaverse Explained for Beginners: A Complete Guide to Investing in Cryptocurrency, NFT, Blockchain, Digital Assets, Web 3 & Future Technologies, 2021.

[10] C. Staff, "Gaming and Non-Fungible Tokens," Cryptopedia, 2021.

[11] D. Boreiko and G. Vidusso, "New blockchain intermediaries: do ICO rating websites do their job well?," The Journal of Alternative Investments, vol. 21, no. 4, pp. 67-79, 2019.

[12] F. Regner, N. Urbach and A. Schweizer, "NFTs in practice–non-fungible tokens as core component of a blockchain-based event ticketing application," in Fortieth International Conference on Information Systems, 2019.

[13] S. Nanayakkara, S. Perera, S. Senaratne, G. T. Weerasuriya and H. M. N. D. Bandara, "Blockchain and Smart Contracts: A Solution for Payment Issues in Construction Supply Chains," Informatics, vol. 8, no. 2, 2021.

[14] ethereum.org, "Ethereum use cases: Non-fungible tokens (NFT)," 21 5 2022. [Online]. Available: https://ethereum.org/en/nft/#:~:text=NFTs%20are%20minted%20through%20smart,the%20NFT%20is%20being%20managed..

[15] M. Mukhopadhyay and K. Ghosh, "Market Microstructure of Non Fungible Tokens," arXiv preprint arXiv:2112.03172, 2021.

[16] P. Kireyev, "NFT Marketplace Design and Market Intelligence," INSEAD Working Paper No. 2022/03/MKT, 2022.

[17] D. W. Arner, J. N. Barberis and R. P. Buckley, "The Evolution of Fintech: A New Post-Crisis Paradigm?," University of Hong Kong Faculty of Law Research Paper No. 2015/047, 2015.

[18] J. Ehrentraud, D. G. Ocampo, L. Garzoni and M. Piccolo, "Policy responses to fintech: a cross-country overview," FSI Insights on policy implementation, no. 23, 2020.

[19] W. Lu, "Blockchain Technology and Its Applications in FinTech," in International Conference on Intelligent, Secure, and Dependable Systems in Distributed and Cloud Environments, 2018.

[20] O. Ali, M. Ally and Y. Dwivedi, "The state of play of blockchain technology in the financial services sector: A systematic literature review," International Journal of Information Management, vol. 54, p. 102199, 2020.

[21] M. M. Queiroz and S. F. Wamba, "Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA," nternational Journal of Information Management, pp. 70-82, 2019.

[22] F. Panisi, "Blockchain and'Smart Contracts': FinTech Innovations to Reduce the Costs of Trust," Available at SSRN 3066543, p. https://dx.doi.org/10.2139/ssrn.3066543, 2017.

[23] D.-R. Kong and T.-C. Lin, "Alternative investments in the Fintech era: The risk and return of Non-Fungible Token (NFT)," Available at SSRN 3914085, 2021.

[24] E.-T. Cheah and J. Fry, "Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin," Economics letters, vol. 130, pp. 32-36, 2015.

[25] A. Urquhart, "The inefficiency of Bitcoin," Economics Letters, vol. 148, pp. 80-82, 2016.

[26] M. Franceschet, "HITS hits art," arXiv:1907.07758v5, 2021.

[27] M. Dowling, "Fertile LAND: Pricing non-fungible tokens," Finance Research Letters, vol. 44, p. 102096, 2021a.

[28] L. Ante, "Non-fungible Token (NFT) Markets on the Ethereum Blockchain: Temporal Development, Cointegration and Interrelations," Available at SSRN 3904683, 2021a.

[29] L. Ante, "The non-fungible token (NFT) market and its relationship with Bitcoin and Ethereum," Available at SSRN 3861106, 2021b.

[30] M. Dowling, "Is non-fungible token pricing driven by cryptocurrencies?," Finance Research Letters, vol. 44, p. 102097, 2021b.

[31] M. Dash, "A Model for Bank Performance Measurement Integrating Multivariate Factor Structure with Multi-Criteria PROMETHEE Methodology," Asian Journal of Finance & Accounting, vol. 9, no. 1, pp. 310-332, 2017.

[32] A. Vlachvei, O. Notta, K. Karantininis and N. Tsounis, Eds., Factors Affecting Firm Competitiveness and Performance in the Modern Business World, IGI Global, 2016, p. 133.

[33] K. Kądziołka, "The Promethee II Method in Multi-Criteria Evaluation of Cryptocurrency Exchanges," Economic and Regional Studies/Studia Ekonomiczne i Regionalne, vol. 14, no. 2, pp. 131-145, 2021.

[34] Z. Aljinović, B. Marasović and T. Šestanović, "Cryptocurrency Portfolio Selection—A Multicriteria Approach," Mathematics, vol. 9, no. 14, p. 1677, 2021.

[35] F. Ülengin, Y. I. Topcu and Ş. Ö. Şahin, "An integrated decision aid system for Bosphorus water-crossing problem," European Journal of Operational Research, vol. 134, no. 1, pp. 179-192, 2001.

[36] J. Papathanasiou and N. Ploskas, Multiple Criteria Decision Aid: Methods, Examples and Python Implementations, Springer Cham, 2018.

[37] G. M. Protonotarios, Bitcoin & Ethereum Trader: Trading Bitcoin and Ethereum Based on Technical Analysis, Market Sentiment, and On-Chain Data, GEORGE M. PROTONOTARIOS, 2021, p. 100.

[38] J. Ma, "Flippening," 2022. [Online]. Available: https://academy.binance.com/en/glossary/flippening. [Accessed 2022].

[39] A. Furlan, "An analysis of arbitrage and cointegration based pairs trading in the cryptocurrency market," Luiss Guido Carli, 2019.

[40] Z. Pál, "Cryptocurrencies as payment alternatives," in Aspects of Financial Literacy, Sumy State University, 2021, p. 343.

[41] E. K. Clemons, D. C. Croson and B. W. Weber, "Market Dominance as a Precursor of a Firm's Failure: Emerging Technologies and the Competitive Advantage of New Entrants," Journal of Management Information Systems, vol. 13, no. 2, pp. 59-75, 1996.

[42] S. Athey and A. Schmutzler, "Investment and Market Dominance," The RAND Journal of Economics, vol. 32, no. 1, pp. 1-26, 2001.

[43] X.-Z. He, P. Hamill and Y. Li, "Can Trend Followers Survive in the Long-Run% Insights from Agent-Based Modeling," in Natural computing in computational finance, Springer, Berlin, Heidelberg, 2008, p. 253–269.

[44] K. Gkillas and P. Katsiampa, "An application of extreme value theory to cryptocurrencies," Economics Letters, vol. 164, pp. 109-111, 2018.

[45] J. Seifoddini, "Evaluating The Top-30 Cryptocurrencies Based On Their Non-Parametric Value At Risk," 2021. [Online]. Available: https://www.publish0x.com/jalal-seifoddini/evaluating-the-top-30-cryptocurrencies-based-on-their-non-pa-xknwnmz.

[46] P. Artzner, F. Delbaen, . J. Eber and D. Heath, "Coherent measures of risk," Mathematical finance, vol. 9, no. 3, pp. 203-228, 1999.

[47] M. E. Falagas, E. I. Pitsouni, G. A. Malietzis and G. Pappas, "Comparison of PubMed, Scopus, web of science, and Google scholar: strengths and weaknesses," The FASEB journal, vol. 22, no. 2, pp. 338-342, 2008.

[48] A. Kati, J. Kinnunen, E. Koskinen and J. Paavilainen, "Free-to-Play Games: Paying Players' Perspective," in In Proceedings of the 22nd International Academic Mindtrek Conference, 2018.

[49] A. Seidl, J. P. Caulkins, R. F. Hartl and P. M. Kort, "Serious strategy for the makers of fun: Analyzing the option to switch from pay-to-play to free-to-play in a two-stage optimal control model with quadratic costs," European Journal of Operational Research, vol. 267, no. 2, pp. 700-715, 2018.

[50] F. García-Monleón, I. Danvila-del-Valle and F. . J. Lara, "Intrinsic value in crypto currencies," Technological Forecasting and Social Change, vol. 162, p. 120393, 2021.

[51] S. T. Howell, M. Niessner and D. Yermack, "Initial coin offerings: Financing growth with cryptocurrency token sales," The Review of Financial Studies, vol. 33, no. 9, pp. 3925-3974, 2020.

[52] H. W. Park and Y. Lee, "How Are Twitter Activities Related to Top Cryptocurrencies' Performance? Evidence from Social Media Network and Sentiment Analysis," Društvena istraživanja: časopis za opća društvena pitanja, vol. 28, no. 3, pp. 435-460, 2019.

[53] Z. Li, Q. Lu, S. Chen, Y. Liu and X. Xu, "A landscape of cryptocurrencies," in 2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), 2019.

[54] B. Ong, T. M. Lee, G. Li and D. L. K. Chuen, "Evaluating the potential of alternative cryptocurrencies," in Handbook of digital currency, Academic Press, 2015, pp. 81-135.

[55] R. Harris, "NFT game Alien Worlds records almost 760K users," App Developer Magazine, no. December, 2021.

[56] F. Shahzad, G. Xiu, J. Wang and M. Shahbaz, "An empirical investigation on the adoption of cryptocurrencies among the people of mainland China," Technology in Society, vol. 55, pp. 33-40, 2018.

[57] Y. Guan and N. Han, "Towards Verifying Ethereum Smart Contracts at Intermediate Language Level," in Formal Methods and Software Engineering: 21st International Conference on Formal Engineering Methods, Shenzhen, 2019.

[58] J. J. Yan and H. Choi, "Security issues in online games," The Electronic Library, vol. 20, no. 2, pp. 125-133, 2002.

[59] T. Min and W. Cai, "A security case study for blockchain games," in 2019 IEEE Games, Entertainment, Media Conference (GEM), 2019.

[60] M. Doumpos and C. Zopounidis, "A multicriteria decision support system for bank rating," Decision Support Systems, vol. 50, no. 1, pp. 50-63, 2010.

[61] J.-P. Brans and P. Vincke, "A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision-Making)," Management science, vol. 31, no. 6, pp. 647-656, 1985.

[62] R. Binnekamp, Preference-based Design in Architecture, Delft University Press, 2010.

[63] F. Gökalp, "Comparing the Financial Performance of Banks in Turkey By Using Promethee Method," Ege Stratejik Araştırmalar Dergisi, vol. 6, no. 1, pp. 63-82, 2015.

[64] S. Paksoy and M. F. Traş, "Investigating Banks' performance For Turkey: An Application of PROMETHEE Method," Cumhuriyet Üniversitesi İktisadi ve İdari Bilimler Dergisi, vol. 18, no. 1, pp. 143-159, 2017.

[65] B. Mareschal, "Preference functions and thresholds," 2018. [Online]. Available: http://www.promethee-gaia.net/FR/assets/preffunctions.pdf. [Accessed 2022].

[66] U. B. Sapate, Econometric Analysis of Weak Form of Market Efficiency, eBooks2go Incorporated, 2017.

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Financial cybercrime in the Islamic Finance Metaverse

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***Abstract* — Financial cybercrime in the metaverse has become increasingly more significant for authorities, corporations, and individuals to address, requiring new regulatory and compliance frameworks, as well as novel cybersecurity mechanisms in order to prevent these crimes. Financial cybercrimes in the metaverse have increased in the last years significantly, with either the massive stealing of cryptocurrencies from exchanges or the sale of fake or dubious NFT and other financial products that have lost significant value within a short period of time. Cybercrimes in the metaverse have taken place at significant scales and given the infancy of regulations as well as the virtual nature of these activities, only few crimes have been prosecuted. Islamic finance may represent a considerable opportunity for the metaverse via connecting the financial services and instruments to real and virtual assets free of speculation. The article provides several recommendations for regulators to address these cybercrime challenges and how Islamic finance can assist in these cybercrimes.**

Keywords—Islamic finance, metaverse, cybercrimes, blockchain

I. INTRODUCTION

Fraud and financial crime is a trillion-dollar industry, where companies may spend around 8.2 billion USD on anti-money laundering controls in 2017 alone, with the number rising. Financial crimes have increased year on year, with both detected and undetected crimes increasing significantly. Furthermore, fraud itself may cause significantly associated cost that make these cybercrimes even costlier [1]. Generally, banks face various risks arising from cybercrime, including the vulnerabilities that relate to financial and fraud crimes in automation and digitization, the massive growth in transactions, and the integration of financial systems within countries. Cybercrime and malicious hacking have significantly intensified. Financial crimes have led to a significant number of regulators that revise rules and account for illegal trafficking and money laundering [2]. There have been economic sanctions, which target both countries, public and private entities. Institutions are more and more realizing that conventional approaches to combating financial cybercrimes are not sufficient, and this requires them to become more nimble. In order to enhance detection, interdiction, and prevention, there is a distinction between fraud and financial crime. New cyberthreats have led to a blurring of these two concepts, and criminal activities have become more complex and interrelated. Legally, there is no distinction in regulation between the two concepts, but the difference arises primarily due to organizational aspects. Normally, financial crimes relate to money laundering and other criminal transgressions, which includes bribery and tax evasion. These involve the use of financial services to support criminal enterprises. The challenges typically arise as a result of compliance issues, specifically when financial institutions avert fines with anti-money laundering activities [3].

Fraud can be generally considered as a host of crimes, which involve forgery, credit scams, and insider threats. This involves both the deception of financial personnel or services in order to achieve theft. Fraud is generally considered as a loss problem and financial institutions apply advanced analytics for the detection and real-time interdiction. The challenges arise from the fact that these crimes often are often together and merge in the metaverse [4].

The Carbanak attacks in 2013 represented a great illustration of financial cybercrimes and fraud. This totaled more than 1 billion USD, and the criminals gained access to the system via phishing, and the fraudulent inflation of balances enabled them to dispense the cash at ATMs. The first weak link was via spear-phishing, which involved the sending of emails with an attachment that installed the Carbanak backdoor (*Figure 1*). This allows to open the backdoor and steal its credentials. With access to the PC, the backdoor allows to search for Admin PCs that allow inflating balances and mimics the behavior of the admins. The criminals then inflate the balances and subsequently retrieve the funds via wire transfer or cash dispense at ATMs [5].

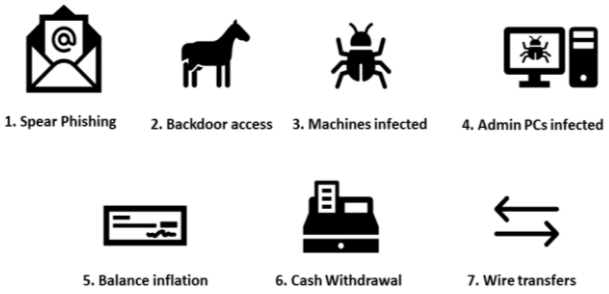

Figure 1: Cyber profile attack format

The challenge arose from the fact that the crime was simultaneously conducted against several banks and utilized their knowledge of the cyber environment, the banking processes, and controls. Furthermore, the criminals were fully aware of the vulnerabilities that arose from the organization's silos and governance. Furthermore, several channels, such as ATMs, credit and debit cards in addition to wire transfers were deployed [6]. This combination of various different methods outlines that fraud, cyberattacks and financial crimes are integrated with each other (*Figure 2*).

Figure 2: Convergence of crimes.

The existing silo approach to these interconnected risks represents a key challenge for many banks and financial providers. Until recent times, most of the fraud is based on transactions where the criminals exploit the weaknesses in the controls of the corporation. These fraud activities can be encountered relatively with channel-specific and point-based controls. Identity-based fraud activities have increased significantly where fraudsters exploit natural or synthetic data [7]. The ambitions of attacks are more ambitious in terms of scope and present everywhere. Digital trust is a critical component of customer experience for many financial service providers and banks, which requires a seamless, secure and speedy digital interface. Challenges arise from the demand for faster risk management, which requires to have solutions available. Challenges arise from the rising cost and lack of comprehensive regulations that address these challenges [8].

Given the growing digitalization and development of the metaverse, many institutions aim to combine efforts to combat financial crime, fraud and cybercrime.

Important is to define the nature of risk-management activities and to be clear about the roles and responsibilities, such that there is complete and clearly delineated coverage. The main countermeasures to combat financial crime involve the identification and authentication of the customer, the monitoring and detection of transactions, and the analysis of behavioral anomalies in addition to the mitigation of risks. The combination of data sources together with analytics enhances visibility and provides a greater insight to enhance detection capabilities [9].

In order to understand better the potential designs that can be considered for dealing with cybercrimes and fraud, there are various operating models that may be taken. These are collaborative, partially integrated, and unified models.

The collaborative model is amongst the most common forms where the domains related to financial crime, fraud, and cybersecurity are independent and have separate roles, responsibilities, and cybersecurity. Each of the units has its own independent framework, cooperating on any risk taxonomy and the data and analytics related to the monitoring of transactions, as well as fraud and other breaches. The challenge is that such an approach limits the transparency related to financial-crime risk, and there may be some coverage gaps in addition to overlaps amongst the groups. Integration is relatively limited as well.

A different approach is the partial integration model for cybersecurity and fraud, which has been taken up by many institutions and regulators. The units maintain their independence but work on a consistent framework and taxonomy. This follows some accepted rules and responsibilities. This implies that a consistent framework for the prevention, risk identification, and assessment process is integrated. Consistency in threat monitoring and detection is improved, but the existing organizational structures do not lead to enhanced transparency. There is furthermore only limited benefit of scale, and the operational units represent a challenge [10].

The final unified model integrates financial crimes, fraud, and cybersecurity operations into a single framework. This leads to the maintenance of common assets and systems via which all the risks are managed in the enterprise. This allows having a single view of customers and the sharing of analytics. This allows to enhance enterprise-wide transparency and outline the underlying risks.

While these new models have led to improvements in how corporations deal with certain forms of cybercrimes, the metaverse represents a completely new challenge in how financial crimes are conducted.

The word "metaverse" has been encountered everywhere in recent years, with Facebook changing its name officially to Meta [1]. Non-fungible tokens (NFT) have become one of the major words of the year, where these tokens form a key part of the virtual universe. This has also led gamers and developers to move into this space, making it more and more attractive to conventional consumers. While there has been considerable attention around the virtual universe, understanding the environment behind the virtual universe and what value it creates is of critical importance. The land prices related to digital land have been on the rise, with Republic Real Estate launching a fund for investors to purchase virtual land [2]. The fund will purchase virtual land across various online metaverses and transform them into hotels, stores, and other uses. This shall lead to an increase in the value of these properties amongst consumers.

While virtual land has, due to its connotation with physical land, attracted considerable interest, the art sector related to NFTs has experienced an even more significant rise, and there is the expectation that equities and bonds will be hosted on a digital asset platform that is built around blockchain technology. Another key area of the metaverse is the gradual online-only shopping and experience, which implies that individuals purchase assets that are entirely virtual. There are several stores that sell clothing and accessories entirely online, which only exist in the metaverse. Furthermore, there are virtual fashion shoes solely for the virtual world, which has attracted considerable investment amounts. The growing remote work operational model, in addition to the growing utilization of artificial intelligence and virtual technologies, has opened up new business models providing customers with different experiences in the virtual world. Another key change is the move towards remote work, where the metaverse can make remote work more permanent and immersive in order to maximize efficiency and interaction. This will enable stronger interaction and engagement of the employees [3].

Given the growing importance of the metaverse, the financial industry has been looking into how to create value within the metaverse space and how fintech solutions can

deliver financial services in this new environment. Furthermore, metaverse technology creates new business model opportunities that may strengthen the utilization of crypto-technology as an alternative financial system.

The technologies behind the metaverse combine technologies such as virtual reality (VR) and augmented reality (AR). This leads to an interactive, immersive and collaborative virtual 3D universe. The idea is that these individual universes may be integrated with each other as well as allowed to connect across the world in various environments. This may be in the form of games but also in terms of real estate, commercial transactions, and other associated environments [4].

As outlined by Facebook's transformation into Meta, financial data and transaction management will become key parts of the metaverse enabling individuals and corporations to transact and operate within these universes. For example, there are digital assets for purchase, such as the World of Warcraft and the Habbo Hotel, and these assets may be even moved from one universe into the other [1].

The current metaverse is a composition of the capabilities of various social media and video game enterprises that build upon their user base and platform in order to connect these individuals. While this first glance may give the impression that the metaverse is solely about gaming, it has become more of another virtual world where individuals may be fully immersed and conduct most of their life within the metaverse. This may range from dating to having their social interactions within the metaverse, but also conduct business across it. This may be in the form of leading a real enterprise or a digital enterprise within the metaverse. Overall, this will lead to someone being completely immersed in the metaverse and living their daily lives within this universe.

II. BLOCKCHAIN AND ITS IMPACT ON FINANCIAL CYBERCRIME

Blockchain technologies have facilitated the development of cryptocurrencies in the last decade. Cryptocurrencies are a collection of binary data that act as medium of exchange, and the individual ownership is stored in a ledger. The ledger is a general database that utilizes strong cryptography in order to secure transaction records. Most cryptocurrencies are fiat currencies that are not backed by or convertible into commodities, such as gold. While most cryptocurrencies have posited their decentralized nature there are several crypto schemes that utilize validators in order to enhance security and maintenance. Furthermore, proof-of-stake models provide the owners with the option to put the tokens as collateral. They subsequently obtain the token in proportion to the amounted stake, and with ownership of the token, there are additional benefits such as network fees, newly minted tokens, or other reward mechanisms. Cryptocurrencies distinguish themselves in their most modern form in terms of that they are not issued mostly by central authorities. While there have been initiatives from central banks to adopt digital currencies, such as the digital yuan or digital euro, most of the existing cryptocurrencies do not have a central authority that controls them but rather rely on decentralized control. This provides some unique opportunities to reduce transaction costs and enable direct transactions without the need for a middleman [15].

While this has opened an entirely new business model, it has also changed the world of crime. Cryptocurrencies pride themselves on being decentralized and independent, which makes them also difficult to trace, given that transactions may pass by conventional banking institutions and central banks. This lack of centralized supervisory allows individuals to perform transactions without any middlemen validating the transaction. Such transactions share similarities with cash transactions that allow individuals to remain totally anonymous. The most famous and recent example of governments aiming at preventing crime and reducing black market transactions is India, where the government invalidated all 500 and 1000 INR banknotes. The assumption was that removing these banknotes as legal tenders overnight would require criminals to declare and deposit their funds in banks, which allows the authorities to track whether someone has extensively underreported transactions as compared to their overall funds [16]. While the disruption has led to considerable economic challenges for the general population, the benefits from the initiative have been limited. The main challenge that arose is that many of the transactions and wealth stored from illegal businesses were already in forms other than banknotes or already processed via the banking system. Additionally, much of the wealth accumulated is also in the form of property, industrial investments, and foreign currencies. Nevertheless, criminals face the challenge that banknotes are issued by a central authority, which makes it a challenge to freely utilize the funds and transfer them across their operations. For wire transfers, the transactions are typically processed via major transaction centers that are subject to restrictions within the jurisdiction they are located in. For example, almost all USD transactions move through the SWIFT network, with US-based institutions performing the intermediary role. If a criminal is flagged within such a transaction, then the transaction may not go through as well as the funds may be frozen. While this has not proven to be failsafe, it has led to a significant reduction in the ability of criminals to utilize the conventional financial system for committing crimes and transferring funds.

Cryptocurrencies distinguish themselves in terms of their decentralized nature, which implies that two parties may conduct a transaction directly between themselves. This implies the absence of a centralized validating party that would otherwise validate and control the transaction. The advantage for criminals is that these transactions can be executed independently and cannot be easily traced. In a simple example, hostage-takers may receive the ransom amount in bitcoin, which can be easily stored and exchanged on the global cryptocurrency market without the ability of authorities to trace the transactions. Furthermore, as the bitcoins are not uniquely identifiable in the blockchain, this further makes these transactions and what was conducted with the received bitcoins impossible to trace [17].

This lack of transparency and anonymity for transacting parties represents an encouragement for criminals to engage in crimes. As the oil pipeline cyberattack has demonstrated, criminals may have a strong preference for cryptocurrency payments given its anonymity and ease of moving around. A USD transaction would require a more elaborate scheme of setting up different bank accounts in various jurisdictions and then converting those funds into banknotes that may be

transported across borders. The Bangladesh Central Bank heist was such an example. Even the transport across borders of these banknotes is a challenge by itself and may lead to confiscation. In contrast, transferring cryptocurrencies from one wallet to another and going from cold storage to hot storage can be done within seconds, which significantly simplifies criminal activity [18].

The recommendation to regulators is to address these challenges with dedicated regulations related to blockchain technology and cybercrime. This may be in the form of real name verification for transactions of cryptocurrencies and the requirement for digital wallet providers to know their customers.

III. VPNs and Proxies and Their Impact on Financial Cybercrime

Virtual private networks and proxies represent another key area of crime facilitation. Virtual private networks extend private networks across the public network and enable users to both send and receive data across shared or public networks in the same form as if they were directly connected to each other. The benefits of VPNs are significant, as it allows to increase functionality, security, and the management of private networks as well as allow individual members to make central resources accessible from anywhere. VPNs have long been of strong interest for criminals to mask their operations and imitate the access of websites from various locations. Specifically, modern VPN services allow the VPN to utilize several VPN gateways and proxies in order to access the internet. Any website that is accessed solely sees the public IP address of the proxy irrespective of where the accessing computer is really located. This masking of the IP address and location allows individuals to access the internet from anywhere without being recognized. This also makes it challenging for law enforcement to determine where the access was made from and may also implicate on purpose a wrong IP address or computer in order to make law enforcement believe that they have caught the criminal [19].

A very famous example was the case of the provider "DoubleVPN" that was recently taken down. The main advantage of the VPN provider was to allow ransomware operators and phishing fraudsters to gain high anonymity via multiple interconnected VPN connections that enabled multiple layers of encryption. While the masking by itself is, in most circumstances, not a crime, the ransomware and phishing attacks conducted by these criminals is, in most circumstances, the crime. While many governments impose restrictions on the encryption technology that can be sold within the jurisdiction and have the right to request the decryption of data, access, and ability to decrypt modern encrypted VPN connections has become significantly more challenging. Improved encryption technology has made it far more complex to decrypt and extract information, which enhances the ability of criminals to evade law enforcement [20].

IV. Islamic Finance Cybercrimes in the Metaverse

The metaverse has become a major feature of attraction that will encompass some of the challenges existing social media and platforms face. Specifically, there have been several financial misconducts where individuals utilized social media in order to compromise individuals and extract financial gain from them. While the metaverse is created, it encompasses all of the challenges that may arise from the creation of a new virtual world. Given that this virtual world shall provide a complementary dimension to everyday life, where individuals interact and engage, this makes the challenges of financial crime even more prominent [21].

As Islamic finance has gained prominence as a facilitator for fairer financial relationships and its connection to real value creation, Islamic finance will also play a critical role in the metaverse. The metaverse represents a significant opportunity to provide Islamic financing in the metaverse and link the financing opportunities to the metaverse operations. Given that the metaverse is a virtual reality of the world, existing challenges related to cybercrimes for Islamic finance will be amplified in the metaverse. A key aspect is that the metaverse will be a virtual world but will be connected extensively to the physical world but allow to do things that are not possible in the physical world. For example, one may instantaneously travel and purchase items in the metaverse without the need for extensive physical travel or being subject to certain regulations. While the metaverse is famous for its integration of 3D virtual reality, augmented reality, open-source development, and artificial intelligence. Peer-to-peer payments and non-fungible tokens are other key features that will be present in the metaverse [22, 23].

This clearly outlines several challenges that may lead to the exploitation of these instruments. The financial cybercrimes in the metaverse encompass various forms. First, competitive gaming within the metaverse may lead to a compromise of the game in favor of one party, leading to significant losses of other players. Cybercriminals exploit weaknesses in the security of games in order to manipulate these. While being perceived as legitimate, the games are biased and lead to negative effects for the individuals.

Another key factor in Islamic finance in the metaverse and potential cybercrimes is the presence of cryptocurrencies. Cryptocurrencies have taken on various forms, be it in the form of volatile and unpegged ones, such as CRO or ETH, and stablecoins that are pegged to a financial asset. All of these experience challenges as they are mostly unregulated and are not covered by depositor protection.

Cryptocurrencies are generally permissible in Islamic finance as they are a means of exchange for the trading of physical goods. While volatility and the arising speculative nature has been a challenge, they do not make cryptocurrencies impermissible. Furthermore, cryptocurrencies being utilized for illegal activities and cybercrimes do not make these cryptocurrencies impermissible or prohibited. The main challenge arises that these cryptocurrencies may evade regulatory oversight and may be utilized for impermissible activities [24]. For example, cryptocurrencies may be utilized for gambling and related activities in the metaverse, which are clearly forbidden in Islamic finance. Individuals may either request financing for these illegal activities, or may try to disguise the activities utilizing existing financing forms. Such cybercrimes and compliance issues with respect to Shariah law have to be taken into account and compliant [25].

The development of non-fungible tokens and growing interest by investors in the metaverse have led to enormous valuations of such assets. This has also been observed in the metaverse, where non-fungible tokens represent ownership of an asset. While in many instances the NFT is connected to physical assets, this may not be the case, and the NFT may refer to a virtual asset that may be more closely considered fraudulent as compared to having any real value. Islamic principles forbid uncertainty and any fraudulent behavior, which acts as a significant deterrent for cybercriminals being able to exploit such instances for their own benefit. Given that there has to be either a connection to a physical asset or a virtual asset with limited speculative room, this necessarily reduces the possibility of fraud.

Regulators should focus on developing a comprehensive legal framework for Islamic finance in the metaverse that takes into account cybercrimes related to the Islamic financial products.

V. Conclusion

Financial cybercrime in the metaverse has become increasingly more significant for authorities, corporations, and individuals to address, requiring new regulatory and compliance frameworks, as well as novel cybersecurity mechanisms in order to prevent these crimes. Financial cybercrimes in the metaverse have increased in the last years significantly, with either the massive stealing of cryptocurrencies from exchanges or the sale of fake or dubious NFT and other financial products that have lost significant value within a short period of time. Cybercrimes in the metaverse have taken place at significant scales, and given the infancy of regulations as well as the virtual nature of these activities, only few crimes have been prosecuted. Islamic finance may represent a considerable opportunity for the metaverse via connecting the financial services and instruments to real and virtual assets free of speculation.

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References

[1] E. R. Leukfeldt, A. Lavorgna and E. R. Kleemans, "Organised cybercrime or cybercrime that is organised? An assessment of the conceptualisation of financial cybercrime as organised crime.," *European Journal on Criminal Policy and Research,* vol. 23, no. 3, pp. 287-300, 2017.

[2] J. Nicholls, A. Kuppa and N. A. Le-Khac, "Financial Cybercrime: A Comprehensive Survey of Deep Learning Approaches to Tackle the Evolving Financial Crime Landscape.," *IEEE Access,* 2021.

[3] E. R. Leukfeldt, E. W. Kruisbergen, E. R. Kleemans and R. A. Roks, "Organized financial cybercrime: Criminal cooperation, logistic bottlenecks, and money flows.," *The Palgrave Handbook of International Cybercrime and Cyberdeviance,* pp. 961-980, 2020.

[4] J. M. Karpoff, "The future of financial fraud.," *Journal of Corporate Finance,* vol. 66, p. 101694, 2021.

[5] S. Hasham, S. Joshi and D. Mikkelsen, "Financial crime and fraud in the age of cybersecurity.," McKinsey & Company, 2019.

[6] S. Kwon, J. Jeong and T. Shon, "Digital forensic readiness for financial network.," in *2019 International Conference on Platform Technology and Service (PlatCon)*, 2019.

[7] S. Y. K. Wang and M. L. Hsieh, "The ATM Hacking Case," in *Digital Robbery*, Springer, 2021, pp. 15-32.

[8] S. Varga, J. Brynielsson and U. Franke, "Cyber-threat perception and risk management in the Swedish financial sector.," *Computers & Security,* p. 102239, 2021.

[9] O. A. Erin, A. D. Kolawole and A. O. Noah, "Risk governance and cybercrime: the hierarchical regression approach.," *Future Business Journal,* vol. 6, pp. 1-15, 2020.

[10] S. M. Karsh, "Emerging Innovation Risk Management in Financial Institutions of United States.," *Economics and Business Quarterly Reviews,* vol. 4, no. 2, 2021.

[11] S.-M. Park and Y.-G. Kim, "A Metaverse: taxonomy, components, applications, and open challenges.," *IEEE Access,* 2022.

[12] N. G. Narin, "A Content Analysis of the Metaverse Articles," *Journal of Metaverse ,* pp. 17-24, 2021.

[13] K. B. Wilson, A. Karg and H. Ghaderi, ". Prospecting non-fungible tokens in the digital economy: Stakeholders and ecosystem, risk and opportunity.," *Business Horizons,* 2021.

[14] I. Wohlgenannt, A. Simons and S. Stieglitz, "Virtual reality," *Business & Information Systems Engineering,* pp. 455-461, 2020.

[15] E. Reddy and A. Minnaar, "Cryptocurrency: A tool and target for cybercrime.," *Acta Criminologica: African Journal of Criminology & Victimology,* vol. 31, no. 3, pp. 71-92, 2018.

[16] B. Sivathanu, " Adoption of digital payment systems in the era of demonetization in India: An empirical study.," *Journal of Science and Technology Policy Management,* 2018.

[17] A. Trozze, J. Kamps, E. A. Akartuna, F. J. Hetzel, B. Kleinberg, T. Davies and S. D. Johnson, "Cryptocurrencies and future financial crime.," *Crime Science,* vol. 11, no. 1, pp. 1-35, 2022.

[18] F. M. Teichmann and M. C. Falker, "Cryptocurrencies and financial crime: solutions from Liechtenstein.," *Journal of Money Laundering Control,* 2020.

[19] W. Ronhaar, W. B. Zehner and R. Langhorne, "Zero Identity—The New Cybersecurity Paradigm," *Marketing of Scientific and Research Organizations,* vol. 42, no. 4, pp. 97-109, 2021.

[20] A. Shah and D. Chudasama, "Investigating Various Approaches and Ways to Detect Cybercrime.," *Journal of Network Security,* vol. 9, no. 2, pp. 12-20, 2021.

[21] M. Ayub, Understanding Islamic Finance, Chichester: John Wiley & Sons, 2007.

[22] M. K. Hassan and R. N. Kayed, "The global financial crisis, risk management and social justice in Islamic finance.," *Risk Management and Social Justice in Islamic Finance,* 2009.

[23] H. Mohamed and H. Ali, Blockchain, Fintech, and Islamic finance: Building the future in the new Islamic digital economy., Berlin: Walter de Gruyter Gmbh & Co KG, 2018.

[24] U. Oseni and N. Ali, Fintech in Islamic finance, Routledge, 2019.

[25] C. Paldi, "Understanding riba and gharar in Islamic finance.," *Journal of Islamic Banking and Finance,* vol. 2, no. 1, pp. 249-259, 2014.

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What the Literature on Medicine, Nursing, Public Health, Midwifery, and Dentistry Reveals: An Overview of the Rapidly Approaching Metaverse

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Abstract*— What is being done in the metaverse literature in a variety of health-related fields, including Medicine, Nursing, Public Health, Midwifery, and Dentistry, and what topics are explored in this literature? In this study, a content analysis of the studies linked with the term metaverse in all health-related literature is presented. The studies were carried out on the documents accessed in Web of Science and Scopus searches made with the words "Metaverse" and "metaverse" on 06/05/2022. For 312 papers, data was retrieved from the Scopus bibliometric database, and for 240 publications, data was retrieved from the Web of Science data source. In the field of health, there haven't been many direct studies on metaverse technology. This is because metaverse technology is made up of many different technologies that work together and are always getting better. Some of these technologies are augmented reality, social networks, virtual reality, blockchain technology, artificial intelligence, and avatar. The study also tells field researchers about metaverse studies that are important in the health sector and about changes in the literature as a whole. According to the research areas, the documents found had to do with the field of health, and only the researches in the field of health were evaluated. It is interesting to think about how metaverse technology will change scientific research, health services, and health-related processes. The study looks at the current state of the literature on metaverse technology, as well as the future of the field and what it can do. Virtual reality or augmented reality applications have defined themselves as augmented reality under the metaverse. These applications are most useful in critical situations in the health sector and in processes that are hard and must be done by trial and error. In addition to the tremendous advances in technologies (blockchain, computer vision, haptic devices, sensors, computer networks) with which metaverse technology is associated in recent years, the mechanical resolution of the sense of touch in the Nobel Peace Prize in physiology and medicine received in 2021 can be seen as one of the field's critical milestones. The growth of the field and past experiences show that many real-world applications can be moved to the metaverse universe in the future. One of the fields that will be affected the most by this interaction is health care.

Keywords*— Health, medicine, nursing, midwifery, dentistry, metaverse.

I. INTRODUCTION

The health system does not appear to be sustainable in the future due to the strain produced by chronic illnesses, rising health-care expenses, a rapidly aging world population, an inadequate workforce in high-demand health-care services, and limited resources. Instead of traditional health services using cutting-edge technology, we need to be able to deliver health services from hospitals to our homes using cutting-edge technology. The Covid-19 outbreak has prompted significant changes in the world of medicine, encouraging patients to seek new ways to give remote care to patients outside of hospitals [47].

The following technologies are important and critical for the Metaverse architecture: augmented reality (AR), virtual reality (VR), user interaction, computer vision, artificial intelligence (AI), and blockchain, robotics and the internet of things, edge computing, computer networks, and hardware infrastructure [14]. With the technology it contains in health services and the huge breakthroughs in technologies that are its stakeholders, the metaverse, which has the ability to influence all sectors in some manner, may create a great shift and revolution.

Professionals in a variety of fields can utilize virtual and augmented reality technology to prepare for unusual events or to hone current skills and competences. The health industry is a critical area where this technology is being used extensively and effectively [14]. Governments in Europe, Asia, and America devote enormous resources to research and development [56]. The implementation of these technologies in education processes has grown in relevance, particularly in pandemic processes like as Covid 19. While face-to-face contact becomes more difficult as Covid-19 spreads, previously thought-to-be offline activities are changed into virtual reality and swiftly expand to education, medical care, fashion, and other industries [28].

Jeon [21] mentioned in his study that universities are making attempts to teach talents who will live in the fourth industrial revolution era, and they are developing comprehensive designs so that students may learn subjects based on societal needs and acquire problem-solving ability. They also mentioned that they are attempting to use the most effective teaching-learning approaches. In this regard, metaverse was employed for course practice in the anatomy course at Seoul National University, and students had the

opportunity to investigate and practice the anatomy of the human body using VR and AR technology.

According to Türk et al. [49], the seeds of the metaverse were planted with the further development of technologies like virtual reality, augmented and mixed reality (XR), wearable technologies, blockchain, NFT, and the internet of things. They also said that creativity in the metaverse would be limitless. Also, one important thing we don't know about how the metaverse will be used is whether it will be one world or more than one. Facebook is already moving quickly in the direction of making its own metaverse environment. Google and Microsoft might do the same thing and build their own Metaverses. In Metaverse, each tech giant might have its own platforms, product family, and formations and product groups [1].

Artificial intelligence, virtual reality, augmented reality, the internet of things, edge computing, etc. are some of the technologies that will make it possible for metaverse technology to be used in health services. These technologies are used in many fields, such as education, research, patient care, rehabilitation services, and clinical applications. There are many opportunities for metaverse integration, and it will be beneficial [55]. Virtual reality and augmented reality are becoming more important every day, so it's important for health professionals to talk about them. Also, it's clear that studies that include current technologies and show how they relate to and help the field will be useful for professionals, students, trainers, and researchers in many health fields, such as medicine, dentistry, nursing, and midwifery. In the study, health studies are focused on metaverse technology, and its possible effects on health education and areas of use are looked at in depth. The study is thought to be important because it will show what the current state of metaverse technology is in the field of health. People are interested in how it will affect health processes from a scientific research point of view, and they want to know what the future holds for the field and what opportunities technology can bring.

II. Metaverse Definitions And Metaverse Platforms

The metaverse, according to Koo [23], is the virtual replication of reality. It has progressed a step beyond cutting-edge technology that allows individuals to have lifelike experiences in virtual reality and the virtual world produced by computers, according to Lee and Kwon [29]. According to Werner et al. [53], the notion of metaverse adds many new characteristics to medical field communication and is a network of virtual spaces where individuals and digital objects may interact. According to Ball [4], he tracked the evolution of the metaverse through eight components: hardware (*f:*1), networking (*f:*2), compute (*f:*3), virtual platforms (*f:*4), interchange tools and standards (*f:*5), payments (*f:*6), metaverse content, services, and assets (*f:*7), and user behaviors (*f:*8).

In the model designed by Radoff [41], metaverse layers include infrastructure (5G, wifi 6, 6G, cloud technologies, etc.), human interface (mobile devices, virtual reality tools, wearable devices, smart glasses), decentralization (edge computing, microservices, blockchain, etc.), spatial computing (augmented reality, virtual reality, motion recognition, spatial mapping, etc.), producer economy (design tools, digital exchanges, commerce), and exploration (agents, ad networks, stumbling blocks) (games, theatre, socializing, shopping, etc.). The seven strata of the metaverse.

The Metaverse is an aesthetically rich virtual environment with a lifelike quality in which individuals may work, play, shop, and interact. It is a network of three-dimensional virtual environments centered on social interaction. A virtual platform that allows developers to construct everything from virtual reality to augmented reality is known as a metaverse platform. Metaverse is a technology category that has gone a long way, and its growth is rising because to investments from major technology firms such as Meta Platforms, Microsoft, and Epic Games [52]. Metaverse is a virtual reality platform built on the blockchain [40]. Metaverse is a network of 3D virtual worlds that use technologies like VR and AR to connect people [42]. Virtual reality or augmented reality applications have identified themselves as augmented reality under the metaverse, notably in important places in the health sector, in procedures that are difficult and critical to perform via trial and error approach.

The metaverse market is expected to expand from $45.5 billion in 2019 to $1.5 trillion in 2030 [1]. Decentraland, The Sandbox, Cryptovoxels, Somnium Space, Roblox, Bloktopia, and Meta Platforms are seven firms that pioneered the advent of the Metaverse and secured the market's quick expansion [54]. Roblox, for example, is a popular platform among both children and adults, with over 20 million games produced on it. The Ethereum blockchain powers Decentraland, a 3D virtual reality realm [36]. It is collaborating with a number of partners from the entertainment, banking, gaming, real estate, and Hong Kong film sectors to develop the SAND money and a virtual Mega City in Sandbox [42].

III. Digital Human

Humanization of AI, useful AI applications, and the creation of autonomously animated digital individuals are all examples of digital humans [46]. Digital people are intended to integrate with any knowledge base, NLP, or other data source. Digital people are lifelike AI-powered humans that can see, hear, and comprehend you, your workers, patients, or clients, allowing them to reproduce "genuine" human exchanges. In addition, digital persons are used as customer service agents, sales concierges, financial advisers, brand ambassadors, digital influencers, customer support representatives, and healthcare consultants. It is used in a variety of industries, including banking, finance, education, real estate, the public sector, entertainment, healthcare, retail, telecommunications, and software technology. Furthermore, 88% of people who engaged with the artificial person thought the digital human was natural. 89% of users said they would prefer digital customer assistance from a human [50].

It is an excellent output for the metaverse world's reality perception, and it may also be expressed as a high-level avatar that is creative and extremely near to reality perception. The fact that this technology is becoming more prevalent is very encouraging.

According to Bickmore et al. [6], strong communication and quality relationships between healthcare personnel and their patients are increasingly acknowledged as a significant component in enhancing not just patient satisfaction but also treatment outcomes across a wide range of healthcare disciplines. Relational agents have been employed with a variety of patient demographics for health education and behavior modification interventions [5-6], and they are also used in the hospital bedside patient education system [7]. They claim that people suffering from depression are more

comfortable communicating with an avatar than with a real person [7]. Many studies have shown that a good therapist-patient connection has a favorable influence on results, particularly in psychotherapy [6].

This concept, originally known as relational agencies, is now known as digital humans in the metaverse world. With its more human-like aspect, digital human, which develops on top of relational agency technology, has usage areas in many different sectors such as augmented reality, electronic commerce, customer relations, which may concern every sector, as well as health, education, film, fashion, and game sectors. Furthermore, he can continue to serve as a guidance and psychiatric counselor in the metaverse by assisting students with a wide range of challenges encountered during their educational processes, such as digital human, virtual, and augmented reality technology.

Avatars are a key stakeholder technology in the metaverse supply chain. This is the digital person, a concept that has just emerged in avatar technology. It can communicate with digital human, particularly through various communication modes such as desktop, mobile, tablet, or kiosk. A digital human is an application that simulates a person's attitude, behavior, and motions. Digital natives are not just concerned with language. They can give you sentiments of enjoyment, empathy, and genuineness. It can grasp the meaning of words by understanding the tone of voice and facial expressions of users, much like a person. They can then employ their natural human tone of voice and body language. As digital chatbots, digital people may be deployed. Torre [48], particularly the top ten list of the greatest businesses generating digital persons and/or avatars that take human-computer interaction to a new level, are as follows: REBLIKA - The Character Company (https://reblika.com/), Synthesia (https://www.synthesia.io/), UneeQ (https://digitalhumans.com/), Soul Machines (https://www.soulmachines.com/), Th3rd (https://3dsaas.com/), Twindom (https://web.twindom.com/).

IV. Metaverse Tools, Haptic Devices, How the 2021 Nobel Prize Received Affects

In addition to the tremendous technological advancements (blockchain, computer vision, haptic devices, artificial intelligence, virtual reality, augmented reality, sensors, computer networks) associated with metaverse technology in recent years, the 2021 Nobel Peace Prize in physiology and medicine for the mechanical resolution of the sense of touch can be viewed as one of the most significant milestones. Many real-world applications will be able to be translated to the metaverse environment in the future, as demonstrated by the fact that the field has progressed and benefited from prior experiences. The healthcare industry will be one of the areas most affected by this relationship.

A haptic device is a device that lets the user and the computer share information in three dimensions. With this device, the user can not only see an object in a virtual environment, but also touch it. At the same time, this device makes it possible to get data from a real object and use it in a virtual one. Today, the use of haptic devices is growing in business, education, and medicine. This is happening at the same time that virtual reality technology is getting better. With this technology, which has a lot of potential for use in medicine, complex changes that used to have to be done by hand can now be done (operations that do not accept mistakes in neurosurgery). For all haptic applications, virtual reality modeling languages like FreeForm, Concept, Mimics, and so on have also been made. With these new developments, haptic devices can be used in more situations [3].

The 2014 Nobel Prize in Physics was awarded to three American and Japanese scientists who invented blue light emitting diodes (LEDs). In the early 1990s, academicians Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura created the first blue LEDs. This enabled the production of a new type of brilliant, energy-efficient white lighting and color LED displays. In the 60 years after the first physics Nobel Prize was awarded, the prize that has had the greatest impact on daily life is without a doubt the prize for relativity [38].

What occurred in 2021, for what did the Nobel Prize go, and how will this invention impact the future of the metaverse? David Julius and Ardem Patapoutian provided the mathematics and formula for the perception of reality through the sense of touch in 2021. David Julius is an American physiologist who discovered "a heat-sensitive sensor in the skin's nerve endings". The molecular biologist and neurologist Ardem Patapoutian discovered "a unique class of sensors that respond to mechanical stimulation in the skin and internal organs". Both findings elucidated "how heat, cold, and touch may trigger impulses in our nervous system," which is crucial to several physiological processes and diseases. Temperature heat pain (core body temperature, inflammatory pain, neuropathic pain, visceral pain, protective reflexes) and touch proprioception (mechanical pain, urination, respiration, blood pressure, skeletal remodeling) were used to describe this case [11].

V. Current Metaverse Platforms In Healthcare

Virtual, augmented, and mixed reality (XR) technologies have the potential to improve the quality and delivery of health education. Utilizing these technologies allows healthcare workers to practice in a secure environment without worry of adverse effects. It gives inexpensive interactive learning at a high level to its consumers [32]. Metaverse has significant potential for use in clinical treatment. Real-time guidance can be offered in the surgeon's field of view via immersive simulations of surgical procedures. By delivering information in the sterile region of the operating theatre, augmented reality will boost surgical precision and adaptability. Metaverse will enable collaborative medical operations and concurrent teaching, training, and planning [47]. Thanks to the Metaverse environment, several healthcare service applications may be successfully digitalized and implemented on various platforms. Future integration of XR applications in service delivery by health institutions with the metaverse will enable institutions to notice possible problems early and conduct proactive reviews to avert harm [55].

Consideration is given to how the metaverse may be utilized in the future to enhance, improve, and possibly transform health care. Collaboration, education, clinical care, wellbeing, and profit are the five topics discussed [47]. According to Sandıkçı [44], when virtual reality is applied to health, this technology will have a prominent position in the health industry. It is also anticipated that it would generate a substantial market in the health industry. They added that as time goes, technical advancements would reduce expenses, allowing for more work to be done in this field.

Hawks and Krasniansky [17] categorized digital health applications in the metaverse environment into two categories.

The first is immersive environments (virtual or hybrid worlds that health care providers and patients interact with for educational, assistive, or therapeutic purposes), and the second is digital twins (representations of real-world entities that exist in virtual worlds and can be manipulated to gain insights) for healthcare decision making. In the healthcare profession, three immersive environments are instructive (Embodied Labs, Giblib, Health Scholars, Osso VR), assistive (Augmedics, Thirdeye, Vicarious Surgery), and therapeutic (Applied VR, BehaVR, Floreo, Luminopia, OxfordVR, Tripp, XRHealth). specified in the title Also, digital twin, muscle groups and organs (Siemens Healthineers, Virtonomy.io), individuals (Babylon, Bio Twin), and populations (Unlearn).

The usage of augmented reality in the health industry has a considerable influence on the training and development of future medical professionals' skills and knowledge bases. In the health care industry, the metaverse has several applications. Patient education, mental health, pain management, medical testing, surgery (remote surgery, telepresence, augmented reality surgery), therapy (treatment planning), medical marketing, medical education (3D human models for education), and illness awareness are examples (virtual patients, medical education) It is accessible for use in therapy, psychotherapy through virtual reality, haptic-assisted rehabilitation, preventative medicine, and patient education, as well as in real-time e-surgery learning, training (architectural design for healthcare facilities), and institutional medical domains [37].

VI. Methodology

On June 5, 2022, Web of Science and Scopus were used to gather data. When the words "metaverse" and "meta verse" were used in searches on Web of Science and Scopus, 312 documents were found in the Scopus bibliometric database and 240 documents were found in the Web of Science bibliometric database. The data that was gathered was filtered bibliometrically based on the areas of research, with a focus on the health field. A full evaluation of the content of research in the field of health was done. For the study's discussion, Google Scholar was used to look up metaverse and related ideas, and related articles were used in the article. Google Scholar is also used because the number of publications found through Web of Science and Scholar resources is lower than expected. Through Google Scholar, more recent and more publications on the metaverse have been found.

The study presents an assessment of the global work done in the field of health in virtual reality and augmented reality. The research questions we focused on in our study;

- Is the metaverse a utopia and a current technology that has the potential to rapidly affect all professions in the health sector (such as medicine, nursing, public health, midwifery, dentistry)?
- What are the digital platforms that exist in our daily lives and what kind of applications and scientific studies have been carried out in the health sector?
- What kind of scientific discussions are held in scientific publications published in journals scanned by Web of Science and Scopus?

VII. Results And Discussion

A. Thorough Review of Web of Science and Scopus

The research fields of our 240 Web of Science pages are as follows; computer science (*f:*82), engineering (*f:*46), education educational research (*f:*30), business economics (*f:*20), communication (*f:*16), psychology (*f:*16), art (*f:*11), arts humanities other topics (*f:*11), science technology other topics (*f:*11), chemistry (*f:*8), environmental sciences ecology (*f:*8), information science library science (*f:*8), telecommunications (*f:*8), imaging science photographic technology (*f:*6), physics (*f:*6), cultural studies (*f:*4), materials science (*f:*4), public environmental occupational health (*f:*4), social sciences other topics (*f:*4), dentistry oral surgery medicine (*f:*3), geography (*f:*3), government law (*f:*3), instruments instrumentation (*f:*3), linguistics (*f:*3), optics (*f:*3), public administration (*f:*3), religion (*f:*3), energy fuels (*f:*2), operations research management science (*f:*2), philosophy (*f:*2), architecture (*f:*1), automation control systems (*f:*1), dermatology (*f:*1), general internal medicine (*f:*1), geology (*f:*1), health care sciences services (*f:*1), music (*f:*1), social issues (*f:*1), sociology (*f:*1), theater (*f:*1), transportation (*f:*1), veterinary sciences (*f:*1).

It is seen that the research areas where the studies are concentrated are mostly computer science, engineering, education educational research studies. A total of ten papers were discovered in the fields of public environmental occupational health (*f:*4), dental oral surgery medicine (*f:*3), dermatology (*f:*1), general internal medicine (*f:*1), and health care sciences services (*f:*1). The year that the associated investigations were conducted vigorously was 2022 (*f:*7). This review of the literature indicates that health researchers will enhance their interest in the metaverse in the literature in recent years.

312 documents were discovered on Scopus. On Scopus, 13 different papers (medicine:7, health professions:3, dentistry:2, nursing:1) have been reached. The documents are listed in the following order; computer science (*f:*201), engineering (*f:*78), social sciences (*f:*67), mathematics (*f:*37), arts and humanities (*f:*35), business, management and accounting (*f:*32), decision sciences (*f:*18), physics and astronomy (*f:*16), psychology (*f:*14), materials science (*f:*13), economics, econometrics and finance (*f:*11), environmental science (*f:*8), medicine (*f:*7), chemistry (*f:*6), energy (*f:*5), biochemistry, genetics and molecular biology (*f:*4), chemical engineering (*f:*4), neuroscience (*f:*4), earth and planetary sciences (*f:*3), health professions (*f:*3), dentistry (*f:*2), agricultural and biological sciences (*f:*1), multidisciplinary (*f:*1), nursing (*f:*1), veterinary (*f:*1).

The materials retrieved from both bibliometric data sources were largely in the form of letters, proceedings, and editor notes rather than articles. The number of papers in the field of health on the metaverse is 13 on Scopus and 10 on Web of Science. Furthermore, six studies retrieved from Web of Science were indexed by Scopus. As a result, the total number of articles found in the two databases is 17. However, more exams revealed that a thorough investigation was conducted on technologies that are stakeholders in metaverse technology. In recent years, this scenario has just lately begun to establish identification with the metaverse term and grouped under an umbrella with engagement via social media or network.

B. Evaluation of Publications Obtained on Web of Science

Ifdil et al. [19] stated in their study that the metaverse has become a popular topic of conversation, that mental health professionals can take advantage of the opportunities on it, and that virtual reality in the metaverse for future mental health assistance professions can be an alternative solution to the COVID-19 pandemic's mental health challenges.

Using the bibliometric technique, Liu et al. [30] examined the methods and outcomes of treatments for post-traumatic stress disorder, anxiety and fear-associated disorder, nervous system disorders and related medical problems, which are the four primary study fields of VR-assisted therapy. He underlines the health care potential of VR, highlighting its advantages of customization, compatibility, affordability, accessibility, incentive, and ease. He also notes that VR-assisted therapy is useful for a range of medical disorders. These benefits enable the incorporation of VR technology into a number of therapies and assist conventional therapies in overcoming the constraints of physical variables that are significant in the context of the present coronavirus disease 2019 (COVID-19) epidemic. In addition, they asserted that the capabilities of VR will facilitate the realization of the Health 4.0 goal and even the exciting future Health Metaverse vision.

According to Locurcio [31], a feeling of presence (the student's perception of being there) has traditionally been seen as crucial for successful learning and proper patient care. In view of the recent two years of mandated social isolation, he suggested that possibly the 'old' telemedicine experience might be upgraded to be more immersive. Additionally, he stated in his research that dentistry education in the metaverse is an extension of the internet that enables people to communicate with one another and their surroundings. They observed that this engagement is also possible through the use of various technologies, such as virtual reality (VR) and augmented reality (AR). He emphasized that despite the fact that these situations may appear remote from our regular educational activities or exclusive to research facilities, they are a reality for solving complex scientific issues.

In his research of dentistry in the metaverse, Kurian et al. [24] predicted that dentistry will play a larger role in medical health applications inside the metaverse technology in the near future. Soon, we may have dental telehealth chats in a virtual metaverse where avatars provide patients with dental guidance. With x-ray or three-dimensional photographs of the canal morphology, we can even observe in your live view that you have performed a root canal, implant placement, and the exact position of the implant and bone during surgery. Kurian et al. [25] stated that greater accessibility is one of the most significant benefits of metaverse technology and that it can provide convenience in accessing dental health for people with limited means, with the added benefit of participating in sessions from anywhere in the world without incurring travel expenses. It also gives an advantage for upgrading teaching models, since several dental education situations may be created.

While Google Earth carried the mirror world function, Second Life assumed the virtual world function. The researchers assessed the viability of a useful project, such as managing emergencies and disasters in real time with Second Life and Google Earth and developing emergency/public health virtual situation rooms. It enables users to perceive, interact with, and even traverse the created world utilizing the implemented applications. The strategy of connecting the three-dimensional environment and the virtual world in such platforms would pique the interest of many applications in the near future [8], particularly in light of Mark Zuckerberg's declaration and the renaming of his firm to meta.

According to Boulos et al. [9], the joy of living in a three-dimensional virtual environment is identical to the pleasure of living in the actual world. Additionally, they claimed that in this virtual environment, two people/avatars may readily identify and value one another's presence. They indicated that they can gain insight into the capabilities of others. Researchers analyzed ways to create Web GIS applications for infectious disease surveillance using period-appropriate technology.

Hassouneh and Brengman's [16] study found that social virtual world users spend millions of dollars on virtual goods and services, yet there are significant security, safety, and privacy issues. Using metaverse technology, Lee & Kwon [29] was experimentally evaluated on alpha generation users who test and purchase cosmetics face-to-face in the cosmetics sector. The objective is to leverage the metaverse as a significant marketing tool by understanding the changing demands of customers in huge markets, such as the cosmetics sector.

C. Evaluation of Publications Obtained on Scopus

In his study, Koo [23] explains that the coronavirus pandemic has made it difficult to provide medical education across international borders, and in particular, it has become nearly impossible to observe surgeries in order to observe and learn about high-tech medical equipment from other countries. In Korea's smart operating room at Seoul National University Bunag Hospital, they conducted an educational practice research in lung cancer surgery utilizing the metaverse and augmented reality. In their study, they described a metaverse training session held in Korea and discussed the potential future applications of this technology in the medical industry. Combining AR and VR, this training session is an example of XR implementation. Due of Covid-19, they added, students have less opportunities to work directly with patients, and it is difficult to provide appropriate surgical instruction using existing video conferencing tools such as Zoom.

In their study, Kim [22] found that such a high level of interest in a technology that has not yet been deployed is an extremely rare and singular occurrence. It is believed that the fast growth of information technology over the past several decades has convinced society that the metaverse could be established quickly. Virtual reality (VR), augmented reality (AR), spatial network, and immutable token (NFT) are among the metaverse's fundamental principles. With the use of special wearable equipment, Metaverse aims to create a virtual three-dimensional realm that resembles the actual world in appearance and feel, and to allow several individuals to interact in this space.

In his study, Huh [18] analyzed the use of computer-based testing in the Korean Medical Licensing Examination on the metaverse. According to them, the popularity of augmented reality, lifelogging, mirror world, and virtual reality has grown dramatically in recent years.

In their study to explain the possibilities and limits of the metaverse for educational applications, Kye et al. [28] classified metadata as augmented reality, lifelogging, mirror

world, and virtual reality. Virtual reality is the most active and widely utilized technology in metaverse type education among the four related types. The most recent phase of non-face-to-face communication has been marked by the regular use of virtual reality, which may be accessed regardless of location or distance. In addition, he argued that the metaverse is a new sector of social communication with limitless possibilities.

For contemporary subjects such as metaverse systems, virtual reality, and contactless systems, it is crucial to comprehend head movement. In their study, Ionut-Cristian and Dan-Marius [20] give a review of the technical literature on head motion monitoring systems based on inertial sensors published during the last decade. This paper provides a summary of available head motion tracking systems utilizing inertial sensors. The related literature has applications in various fields, including medicine, entertainment, health monitoring, and sports education, for the recognition and classification of human activity, which occupies an important place in the metaverse, as well as the determination of head movement and activities via wearable devices.

The healthcare industry is already utilizing augmented reality (AR) resources and has much to gain from this future technological development [10,51]. Werner et al. [53] reported that Metaverse has begun to be used in fetal medicine and gynecology, and that the study's objectives range from the ability to view an imaging array of two-dimensional cross-sections to a collaborative navigation within a three-dimensional organ by training experts from different fields in multidisciplinary discussions that occur in real time and across geographic boundaries. They indicated that they intend to include variable features.

According to Werner et al. [53], metaverse has tremendous potential as a digital tool to assist students in enhancing their collaboration with multidisciplinary teams and comprehension of difficult prenatal abnormalities and gynecological diseases. Therefore, it has a useful application as a teaching aid.

Liao and Kang [57] stated that, smart care has been a trend in care facilities and households in recent years, and ambient assisted living (AAL) has been a subject of rising scholarly attention in the last decade, paralleling societal aging and the proliferation of internet and mobile technology. They also noted that at the extreme of AAL is "above science", a situation in which human functions are heavily superseded by scientific technologies, which not only jeopardizes the health of older people, but also exacerbates the progression of dysfunctions by ignoring their desire for self-esteem and autonomy. As a result, the goal of AAL should be to develop a web ecosystem rather than a linearly clustered mix of computerized instruments.

VIII. Strengths And Limitations

Korean studies were met often throughout the study. The appraisal of these conversations in the literature is insufficient at this time owing to translation issues. In addition, when the document type of the research was reviewed, it was discovered that there was an abundance of letters and editorials. These materials are of a generic nature and do not contain exhaustive information about the evolution of the subject or a particular advancement in the area. Although this circumstance makes the search for the field appear vigorous, the quality of the resulting documents is unclear. This might be due to the issue being current.

IX. Discussion, Conclusion And Recommendations

In the study, field researchers were supplied with information regarding metaverse studies in the health sector and general trends in the literature. According to the study fields, the received papers were correlated with the field of health, and only the health-related research was evaluated. Virtual reality or augmented reality apps have characterized themselves as augmented reality inside the metaverse. These applications are prominent in the health care industry and in procedures that are difficult and crucial to implement via trial and error. In addition to the tremendous advances in many related technologies (blockchain, computer vision, haptic devices, sensors, computer networks) in recent years, the mechanical resolution of the sense of touch awarded the Nobel Peace Prize in Physics in 2021 is one of the most significant milestones for the field. Many real-world applications will be able to be transferred to the metaverse environment in the future, based on prior experiences and the field's evolution. It is believed that this breakthrough, which was awarded the Nobel Prize, would boost the perception of reality in the metaverse universe and the level of reality perception recorded by haptic technologies in particular. Health might also be considered one of the industries that will be most significantly impacted by this connection.

The constantly expanding need for health employees, along with the quick opening of new departments and programs to fulfill this demand, necessitates the improvement of the skills and capabilities of newly graduated health professionals. The infrastructure and opportunity afforded by Metaverse technology give significant prospects for enhancing the education of health care workers. Specifically, augmented reality technology has evolved as a vital utility, serving as the metaverse's equivalent of virtual reality and augmented reality technology. The majority of the results from the examination of Scopus and Web of Science databases point in this direction. It has been found that metaverse investigations are typically focused in the health literature alongside augmented reality or virtual reality research, or as simulation-based studies. This condition is supported by Damar and Turhan Damar's [14] evaluation of augmented reality and virtual reality studies in nursing, which is one of the most significant fields in the health industry. According to them, there are several researches on patient and student education, particularly in the field of nursing. The ultimate objective of these research is to give students with instructional information that enhances their learning processes as frequently as required by their field of study. In addition, technology contributes significantly to the acquisition of expertise and competence. This contribution is accomplished via monitoring their behaviors and identifying potential process faults.

According to Yilmaz et al. [55], intense usage of metaverse apps can lead to a variety of unfavorable consequences, including virtual addiction, social isolation, behavioral problems, and increased worry and stress. In his study, Kuş [26] asserts that although metaverse technology offers various solutions and opportunities in the fields of education, cultural production, the economy, and collaboration, it also carries with it a number of concerns and potential threats, similar to those posed by previously

developed technologies. He identified these risks as the quickly advancing technology, profit-driven technical efforts, humanity's failure to adapt to these advancements, and the testability and quality of material in the virtual and social worlds.

Despite the fact that metaverse technology provides security in terms of the technologies it contains (such as edge computing and blockchain), security in the virtual economy, and confidence in the safe storage and presentation of data, it is believed that it will always contain such insecurities due to its commercial nature. In addition, this notion has been more popular [34-35] after the advent of Facebook's creator, Mark Zuckerberg [13]. However, Facebook's record is troublesome owing of the issues it has already produced for its users [15,39]. The focus of the study is on the realm of health and metaverse technologies. Consequently, there is little doubt that the quality-sensitive nature of data protection in this field is considerably greater. For healthcare organizations, private/proprietary blockchains, which require authorization to join the network, are preferable than public blockchains, according to Mamun [33].

In their work, Hawks and Krasniansky [17] emphasized their excitement about the metaverse's potential to minimize the load on patients' actual lives by expanding access to therapeutic settings and modelling probability prior to care choices. They were particularly interested in how these solutions might strengthen linkages within virtual communities, reduce obstacles to social isolation for the elderly and disabled, and facilitate participation in research.

According to Bickmore et al. [6], there are several reasons for adding emotional and relational communication behaviors in health-oriented computer systems, each of which is discussed in turn. As with human-human interactions, these communication behaviors are essential for enhancing patient satisfaction and health outcomes. Second, the growth of patient-centered technology presents previously unimaginable prospects for healthcare. Systems that can carefully listen to patients, instill confidence and provide knowledge, negotiate daily treatment regimens, and are accessible from home can be built. In addition, it is possible to design systems that can track a patient's hospitalization and provide access to both the practical and emotional parts of human care. Education and communication research can utilize technologies that accurately replicate the communication behavior of healthcare practitioners in certain regions.

Although metaverse technologies are not yet mainstream in the field of digital health, there are signs of early investment and innovation. For instance, in the United States, eleven digital health programs incorporating VR or AR technology have been allocated $198 million. This is about 1 percent of overall health expenses. In 2020, 93 million dollars will be provided to this region through eight agreements [17]. Digital healthcare of numerous applications and environments in the industry (Embodied Labs, Giblib, Health Scholars, Osso VR, Augmedics, Thirdeye, Vicarious Surgical, Applied VR, Behavr, Floreo, Luminopia, Oxfordvr, Tripp, Xrhealth, Siemens Healthineers, Virtonomy.Io) can be viewed as solid evidence that the field will become much more prevalent in the future.

Metaverse technology is seen as crucial and helpful, particularly in studies where student repetition is difficult but where accurate student interaction is vital in a probable situation. According to Zheng et al. [56], their work in the realm of virtual reality falls into two broad categories. First, research to develop certain vocations or passions, such as virtual product design and surgical simulation. Second, attempts to create and improve the technology itself, such as haptic feedback devices, take the shape of high-quality, pleasant screens and quick, precise three-dimensional viewers.

Due to its superior three-dimensional imagery, virtual reality systems are ideal for medical imaging, training, and pre-operative planning. Virtual reality technologies are suited for clinical application in instances when physicians do not need to see the patient or his environment directly since users' eyes are entirely covered [2]. It will have several educational applications in nursing and other health-related fields. Kyaw et al. [27] describe virtual reality as a technology that enables the user to explore and alter computer-generated real or artificial three-dimensional multimedia sensory environments in real time in order to get clinically applicable information.

In their study, Riva [43] noted that there is a great deal of research on virtual reality or augmented health in the field of health, and that there has been a steady increase in the use of virtual reality in health services as information technology has improved and costs have decreased over the past ten years. Nonetheless, important clinical databases Medline and Psycinfo indicate that research in the field of virtual reality is growing quickly.

Mozumder et al. [37] proposed metaverse technology in their work for smart healthcare facilities. It can be suggested that countries such as Turkey, which make important infrastructure investments in the field of health, should give more importance to smart healthcare facilities in the health sector and take initiatives in order to benefit more from the possibilities of metaverse technology.

Yilmaz et al. (2022) claimed that the application of technologies intended for use in the metaverse may demand a high degree of specialized training and that the development of these technologies in the field of health requires a thorough health personnel training. The addition of metaverse technology lectures to the curricula of professions that teach health professionals, such as nursing, medicine, midwifery, and dentistry, is another option. Many courses, such as extended reality, health application areas, and virtual reality application development, can be added to the curriculum. This will assist the adaptation of health professionals to new technologies, which have the potential to hit the market quickly.

REFERENCES

[1] Ağırman, E., & Barakalı, O. C. (2022). Finans ve Finansal Hizmetlerin Geleceği: Metaverse. Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi, 9(2), 329-346.

[2] Andrews, C., Southworth, M. K., Silva, J. N., & Silva, J. R. (2019). Extended reality in medical practice. Current Treatment Options in Cardiovascular Medicine, 21(4), 1-12.

[3] Balkan, T., Konukseven, E.İ., Koku, A.B., Başer, Ö.,& Bideci, S. (2008). "Haptic" Dokunma Hisli ve Kuvvet Geri Beslemeli Arayüz Sistem Tasarımı. Accessed Date: 16/06/2022. https://open.metu.edu.tr/bitstream/handle/11511/49641/T0RJM09EZz0.pdf

[4] Ball, M. (2021). Framework for the Metaverse. Accessed Date: 18/06/2022. https://www.matthewball.vc/all/forwardtothemetaverseprimer

[5] Bickmore, T. W., & Picard, R. W. (2005). Establishing and maintaining long-term human-computer relationships. ACM Transactions on Computer-Human Interaction (TOCHI), 12(2), 293-327.

[6] Bickmore, T., Gruber, A., & Picard, R. (2005). Establishing the computer–patient working alliance in automated health behavior change interventions. Patient education and counseling, 59(1), 21-30.

[7] Bickmore, T., Vardoulakis, L., Jack, B., & Paasche-Orlow, M. (2013). Automated promotion of technology acceptance by clinicians using relational agents. In International Workshop on Intelligent Virtual Agents (pp. 68-78). Springer, Berlin, Heidelberg.

[8] Boulos, M. N. K., & Burden, D. (2007). Web GIS in practice V: 3-D interactive and real-time mapping in Second Life. International Journal of Health Geographics, 6(51),1-16. https://doi.org/10.1186/1476-072X-6-51

[9] Boulos, M. N. K., Scotch, M., Cheung, K. H., & Burden, D. (2008). Web GIS in practice VI: a demo playlist of geo-mashups for public health neogeographers. International Journal of Health Geographics, 7(38), 1-16. https://doi.org/10.1186/1476-072X-7-38

[10] Castro, P. T., Júnior, E. A., Lopes, J., Ribeiro, G., & Werner, H. (2022). Placenta accreta: Virtual reality from 3D images of magnetic resonance imaging. Journal of clinical ultrasound: JCU, 50(1), 119-120. https://doi.org/10.1002/jcu.23098

[11] CGTN, (2021). 2 scientists awarded 2021 Nobel Prize in Physiology or Medicine. Accessed Date: 16/06/2022. https://news.cgtn.com/news/2021-10-04/Two-scientists-awarded-2021-Nobel-Prize-in-Physiology-or-Medicine-145iMc7OQjS/index.html

[12] Clegg, N. (2021). Investing in European Talent to Help Build the Metaverse. Access date: 08/11/2021, https://about.fb.com/news/2021/10/creatingjobs-europe-metaverse/

[13] Damar, M. (2021). Metaverse Shape of Your Life for Future: A bibliometric snapshot. Journal of Metaverse, 1(1), 1-8.

[14] Damar, M., & Turhan Damar, H. (2021). Artırılmış Gerçeklik, Sanal Gerçeklik ve Metaverse: Hemşirelik Disiplini İçin Önemi Ve Geleceği. Varışoğlu, Y. & Vural P.I. (Ed.). Sağlık & Bilim: Hemşirelik-3. İstanbul: Efe Akademi Yayınevi.

[15] Esteve, A. (2017). The business of personal data: Google, Facebook, and privacy issues in the EU and the USA. International Data Privacy Law, 7(1), 36-47.

[16] Hassouneh, D.,& Brengman, M.(2015). Metaverse Retailing: Are SVW Users Ready to Buy Real Products from Virtual World Stores?. In 12th International IADIS Conference on e-Commerce and Digital Marketing (EC 2015), pp. 104-110.

[17] Hawks, C. & Krasniansky, A. (2022). Digital health enters the metaverse. Accessed Date: 13.06.2022. https://rockhealth.com/insights/digital-health-enters-the-metaverse/

[18] Huh, S. (2022). Application of computer-based testing in the Korean Medical Licensing Examination, the emergence of the metaverse in medical education, journal metrics and statistics, and appreciation to reviewers and volunteers. Journal of Educational Evaluation for Health Professions, 19(2),1-6. https://doi.org/10.3352/jeehp.2022.19.2

[19] Ifdil, I., Situmorang, D. D. B., Firman, F., Zola, N., Rangka, I. B., & Fadli, R. P. (2022). Virtual reality in Metaverse for future mental health-helping profession: an alternative solution to the mental health challenges of the COVID-19 pandemic. Journal of Public Health, 2022; fdac049, 1-2. https://doi.org/10.1093/pubmed/fdac049

[20] Ionut-Cristian, S., & Dan-Marius, D. (2021). Using Inertial Sensors to Determine Head Motion—A Review. Journal of Imaging, 7(265), 1-20. https://doi.org/10.3390/jimaging7120265

[21] Jeon, J. H. (2021). A study on education utilizing metaverse for effective communication in a convergence subject. International Journal of Internet, Broadcasting and Communication, 13(4), 129-134.

[22] Kim, K. (2022). Metaverse in journal publishing. Science Editing, 9(1),1-2. https://doi.org/10.6087/kcse.256

[23] Koo, H. (2021). Training in lung cancer surgery through the metaverse, including extended reality, in the smart operating room of Seoul National University Bundang Hospital, Korea. Journal of educational evaluation for health professions, 18(33), 1-4. https://dx.doi.org/10.3352%2Fjeehp.2021.18.33

[24] Kurian, N., Cherian, J. M., & Varghese, K. G. (2022). Dentistry in the metaverse. British Dental Journal, 232(4), 191-191. https://doi.org/10.1038/s41415-022-4003-6

[25] Kurian, N., Sabu, A. M., Subramanium, A., & Isaac, T. K. (2021). Smart glasses. British dental journal, 231(9), 532-532.

[26] Kuş, O. (2021). Metaverse: 'Dijital büyük patlamada'fırsatlar ve endişelere yönelik algılar. Intermedia International E-journal, 8(15), 245-266.

[27] Kyaw, B. M., Saxena, N., Posadzki, P., Vseteckova, J., Nikolaou, C. K., George, P. P., ... & Car, L. T. (2019). Virtual reality for health professions education: systematic review and meta-analysis by the digital health education collaboration. Journal of Medical Internet Research, 21(1), e12959,1-13.

[28] Kye, B., Han, N., Kim, E., Park, Y., & Jo, S. (2021). Educational applications of metaverse: possibilities and limitations. Journal of Educational Evaluation for Health Professions, 18(32), 1-13. https://doi.org/10.3352/jeehp.2021.18.32

[29] Lee, J., & Kwon, K. H. (2022). The Future Value and Direction of Cosmetics in the Era of Metaverse. Journal of Cosmetic Dermatology, 2022,00, 1-8. https://doi.org/10.1111/jocd.14794

[30] Liu, Z., Ren, L., Xiao, C., Zhang, K., & Demian, P. (2022). Virtual Reality Aided Therapy towards Health 4.0: A Two-Decade Bibliometric Analysis. International Journal of Environmental Research and Public Health, 19(1525),1-26. https://doi.org/10.3390/ijerph19031525

[31] Locurcio, L. L. (2022). Dental education in the metaverse. British Dental Journal, 232(4), 191-191. https://doi.org/10.1038/s41415-022-3990-7

[32] Logeswaran, A., Munsch, C., Chong, Y. J., Ralph, N., & McCrossnan, J. (2021). The role of extended reality technology in healthcare education: Towards a learner-centred approach. Future healthcare journal, 8(1), e79-e84.

[33] Mamun, Q. (2022). Blockchain technology in the future of healthcare. Smart Health, 23, 100223.

[34] Meta, (2021). Introducing Meta: A Social Technology Company. Accessed Date: 18/06/2022. https://about.fb.com/news/2021/10/facebook-company-is-now-meta/

[35] Milmo, D. (2021). Enter the metaverse: the digital future Mark Zuckerberg is steering us toward. Accessed Date: 18/06/2022. https://www.theguardian.com/technology/2021/oct/28/facebook-mark-zuckerberg-meta-metaverse

[36] Mintable Editorial, (2022). 7 Metaverse Platforms You Can Join Right Now. Accessed Date: 13.06.2022. https://editorial.mintable.app/2021/12/12/5-metaverse-platforms-you-can-join-right-now/

[37] Mozumder, M. A. I., Sheeraz, M. M., Athar, A., Aich, S., & Kim, H. C. (2022). Overview: technology roadmap of the future trend of metaverse based on IoT, blockchain, AI technique, and medical domain metaverse activity. In 2022 24th International Conference on Advanced Communication Technology (ICACT) (pp. 256-261). IEEE.

[38] Nobel Prizes, (2014). The Nobel Prize in Physics 2014. Accessed Date: 16/06/2022. https://www.nobelprize.org/prizes/physics/2014/press-release/

[39] Nyoni, P., & Velempini, M. (2018). Privacy and user awareness on Facebook. South African Journal of Science, 114(5-6), 1-5.

[40] Palaha, J. (2022). 11 Best Metaverse Platforms To Watch Out For in 2022. Accessed Date: 13.06.2022. https://www.jatinderpalaha.com/metaverse-platforms/

[41] Radoff, J. (2021). The Metaverse Value-Chain. Accessed Date: 18/06/2022. https://medium.com/building-the-metaverse/the-metaverse-value-chain-afcf9e09e3a7

[42] Remnani, M. (2022). Top three Metaverse platforms in 2022. And no, it doesn't include Facebook. Accessed Date: 13.06.2022. https://analyticsindiamag.com/top-three-metaverse-platforms-in-2022-and-no-it-doesnt-include-facebook/

[43] Riva, G. (2002). Virtual reality for health care: the status of research. Cyberpsychology & Behavior, 5(3), 219-225.

[44] Sandıkçı, M.B. (2022). Sportif Rekreasyonel Faaliyetler ile Sağlık Açısından Metaverse ve Sanal Gerçeklik Teknolojisi. Editör Aysel Kızılkaya Namlı, Abdullah Bingölbalı (pp.65-74). Beden Eğitimi ve Sport Araştırmaları. İstanbul: Efe Akademi.

[45] Son, H., Ross, A., Mendoza-Tirado, E., & Lee, L. J. (2022). Virtual Reality in Clinical Practice and Research: Viewpoint on Novel Applications for Nursing. JMIR nursing, 5(1), e34036. https://doi.org/10.2196/34036

[46] Soulmachines, (2022). Where Deep Science & Technology Meet Real World Applications. Accessed Date: 16/06/2022. https://www.soulmachines.com/

[47] Thomason, J. (2021). MetaHealth-How will the Metaverse Change Health Care?. Journal of Metaverse, 1(1), 13-16.

[48] Torre, G. (2022). Top 10 startups producing digital humans. Accessed Date: 16/06/2022. https://www.linkedin.com/feed/update/urn:li:activity:6942938024863244288/

[49] Türk, G. D., Bayrakcı, S., & Akçay, E. (2022). Metaverse ve Benlik Sunumu. Turkish Online Journal of Design Art and Communication, 12(2), 316-333.

[50] UNEEEQ, (2022). What are Digital Humans? Accessed Date: 16/06/2022. https://insights.digitalhumans.com/thank-you-for-downloading-this-ebook-uneeq?submissionGuid=bc2cf5b5-f1fe-4bcf-9535-9f00bae14ae7

[51] Uruthiralingam, U., & Rea, P.M. (2020). Augmented and Virtual Reality in Anatomical Education – A Systematic Review. In: Rea, P. (eds) Biomedical Visualisation. Advances in Experimental Medicine and Biology, vol 1235. Springer, Cham. https://doi.org/10.1007/978-3-030-37639-0_5

[52] Veda, (2022). Top 10 Metaverse Platforms That Will Replace Social Medıa In Future. Accessed Date: 13.06.2022. https://www.analyticsinsight.net/top-10-metaverse-platforms-that-will-replace-social-media-in-future/#:~:text=A%20metaverse%20platform%20is%20a,have%20helped%20accelerate%20its%20growth.

[53] Werner, H., Ribeiro, G., Arcoverde, V., Lopes, J., & Velho, L. (2022). The use of metaverse in fetal medicine and gynecology. European Journal of Radiology, 150, 110241-110241. https://doi.org/10.1016/j.ejrad.2022.110241

[54] XRToday, (2022). The Top Metaverse Platforms in 2022 to Watch. Accessed Date: 13.06.2022. https://www.xrtoday.com/virtual-reality/the-top-metaverse-platforms-in-2022-to-watch/

[55] Yılmaz, F., Mete, A. H., Türkön, B. F., & İnce, Ö.(2022). Sağlık Hizmetlerinin Geleceğinde Metaverse Ekosistemi ve Teknolojileri: Uygulamalar, Fırsatlar ve Zorluklar. Eurasian Journal of Health Technology Assessment, 6(1), 1-22.

[56] Zheng, J. M., Chan, K. W., & Gibson, I. (1998). Virtual reality. IEEE Potentials, 17(2), 20-23.

[57] Liao, P. H., & Kang, S. C. J. (2022). The Mindset and Realization of Precision Care Provided by the Science of Ambient-Assisted Living. Hu Li Za Zhi, 69(2), 19-24. doi: 10.6224/JN.202204_69(2).04.

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Entrepreneurship in The World of Metaverse: Virtual or Real?

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***Abstract*— In this study, an in-depth literature review method was applied. Period; It examines academic studies and current information on the internet and its interpretation of entrepreneurship in the metaverse world. For those who want to be entrepreneurs in the world of Metaverse, business opportunities, conveniences and difficulties of Metaverse are evaluated. The concepts of virtual reality and virtual world, which are the leading steps of the rapidly developing digital age, are gaining importance. The metaverse world, which leads them and breaks new ground in the virtual world, is a universe in which it is predicted that investors will make large investments in terms of technology and economy. For this purpose, the researcher examined studies in the metaverse literature, and as a result of these studies, the subject of entrepreneurship in the metaverse world was discussed. In the metaverse world, the study results on entrepreneurship are seen as an opportunity to be seized economically. Those who will participate in the upcoming metaverse shift will seize this great opportunity. Another finding is that taking place in the metaverse world is not suitable for the time being in terms of costs. To avoid being affected by increasing costs, it is recommended that entrepreneurial individuals first determine a good idea and make a good feasibility study on how to realise this idea in the virtual world. This article is an original study that addresses the benefits, conveniences and challenges of being an entrepreneur in the Metaverse world. The literature review found no investigation on entrepreneurship in the Metaverse world. The fact that the Metaverse has the potential to have great effects on the business world and social life standards in the future makes this research more interesting. In addition, by specifying the impact of Metaverse on the business world, it has been tried to shed light on the problems and opportunities that large or small-scale enterprises and entrepreneurs will face in the future.**

Keywords*— *Entrepreneurship, metaverse, NFT, virtual world, VR/AR.

I. INTRODUCTION

Since the limits of innovative entrepreneurship are being pushed in today's world, young people who will produce software and hardware that make life easier need to focus on the little-known facts of the new world and be prepared, the metaverse, also known as the "virtual universe," which is considered as the next stage in the development of the internet, is the name of the perceptual universe in which people feel entirely mentally thanks to augmented virtual reality devices without any physical effort. This universe enables humans to be included in an artificial physical environment thanks to computers, Android devices, and 3D devices. Many people and organizations worldwide are rapidly entering the metaverse process, including foresight about the future. In this virtual universe, which is very popular for entrepreneurs, everyone should have an avatar. We will be able to attend our Metaverse World meetings by dressing in the clothes we choose with our avatar, voice, and facial expressions. We will be able to travel the world from here and realize many things from our shopping to our investments. For example, wherever he is in the world, he will be able to use this virtual universe when he wants to wander or shop somewhere.

Developed countries and world brands have been working in informatics since the second half of the 1990s, attracting the attention of young people to this field with the guidance and infrastructure of the public. Opportunities await young people in the 'metaverse' world in virtual reality (VR), augmented reality (AR), artificial intelligence, blockchain, 5G, wearable technologies, and sensor technologies. Augmented reality was developed to perform more accurate and necessary improvement activities on three-dimensional structures and provide essential opportunities to the business world and consumers; It is the design of all objects in the real world with computer-generated sound, image, and graphic data and provides a physical appearance. In short, it is the creation of reality by computer [1]. On the other hand, virtual reality is an immersive environment experienced through computers, where users have real-time and multi-sensory interactions. Thanks to these technologies, businesses can easily access the real-world data they need [2].

The Covid-19 pandemic has caused some sectors to enter the metaverse world quickly. Especially fields such as medical, recycling systems, online systems, energy efficiency, green energy, robots, and drone technologies are very attractive for young entrepreneurs. The Metaverse world provides today's easy access to missed opportunities in the past. For example, a young person in Silicon Valley and a young person in Turkey interested in this world can work on the same system. Turkey, which has a young population, needs to act quickly with its institutions by using this advantage. It should not miss opportunities by preparing for the transition to Web 3.0. In this study, the world of the metaverse, entrepreneurship in the world of the metaverse, possible conveniences [3], [4], and difficulties [5]–[7] that may arise in the world of the metaverse were examined within the scope of the relevant literature. In the study, recommendations were made to entrepreneurs and entrepreneurial candidates by making predictions of the metaverse world.

A. What is Metaverse?

The word metaverse is derived from meta and universe [8]. The Metaverse is a collective virtual shared space created by the convergence of virtually augmented

physical reality and physically persistent virtual space, including the sum of all virtual worlds, augmented reality, and the internet [9]. "Metaverse" was first coined by science fiction writer Neal Stephenson in his 1992 novel "Snow Crash." The “Snow Crash” metaverse is a hugely popular virtual world experienced by users equipped with augmented reality technology [10], [11]. The realistic virtual world is a virtual space where digital avatars represent people. The virtual world constantly grows and evolves depending on the decisions and actions of society. People will be able to enter the metaverse entirely virtually or interact with parts of it in their physical space with the help of augmented and mixed reality. Metaverse is used to create a virtual digital world and connect this world with the physical world [7]. Mark Zuckerberg announced that Facebook would change its name to Meta in October 2021 and make significant investments in the metaverse [12], [13].

Even if the Metaverse lags behind the fantastic visions captured by science fiction writers, it is likely to generate trillions of value as a new computing platform or content medium. Metaverse is becoming the gateway to most digital experiences, a vital component of all physical experiences, and the next great business platform. The value of being a participant in such a system will also be great. Today, there is no internet owner, but when the most valuable publicly traded companies in the world are looked at, it is seen that the leading internet companies are at the top. For this reason, the metaverse world has the potential to replace the internet and show a remarkable rise in economic terms [14]. The metaverse can produce more and more opportunities than appears on the internet. New companies, products, and services will emerge to manage payment processing, authentication, recruitment, advertising, content creation, and security. This means that many of today's employees will end their jobs or become new job opportunities [15].

Eight "building blocks" have symbiotic effects on the emergence and development of the Metaverse [16]. These are Hardware; Nothing can happen without hardware (physical technologies) that interacts with and enhances the Metaverse. Enterprise hardware is used to operate or build consumer mobile phones, tactile gloves, virtual/AR-based. Networking; bandwidth (speed), latency, and reliability are used as performance indicators. It depends on the quality of the service. Compute; Availability and development of computing power limits define the metadata store. It includes enabling and providing computing power to support the metadatabase while performing various and demanding functions such as physics computation, processing, data reconciliation and synchronization, artificial intelligence, projection, motion capture, and translation. Virtual platforms; users interact with the metadata store, have an interface through virtual platforms, and are accessed from various devices. It includes developing and studying immersive digital and often three-dimensional simulations, environments, and worlds in which users can explore, create, socialize, and participate in various experiences (playing games, education, shopping, listening to music, etc.). Interchange standards and tools include a broadly defined category of different technical solutions, protocols, formats, and services for partnership or interoperability. Payments: It is generally assumed that blockchain coins will be used for purchases in the metaverse world, but payment systems can also be realized in barter or NFT or cryptocurrencies. Content, services, and assets; Brands will be content providers in the metaverse world. This building block covers all businesses and services on the metaverse and independent content. Consumer and business behavior; It includes observable changes in consumer behavior and business attitudes that are directly related to changes in the metaverse. Figure 1 shows the relationship between these building blocks and four different avatars.

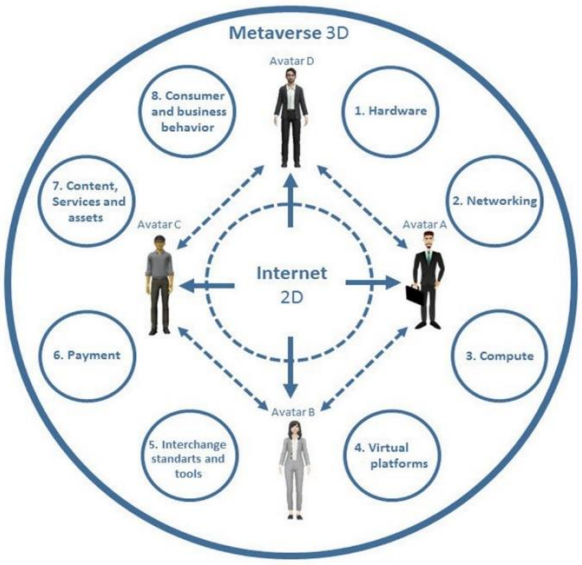

Fig. 1. Metaverse building blocks and acting avatars [17].

Metaverse requires a lot of new technologies, protocols, companies, innovations, and discoveries to work. These will emerge not directly as “pre-metaverse” and “post-metaverse” but gradually as they integrate and merge with different products, services, and capabilities over time. First of all, a few essential elements need to be fulfilled. Metaverse requires infrastructure that does not currently exist. Because the internet has not been prepared with the capacity to handle this experience, it only has the necessary infrastructure for receiving and sending files [18]. Metaverse requires more than what video conferencing and video games offer and a high concurrency infrastructure [19], [20]. Most video chat programs allow up to a few dozen people to talk to each other. If a situation reaches hundreds of people, a live broadcast image of a few people can be delivered to the audience instead of two-way sharing [21]. There are many obstacles on the way to the Metaverse. The biggest hurdles are also hardware limitations. Currently, worldwide networking and computing capabilities will not yet be able to support an enduring digital world that can be experienced in real-time by millions of concurrent users. Even with this level of networking and computing power available, the energy consumption of such an effort would pose problems for both national electricity grids and the environment [22]. If hardware, energy, and technology are sufficient, broad cultural changes will be necessary to foster the development of a true metaverse. Relatively high-quality virtual reality and augmented reality technologies are already available to consumers, but according to the 2020 report by Thrive Analytics and

ARtillery Intelligence, Less than 20% of Americans are familiar with VR headsets. Also, experts predict that devices like VR and AR have a chance to surpass game consoles by 2025 at the earliest [23].

To summarize, Metaverse is a new reality universe and dimension where virtual and real can be experienced simultaneously, formed as a result of combining all virtual worlds and content on the internet, using augmented reality (AR), virtual reality (virtual reality) VR and blockchain technologies. Without sharp distinctions such as virtual and real in the metaverse, users can access all content and experiences in the metaverse and from anywhere, either in augmented reality (AR) or virtual reality (VR) mode. Since the virtual and real worlds are so intertwined, users exist simultaneously in both environments with the help of their digital avatars, and their actions on both sides affect each other in real-time [24].

B. Metaverse Economy Projects

In the metaverse world, companies will emerge that produce new products and services to manage the new content landscape, computing platform, authentication, recruitment, advertising, security, digital identity and presence, and similar issues. The most important opportunity is commerce, finance, fintech, creativity, virtual environment, different groups, environments, communities, etc. In the metaverse, a single safe environment where the parties that focus on goods or services will work together with a single idea, it is possible to bring reality and clarity to the idea formed. In addition, the proliferation of metaverse and metaverse coins will enable the cryptocurrencies used within their groups to be used as a payment or investment tool between different groups or to pay the fees in the new virtual universe formed with these cryptocurrencies [23]. Blockchain technology, decentralization, and the development and rise of new industries within the metaverse can effectively drive economic growth [25]. Companies need to transform their marketing strategies from buying ads online to existing in a shared, virtual economy. Companies must conduct market research on their new customers in the metadatabase. How people act and their preferences in the metaverse can be different from how they behave in real life and what they shop for. While it is inevitable that there will be ads in the metaverse, brands can be a part of creating the metaverse itself [26].

Today, many world brands invest in the metaverse. For example, Facebook's acquisition of the Oculus company, which works on virtual reality devices, for 2 billion dollars has accelerated the process considerably. Facebook has signed cooperation agreements with essential software companies such as Microsoft in this field. In addition, game platforms such as Roblox continue to make significant R&D investments in this field [25]. This universe should not be considered an area of the game or coin industry. Currently available digital currencies will be used in the metaverse world, including NFTs, for the next period. The metaverse, in particular, is becoming a more attractive alternative world than ever for people to escape to during the Covid-19 global pandemic. The Metaverse will impact small, medium, or large businesses and potentially everyone. Meta is not alone in pouring millions of dollars into building this digital world. In December 2021, the Republican District of New York made a record-breaking $4.3 million investment in metaverse real estate through The Sandbox; Just a month before that record, Canadian Tokens.com spent $2.4 million on digital land on another metaverse platform, Decentraland [11].

C. Metaverse Education and Culture Projects

In recent years, the metaverse has received significant attention worldwide with the development of related technologies. For the Metaverse to be a realistic society with direct and physical interactions, The concepts of race, gender, and even physical disability need to be weakened. It is thought to be very beneficial for society [27]. However, Metaverse development is still in its infancy, with great potential for improvement [28]. Increasing virtual and participatory activities in cyberspace creates new social communication and interaction forms. In this scenario, the metaverse concept is vital to understand how the relationship between virtuality and cultural communication has changed and how this phenomenon plays a crucial role in virtual heritage. The metaverse can also be defined as a virtual place where a cyber community of individuals can share social interactions without the constraints of the physical world [29].

It is thought that people will not wander in the Metaverse one by one but will establish friendships and relationships that will affect their decisions. Brands need to continue to adapt to playstyles and interactions. Customers will be able to talk to brands and interact with them in 3D, like through social media [26]. Innovations in information technology have provided new opportunities for employee training beyond traditional seminars and discussions, such as using low-cost simulations that use virtual worlds as a platform for communication and interaction. At the current stage, virtual worlds and meta versions provide ideal learning environments for tackling a group problem such as culture and allow the creation of potentially complex comprehensive games. Let's take some essential components of organizational culture and compare them with the learning objectives of some traditional games. It is found that the ideal simulation required to solve the problem of culture in organizations consists of a mixture of processes and random events [30].

With augmented reality (AR) and virtual reality (VR) devices, interactive online ecosystems can be created for specific training courses, providing participants with the virtual challenges and tests necessary to pass this training successfully. Most importantly, this training can be applied to any industry, such as virtual customers or patients, where AI avatar bots are used as part of an immersive and engaging learning experience. Different 3D ecosystems can be created to specifically meet the needs of businesses [24]. Using these 3D event platforms, companies can host and attend meetings, create breakout spaces, hold team-building sessions, participate in corporate partnership calls, and even create and promote webinars. Metaverse can host or connect to any web content, images, videos, and PDFs and have domains that connect in the same way that web pages are linked. Within the metaverse, the avatar serves as a personal staff member in a world where interaction with others is possible. The ergonomics of the environment reflect the office or space

where the event takes place or usually takes place. In short, Metaverse can work with or transform reality and everyday work practices [23]. Opportunities to work with simulated experiments without affecting the results of harmful reality experiments in education will increase the quality of education. In addition, the realism in the simulation environment will make the subjects easier to grasp and understand.

D. Metaverse Shopping Projects

There has been a significant transformation in almost all industrial sectors in recent years, especially in retail. The internet and smartphones have heavily influenced the retail industry. E-commerce sites are taking the place of physical stores, and now e-commerce is about to be gradually replaced by shopping via social networks. As the next step in this digitalization process, the metaverse offers businesses and consumers a future where individuals will live, work and shop in a virtual world. For example, it is planned to establish a metaverse store that is transformed into a 3-dimensional, virtual experience that reflects the physical world. A brand will have digitized products within this store that can be purchased by thousands of users worldwide. Users can shop with their avatars in this digital showcase and make their selections for home delivery. As a result, it is predicted that retail giants, regardless of the industry, will gradually transition towards the metaverse world in the next decade due to increased customer interaction and increased time spent on the relevant platform. This will increase the company's budget and resources devoted to entering their brands into the metaverse. Virtual fashion, avatars, and virtual real estate (housing, cars, etc.) will have their value in the metaverse. Companies will have to design brands for different people at different stages of the economic situation. People who invest in metadata may have their businesses and properties in the metaverse, so there may be opportunities to partner with companies that do not exist physically. Virtual fashion houses and designers will have the opportunity to enter an entirely new digital priority clothing market.

With Facebook changing its name to “Meta” and turning its vision to the development of metaverse projects, technology enthusiasts have started to explore this universe more. The same is true for crypto investors. After Facebook's announcement, local tokens of metaverse projects began to rise. Almost everyone is excited about this new concept, as it has been likened to the “future version of the Internet.” Huang Renxun, CEO of Nvidia, one of the most influential people in science and technology, recently made statements about the metaverse at the Computex Virtual conference and said that he believes we are at the peak of the super universe and that he cares about the potential of the metaverse, and even in his speech that the metaverse has come to “simulate the future." It is known that in 2021, the word NFT (Non-Fungible Token) has been heard by many people, and the NFT frenzy has surrounded the whole world. [31]. It has made a big splash in the art and crypto worlds, especially after an artist named Beeple's NFT “Everyday's: The First 500 Days”, the first fully digital artwork sold by Christie's, sold for $69.3 million in March. This sale places Beeple, real name Mike Winkelmann, among the three most valuable living artists.

NFT has confirmed that a digital asset is unique and cannot be identical to each other, not interchangeable. Data is collected and stored in a digital gallery called a blockchain. Games, photos, music, cartoons, etc. All works can be arranged as NFTs within the scope of digital art. Holders have a digitally tracked hash code that can be followed, sold, and purchased digitally. So all content in the field of art, all television shows, simple avatars, etc., all digital content can be sold and bought. It would not be right to reduce the relationship between Metaverse and NFT to just a digital art gallery. The metaverse universe will be so vast and impressive that you can be whatever you want. The main appeal of the metaverse lies in its immersive experiences in style because the projection of affairs in the metaverse would be of immense value. Metaverse is a social revolution and an innovative model for NFTs. So NFT and Metaverse integration would naturally be appropriate. Metaverse will provide an excellent platform for NFTs to showcase. In summary, NFT will be the core infrastructure of Metaverse, and Metaverse will be the most prominent implementer of NFT [32].

II. ENTREPRENEURSHIP

The term entrepreneur comes from the French word “entreprendre” [33], meaning “to undertake.” In the twentieth century, the entrepreneur began to be viewed as an innovator, and Schumpeter defined the entrepreneur; He described it as a reformist and revolutionary person who produces a new invention and a new good or produces an old one with a new method and creates new sources and outlets for products [34]. In another definition, an entrepreneur; is the person who innovates or develops, finds opportunities and transforms them into viable ideas, adds value to these ideas with effort, money, or skills over time takes the risks of the competitive market space to implement their ideas and turns their efforts into money [35], [36]. On the other hand, entrepreneurship is associated with the ability to have production factors, organization, and risk-taking characteristics to take advantage of the opportunities arising from environmental factors or produce economic goods or services to reveal new opportunities [37], [38]. In other words, it is a dynamically operated process for developing new products and building the future [39]. Entrepreneurship is a personality and motivation business and emerges in the cycle of achievement, risk-taking, and innovation. Entrepreneurs with high motivation for success make risky, innovative decisions in uncertain environments [40].

Today, the new generation entrepreneurship model is virtual entrepreneurship [41]. Virtual entrepreneurship, which has revolutionized businesses in the new world order, is a distinctive type of entrepreneurship as it develops new tools to facilitate the business processes of entrepreneurs [42]. Virtual entrepreneurship includes developing new digital technologies and creating new areas where these technologies can be used, starting new ventures, or digital transformation of existing businesses [43]. Some entrepreneurship can be realized with digital methods instead of traditional applications [44]. A virtual entrepreneur is a person who creates new business opportunities, can create new teams, has leadership characteristics, has a good understanding of software technology, can use digital tools well, wants to start his own business, produces creative ideas, and wants to sell

the service and product on the internet. There are three different types [45]. *Light virtual entrepreneurship*; Internet technology, and digital tools are perceived and applied as complementary to traditional methods. *Medium virtual entrepreneurship*; businesses allocate significant funding to digital mechanisms for core products, product delivery, or other value chain components. *Extreme virtual entrepreneurship*; All processes and processes, from the production process of products and services to their delivery to customers, are digital.

III. Entrepreneurship in the World of Metaverse

Virtual worlds represent a new market with a diverse economy, and entrepreneurs seeking profitable opportunities are trying to take advantage of this new technology. In the metaverse world, all the necessary conditions for entrepreneurship exist; A new technology that provides new sources of income, an entrepreneur willing to invest money to increase his wealth, and a market with a well-understood economy. Entrepreneurs need to define the strategy they adapt well to succeed in various markets [46]. As a result, venture creation in virtual worlds may be relatively simple but opens up new possibilities in the future.

Entrepreneurship ideas through the virtual world were initially featured on the cover page of Business Week on May 1, 2006, as “virtual world, real money, a journey to a place where thousands of people live imaginary lives in cyberspace, and some even get along well” [47]. The European Commission [48], has emphasized that entrepreneurship is important because it contributes to job creation, growth, and competitiveness and unlocks personal potential [49]. Therefore, the development of the idea of entrepreneurship in virtual worlds is becoming increasingly important [46]. This situation brings to mind the following question: Is entrepreneurship an virtual or a real in the metaverse world?

The mobility in the entrepreneurial world is experiencing a remarkable rise with the introduction of 'new universes' such as the metaverse. After 2021, it is already thought that 2022 will double the previous year. In addition to new entrepreneurs, platforms also work very effectively. The new era of entrepreneurship will take place in a new universe beyond the physical universe, in the metaverse, with both the entrepreneur and the investor hat. With NFTs, the game world has taken its development to the next level. The basis of the metaverse is somewhat based on this game world. Generation Z lives in this metaverse world thanks to games [50]. All of these combined to form a new world. It has created its ecosystem, almost like a parallel to the physical universe. Metaverse creates a significant opportunity for entrepreneurs. Considered based on companies, a digital transformation has been entered. Many brands have the potential to be new growth areas for many products in this world. When the Covid-19 pandemic process is added to all these, the importance has gained a reputation [51]. The pandemic has caused our jobs, schools, and other services to rely on the digital world to keep running, and nearly everything has gone online. We attended classes and business meetings online with software applications, and we could run our business from home. Our lives were able to continue with the existence of social media and the internet.

For this reason, it is thought that the future lives of companies that cannot take part in the digital transformation trend will be complicated. Planning and initiatives can be made in many areas in the metaverse, from an advertising agency to make events. It is predicted that every business and enterprise's metaverse version and model will emerge. The critical thing about entrepreneurship here is acting early and creating a vision.

Many firms have started buying metaverse real estate in the hope of using it to engage with a new digital audience in the future. One of the leading companies in this regard is Prager Metis International LLC. It is a New York City firm. The firm has offices on three continents and has decided to participate in the Decentraland metaverse platform. Prager Metis' new meta office is exciting and full of potential, but that doesn't mean it's free. The firm paid a pretty $35,000 fee for the three-story digital space. While not every investment is as big as Prager Metis's, it shows how significant assets can be made into the metaverse of severe businesses about the opportunity [3], [4].

A. Job Opportunities in Metaverse

On October 28, 2021, Meta hosted Connect 2021 from its internet video channel, describing the numerous possibilities of augmented and virtual reality. This video explains that different opportunities can be offered to all businesses, large or small, in about ten years [52]. As with the rapid changes in the digital age, the transition to the Metaverse world is approaching rapidly. Most users and investors have seen the economic return of the opportunities that emerged from desktop internet use to mobile internet. Information about the metaverse will be needed to capture the opportunities the metaverse world will bring. For this reason, individuals need to develop themselves and develop innovative thoughts to seize the upcoming opportunities by learning about the metaverse [13], [53].

1) Focusing on 2D Applications. Metaverse is the most significant opportunity for modern business since the advent of the internet. As the next evolution of digital platforms, it is thought to replace today's mobile internet. In the future, it is predicted that the primary way for people to experience the metaverse in the short term will be through 2D applications. It's crucial to focus on the skills you use today to help you grow the business with social media apps. During Connect, Meta highlights many potential use cases of how meta technologies will play a role in the Metaverse. There are several ways to imagine how 2D applications will lead to a more immersive experience in the future [54]: Commerce: With the rise of digital commerce, the metaverse opens up new opportunities for buyers and sellers to connect in a new way. For example, it becomes more immersive with the option to purchase physical or digital products from your store on Instagram. Entertainment: You could host a paid online event on Facebook today, but imagine if you could turn it into a mixed reality experience where people could attend in person or buy a ticket for the virtual experience. Two friends attending the concert held in Metaverse can enjoy the same concert. Thus, thanks to mixed reality, people are provided with a high level of interaction.

Metaverse allows you to visit other countries from your physical environment. The tourism industry benefits greatly from VR as it will enable people to explore any part of the world by wearing a headset. Before investing in expensive air and hotel packages, travellers can use the VR experience to decide whether visiting the destination is worth the planning and expense. Even people who have no intention of physically travelling the world can now participate in international virtual tours. Some people cannot travel due to health reasons or a limited entertainment budget. VR also provides useful experiences for people with disabilities who need to stay in a wheelchair. VR allows people with a heavy workload to travel. Virtual tourism helps eliminate monotonous patterns and gives a deeper perspective on geography and global issues. VR platforms include forms of entertainment such as virtual parks, galleries, museums and theatres. In recent years, the game industry has become even more popular with the closures at home during the pandemic. Metaverse makes gaming more innovative and challenging. Combining physical and digital objects, VR and augmented reality (AR) have become essential elements of modern gaming [55].

2) Enhance Physical World Experiences with Metaverse. In the Metaverse world, physical retail stores are modernised to be more digital. Over the past decade, thousands of retail stores in the United States have closed due to financial struggles. Shopping centres are partially closing due to the pandemic, and online shopping increases every year. VR is emerging as the solution to liven up retail stores as it provides technology that many consumers don't have at home. In addition, VR experiences speed up purchasing decisions as they can quickly answer many consumers' questions. One of the best ways to excite customers with virtual experiences is to develop a VR app that enhances the in-store experience. Interactive apps become reminders of local establishments and help build brand awareness. They're also useful for testing consumer acceptance of a product and can be the answer to the biggest small business challenge of increasing profits. Metaverse allows consumers to test products before purchasing. It will enable its customers to experience effects at real-site sales points using a headset with glasses that provides a 360-degree experience. This simulation will be able to give lots of details for the consumer to review. Every local marketing vendor should inform consumers about connecting products through VR engagement. "Try before you buy" strategy is proven to increase sales [56]. Traditionally, shoppers like to touch products before buying, using multi-sensory perception. In other words, people want to hold objects to feel the weight and texture. During the pandemic outbreak, shoppers were restricted from touching products and surfaces in retail stores. The solution to this problem has been virtual reality. Especially with the pandemic going on for the last year, we live in a hybrid world of online and offline [57]. From video calls to messaging, we need it more than ever. However, the metastore aims to simplify them with less friction and enhance their physical world experience. Current use cases of augmented reality, including Spark AR, are great examples of how metadata can meet the physical world. We've seen businesses use AR to allow customers to virtually drop furniture into their homes to see how it will fit or let people try on makeup or eyeglasses directly from their Facebook feed. Regardless of industry, there will be metaverse use cases for businesses trying to leverage mixed reality and physical world experiences.

Metaverse also has many health benefits. It provides medical professionals with powerful insights about patients. Doctors are among the first professionals to test VR technology. At first, hospitals were hesitant to invest in this complex equipment, which seemed like an intense learning curve. Still, over time, VR technology provides doctors with rich patient data that was impossible to collect in the last century. A more comprehensive view of human anatomy is now used to assist doctors in performing surgery and rehabilitating patients. Modern medical equipment encompassing VR can scan a patient's internal organs to give a surgeon more detailed views than traditional X-rays. Thanks to the increased visibility of biological processes, doctors can diagnose health problems much earlier with VR. Doctors wearing VR glasses now have "X-ray vision" that helps them navigate complex surgeries involving the spine or brain [58].

In Metaverse, architects and engineers can easily showcase their designs. Architects use VR to communicate building design options to clients. Combined VR and AR solutions provide expectations with more intuitive architectural visualisation than traditional plans. For example, this form of panoramic visualisation works well with displaying spiral staircases and other artistic geometric structures [59]. Virtual tours by architects and engineers show the structures from every angle. It gives consumers a strong feeling that they are in the field, opening the doors and looking through the windows. Engineers can use VR to view highway and bridge projects viewed from the air by drones.

Metaverse makes education more enjoyable. The best learning conditions are found in a positive interactive environment provided by virtual experiences. Universities and career schools can use VR devices to make education fun and encourage students to delve deeper into a field. As in business education, VR demystifies complex course materials by simulating real-world experiences for college students [60]. Metaverse assists human resources in businesses with recruitment and training. Hiring talented and qualified people is a serious concern for certain companies, flooded with thousands of job applications piling up. VR makes interviewing candidates more seamless and provides staff orientation and training. Using augmented reality with VR allows hands-on training in the real world as workers can wear gloves and interact with virtual equipment. With these immersive experiences, learning curves are accelerated significantly, and complex systems are simplified to use. Because VR provides broad visibility, it makes it easier to locate system components, and complex equipment is now easier for technicians to learn. The automotive industry embraces VR technology as it works well with industrial automation [61]. One of the strengths of the metaverse is that it allows for remote collaboration using VR.

3) Building the Metaverse. Companies do not use the metaverse alone; Businesses will build to be a global partnership by creators, politicians and entrepreneurs [62]. Metaverse has been built from its inception with the framework and foundation of creating a new space where people can feel safe. Integrity, security and privacy will be

weaved into the fabric, working with government officials, business operators and academics to consider issues and opportunities in the metaverse. The mobile internet has provided a new way to personalise experiences and meet people's growing expectations of how they want to interact with businesses. It is believed that the metaverse will drive this trend and that meta technologies will play an important role. The business opportunity will follow consumer behaviour in the Metaverse, as in the mobile internet. It's important to continue to build the business for today's options by innovating and experimenting with Facebook, Instagram, Messenger or WhatsApp while growing the audience, as connections made on these platforms will still be valid in the Metaverse [63]. The most successful brands in business history are developing and keeping up-to-date by understanding the changing needs of their customers. For example, you can enter the metaverse by creating new commerce channels on Facebook and Instagram or creating filters with "Spark AR Studio" [64]. Augmented reality ads can help customers understand the products from home.

Metaverse makes the promotion of new products more permanent. Entrepreneurs use VR to prototype, design and promote product launches. Previously the entire process was often too expensive and time-consuming for the average person to follow; VR paves the way for product developers to enter markets with a minimal upfront cost. It also provides a way for entrepreneurs to quickly create and test products to determine which products attract enough demand for mass production. This gives entrepreneurs the power to adjust and improve products based on real-time market feedback quickly. However, virtual experiences can be used to persuade investors to take risks and invest in a prototype or product.

B. Challenges for Entrepreneurship in the Metaverse World

Metaverse offers users the potential to earn fun experiences and even financial rewards. For businesses, the metaverse requires heavy investment and a shift in many forms of business. The payoff may be astronomical over time, but that doesn't change that most companies are now in a costly lead stage for the metaverse. Some of these concerns may fade over time, while other difficulties may arise. J. Wong, Ernst & Young's Global Chief Innovation Officer (2022), is aware of significant concerns about the metaverse but sees it as the inevitable next step in the technology world. He also points out that early adopters must be prepared to face cost, regulation, procurement, and security challenges in creating the metadata warehouse. For example, building financial infrastructure and new trading experiences create opportunities for fraud. Hackers are a threat at every turn. Identity theft is already a big enough problem in the real world. Managing its presence in the metaverse can be much more difficult because governance will be an essential issue. Jurisdiction can be complex as international companies only try to sign contracts and agreements in a digital space. This can lead to disagreements between various governments when resolving things like content control and legal rights. According to Wong (2022), none of these must be deal-breakers; they are just obstacles businesses must overcome.

It is tempting for a business to view the Metaverse as an excellent opportunity to make easy money. After all, you don't need to lay a foundation for a building or rent a physical space. However, this does not mean that metadata storage will be a small investment. Conversely, while users may have free access, businesses may have a much higher "pay to play" threshold. The rapid growth of the cryptocurrency is making it very risky for many investors, but the metaverse announcement is thought only to perpetuate this chaotic but profitable situation. The Metaverse is a digital landscape, and the most natural form of currency would be a digital currency. Blockchain-based cryptocurrencies are ready to respond to this need with aplomb. Both the current digital tender and the numerous future iterations have the potential to be the driving engine behind financial interactions in the metadatabase [65]. As businesses prepare for the impact of the meta-universe, they must be open-minded and ready to adapt. Investing in digital real estate, embracing crypto, and brands must be flexible and controlled as they face visible and unforeseen challenges. If a company can do these things, it can avoid negative impacts and survive and prosper in the new digital age [5].

The metaverse is closely linked to the real world and corresponds to a real identity. The security and privacy of user data are the most significant real-world issues. With the emergence of the metaverse, the amount of personal data collected will be pretty substantial. Multiple companies will likely work together to create one or more metaverses in the future. Therefore, companies may need to make significant investments to ensure the privacy and security of the metaverse. In constructing next-generation networks, the metaverse must consider data privacy protection issues, just as in the previous network environment [66], [67].

IV. Result And Discussion

Activities such as creating and developing a new business, making innovations, acting flexible and dynamic, being creative and taking risks lie based on the entrepreneurship phenomenon. In real life, entrepreneurs earn income with their existing products and products and the services they offer to their customers. It has been seen that the entrepreneurs who are already present to continue their entrepreneurial activity in the metaverse world will evaluate the opportunities in this world and also make large investments to gain material and moral gain from the products and services they will offer for sale here. Characteristics are important for entrepreneurs to continue their lives successfully [68]. For this reason, they need to give importance to their individual and social attributes while continuing their entrepreneurial activities. On the other hand, it has been determined as a result of the examinations that the users who want to continue their entrepreneurial activities in the metaverse world should have knowledge and experience in design, computer hardware and software, and their entrepreneurial characteristics.

Types of entrepreneurship in real life; ownership, size, features and John Chicken model [69]. In the metaverse world, which is also called a virtual world, it is seen that the ownership dimension comes to the fore in terms of the products created by the users and the sales of the space they own. Looking at the real-life course of the entrepreneurial process, personal, sociological, organisational and environmental factors are examined under the headings of

innovation, triggering event, practice and development for entrepreneurs. Looking at the same situation from the metaverse world, it has been seen that real users who want to be entrepreneurs in the virtual world should first enter the metaverse and start to evaluate the entrepreneurship opportunities that exist in the metaverse world after examining the existing entrepreneurial activities.

Metaverse offers people an immersive 3D experience of not only human interactions but also products and services. In the metaverse, the possibilities for showing products, how tools or machines work, how clothes are for you, and how to experience museums and attractions are endless. Businesses will have opportunities to set up manufacturing centres in shopping malls and transportation hubs and provide high-accuracy professional 3D scans for customers' bodies to be templates for metaverse avatars [70]. With an avatar like this, you can perfectly match an outfit you like and see how you'll look when you're walking around. There are travel and movement restrictions in any global pandemic or quarantine. This issue should not be feared anymore because the metaverse ensures that many things we can do in normal life can now be done in this environment. Metaverse creates a virtual environment suitable for our preferences, where we can quickly realize business, entertainment, education, and travel opportunities. For example, it gives you the best alternative for your family holidays. You and your family may be skiing while talking in an Alpine region that rivals the Swiss Alps, and you could be displaced in seconds. Metaverse is also drastically changing the real estate industry and how real estate agents work. It offers an immersive 3D experience for property viewing and reviewing real estate development and renovation. This industry and many other industries can be plagued by capital, and human talent poured into their metaverse versions [71].

Although retail has transitioned to e-commerce before the global pandemic, a new transformation occurs with the metaverse. Virtual malls, stores and consumers can try virtual versions of physical products before purchasing them in the real world. This conversion can also be accomplished by selling and buying virtual goods with real-world currencies or cryptocurrencies. The effects of the metaverse can be quite high, especially in the changes in the games. It doesn't take much imagination to see how the game will change in marketing, branding and advertising [25]. Although the Metaverse started with the game industry, it can also change the game industry following its purpose. It is foreseen that this innovation will spread and change many other sectors. As Mark Zuckerberg noted, it is thought that in 5-10 years, Metaverse will become mainstream [72].

The pace of development of the Metaverse can be attributed to the impact of the Covid-19 pandemic on global society. With remote access services, mandatory changes were made in working hours in workplaces throughout the pandemic process. Even after the pandemic is over, most businesses continue to adopt flexible working models, including the ability to work remotely. Metaverse has a vital role in keeping employees connected to the organization while helping to overcome productivity problems related to remote working, such as video conferencing [73]–[75].

V. CONCLUSION

This study it is aimed to give information by examining the relevant literature on behalf of the difficulties and conveniences of entrepreneurship in the metaverse world and the opportunities it will provide to entrepreneurs. In this virtual world, where entrepreneurs will make their dreams come true, it is important to shed light on their future visions and guide them. Although not all of the foreseen problems are solved, minimising the effects that will arise is another goal of this study. Recent technological advances indicate readiness for the next wave of development, which is predicted to include the expansion of business applications and investments in the metaverse world [76]. While the metaverse world and the physical world move together, there are no movement restrictions and space limits in the virtual world. For this reason, it is possible to make designs and applications without borders in this digital environment where entrepreneurs will put their business ideas into practice. Thus, new business opportunities in the digital world for entrepreneurs are increasing day by day.

In the Metaverse world, the idea of entrepreneurship offers new business opportunities to many people today. Thinking that besides those who already have a business, people who do not have a company or industry can operate in the field of metaverse entrepreneurship, they are preparing for this new process. The main reason metaverse entrepreneurship has become popular is that there are many advantages of being an entrepreneur in the internet environment. This type of entrepreneurship, which easily closes the real differences between products and services and customers, provides an advantage beyond expectations in the market. Thanks to eliminating geographical barriers, a business environment can be established in any desired area. It's the easiest way to be a boss at your own business instead of being an hourly employee. One of the most interesting aspects is that the earning has no certain limitations. While working in any job for only a certain amount of salary, there is the advantage of making as much money as worked and served in the field of metaverse entrepreneurship. It is possible to determine the working hours by individuals and, if necessary, trade in the international arena. Metaverse also has many benefits in terms of marketing; It provides a map of possibilities, with a targeted emphasis on transparency, traceability, property rights, anti-fraud mechanisms, and trust and loyalty to consumers. NFTs may also be used to represent limited real or digital products [77].Since limited availability makes it difficult for consumers to procure these products, some world brands (Gucci, Dolce Gabbana, etc.) provide convenience to consumers with NFTs. The combination of a luxury brand and NFTs becomes more applicable in the gaming world; For example, an avatar might wear Gucci shoes or a bag. By evaluating the popularity and demand of these digital products, a company can determine how much to produce accordingly. As brands learn more about the NFT production process, they can increase their advertising and marketing revenues by keeping a close eye on the latest technologies [78].

Although Metaverse entrepreneurship is a world of opportunities in all aspects, it has some difficulties and the advantages it provides. Especially to be successful in

metaverse entrepreneurship, it is necessary to work with perseverance and dedication. If entrepreneurs are not closely related to technology and do not know the digital world well, it will not be easy to achieve success. The competitive environment is more intense than normal, and it can be said that those who see opportunities take their place in this sector in the very early periods. For this reason, if entrepreneurs want to operate in the field of metaverse entrepreneurship, it will be necessary to say that their competitors are very large. At the same time, if the entrepreneurs do not have a unique business idea, it will not be easy for the people they will address to accept them in this field.

In this study, which examines entrepreneurship in the metaverse world, it has been seen that entrepreneurs who successfully carry out their entrepreneurial activities within the metaverse should be open to designer and technological innovations and their knowledge and abilities. For this reason, it is recommended to have good software and hardware knowledge for those who want to be successful entrepreneurs in the metaverse world. However, it should be noted that the business ideas they will use in this virtual universe are also effective and prestigious. Considering the popularity of Metaverse among young people, the target audience in the applications to be realised is mostly young people. For this reason, it should be noted that the needs and expectations of the young population should be well determined, and the initiatives should be directed towards them. It is predicted that the return of business ideas designed by entrepreneurs in the metaverse will be higher due to the costs in the real world. It is also recommended that entrepreneurs do an excellent feasibility study to implement their business ideas in the metaverse world. In this feasibility study, they should develop an alternative plan against the profit and loss calculations and the difficulties that may arise in the system. Since Metaverse is seen as a necessary technology for development, the state should encourage entrepreneurs in this field. Entrepreneurs should be supported with the required financial aid (grants, loans, etc.) to develop their projects. As the amount and value of data on entrepreneurs in the Metaverse increases, so does the need for security and reliability. Blockchain technology is critical to ensuring data security in the metaverse, and artificial intelligence is used to protect the diversity and richness of the metaverse. Entrepreneurs need to keep their data secure regarding the sustainability of their activities on the metaverse and therefore use the necessary industry 4.0 components.

Since Metaverse is a new field of study, studies on this subject are pioneering. With the increase in commercial activities in the metaverse, entrepreneurs need to have information about the metaverse and learn the concepts and theories. For future researchers, entrepreneurs' perception of the metaverse world is a subject that needs to be investigated. For this reason, it can be recommended to develop a scale to measure the perceptions of entrepreneurs. In addition, it is thought that qualitative studies (based on observation and interview) to be conducted with entrepreneurs on this subject will provide important information. It is recommended to carry out longitudinal studies that will determine the effectiveness of the entrepreneurs in the Metaverse in the process.

REFERENCES

[1] J. B. Madsen, "Aspects of User Experience in Augmented Reality", Aalborg Universitetsforlag, 2016.

[2] D. Gomez, G. Burdea, ve N. Langrana, "Integration of the Rutgers Master II in a virtual reality simulation", içinde *Proceedings Virtual Reality Annual International Symposium '95*, 1995, ss. 198–202.

[3] M. Cohn, "Prager Metis sets up first CPA firm in metaverse", *Accounting Today*, 2022.

[4] M. Maurer, "Accounting Firms Scoop Up Virtual Land in the Metaverse", *The Wall Street Journal*, 2022.

[5] R. Dixon, "What You Need To Know About How the Metaverse Will Affect Business", *Entrepreneur*, 2022.

[6] J. Wong, "How Will The Metaverse Impact Businesses In The Consumer Goods Sector?", *Forbes*, 2022.

[7] L. Zhang, "MRA: Metaverse Reference Architecture", içinde *Internet of Things -- ICIOT 2021*, 2022, ss. 102–120.

[8] C. Hackl, "Defining The Metaverse Today", *Forbes*, 2021. [Çevrimiçi]. Available at: https://www.forbes.com/sites/cathyhackl/2021/05/02/defining-the-metaverse-today/?sh=7c386ad46448.

[9] D. L. Panucci ve T. Bullard-Whyke, "'Coherency' Alternative to the 'Singularity': Coherent Heart Entrainment", içinde Handbook of Research on Global Media's Preternatural Influence on Global Technological Singularity, Culture, and Government (Advances in Media, Entertainment, and the Arts), Information Science Reference, 2022, s. 46.

[10] D. Yang *vd.*, "Expert consensus on the metaverse in medicine", *Clin. eHealth*, c. 5, ss. 1–9, 2022.

[11] J. H. I. Seow, "Metaverse: A Game-changing Innovation For Entrepreneurs", *Entrepreneur*, 2021.

[12] H. soo Choi ve S. heon Kim, "A content service deployment plan for metaverse museum exhibitions—Centering on the combination of beacons and HMDs", *Int. J. Inf. Manage.*, c. 37, sayı 1, ss. 1519–1527, Şub. 2017.

[13] S. Kraus, D. Kanbach, P. Krysta, M. Steinhoff, ve N. Tomini, "Facebook and the creation of the metaverse: Radical business model innovation or incremental transformation?", *Int. J. Entrep. Behav. Res.*, ss. 1–27, 2022.

[14] S. B. Hall ve B.-L. Moritz, "3 technologies that will shape the future of the metaverse – and the human experience", *World Economic Forum*, 2022. [Çevrimiçi]. Available at: https://www.weforum.org/agenda/2022/02/future-of-the-metaverse-vr-ar-and-brain-computer/.

[15] M. Ball, "Evolving User + Business Behaviors and the Metaverse", içinde *The Metaverse Primer*, 2021, s. Part IX.

[16] M. Ball, "The metaverse: and how it will revolutionize everything", *Liveright Publishing Corporation*, 2022. [Çevrimiçi]. Available at:

https://www.matthewball.vc/all/forwardtothemetaversepr imer.

[17] S. Hollensen, P. Kotler, ve M. O. Opresnik, "Metaverse – the new marketing universe", *J. Bus. Strategy*, c. ahead-of-p, sayı ahead-of-print, 2022.

[18] A. C. Max, "Mark Zuckerberg's metaverse will require computing tech no one knows how to build", *Protocol*, 2022. [Çevrimiçi]. Available at: https://www.protocol.com/enterprise/metaverse-zuckerberg-computing-infrastructure.

[19] R. S. Somula ve R. Sasikala, "A survey on mobile cloud computing: Mobile Computing + Cloud Computing (MCC = MC + CC)", *Scalable Comput. Pract. Exp.*, c. 19, sayı 4, ss. 309–337, 2018.

[20] M. Bi, Y. Wang, Y. Li, ve X. Tong, "A Privacy-Preserving Mechanism based on Local Differential Privacy in Edge Computing", *China Commun.*, c. 17, sayı 9, ss. 50–65, 2020.

[21] M. Ball, "The Metaverse: What It Is, Where to Find it, and Who Will Build It", *MatthewBall.vc*, 2020. [Çevrimiçi]. Available at: https://www.matthewball.vc/all/themetaverse.

[22] D. Owens, A. Mitchell, D. Khazanchi, ve I. ZIgurs, "An Empirical Investigation of Virtual World Projects and Metaverse Technology Capabilities", *SIGMIS Database*, c. 42, sayı 1, ss. 74–101, 2011.

[23] L. Lee *vd.*, "All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda", *J. Latex Cl. Files*, c. 14, sayı 8, 2021.

[24] Y. Bian, J. Leng, ve J. L. Zhao, "Demystifying Metaverse as a New Paradigm of Enterprise Digitization", içinde *Big Data -- BigData 2021*, 2022, ss. 109–119.

[25] H. Ning *vd.*, "A Survey on Metaverse: the State-of-the-art, Technologies, Applications, and Challenges", *CoRR*, c. abs/2111.0, 2021.

[26] C. Hackl, "The Metaverse Is Coming And It's A Very Big Deal", *Forbes*, 2020. [Çevrimiçi]. Available at: https://www.forbes.com/sites/cathyhackl/2020/07/05/the-metaverse-is-coming--its-a-very-big-deal/?sh=3c0db5d440fa.

[27] N. Kelly, "Some Predictions for How the Metaverse Will Impact Our Lives", *Entrepreneur*, 2022.

[28] H. Duan, J. Li, S. Fan, Z. Lin, X. Wu, ve W. Cai, "Metaverse for Social Good: A University Campus Prototype", içinde *Proceedings of the 29th ACM International Conference on Multimedia*, New York, NY, USA: Association for Computing Machinery, 2021, ss. 153–161.

[29] M. Forte, N. Lercari, F. Galeazzi, ve D. Borra, "Metaverse Communities and Archaeology: The Case of Teramo", içinde *3rd International Conference dedicated on Digital Heritage*, 2010, ss. 79–85.

[30] E. Dai ve J. Bal, "Harmonising culture in co-operative business ventures: using a simulation in a metaverse", içinde *Proceedings of the 3rd European Conference on Games Based Learning*, 2009, ss. 412–420.

[31] K. B. Wilson, A. Karg, ve H. Ghaderi, "Prospecting non-fungible tokens in the digital economy: Stakeholders and ecosystem, risk and opportunity", *Bus. Horiz.*, 2021.

[32] D. Tomás, "The new crypto niche: NFTs, play-to-earn, and metaverse tokens", *Financ. Res. Lett.*, s. 102742, 2022.

[33] S. Boutillier ve D. Uzunidis, "Entrepreneur: Etymological Bases", içinde *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship*, New York, NY: Springer New York, 2013, ss. 580–584.

[34] C. Marcotte, "Entrepreneurship and innovation in emerging economies", *Int. J. Entrep. Behav. Res.*, c. 20, sayı 1, ss. 42–65, Oca. 2014.

[35] M. Betta, R. Jones, ve J. Latham, "Entrepreneurship and the innovative self: A Schumpeterian reflection", *Int. J. Entrep. Behav. Res.*, c. 16, sayı 3, ss. 229–244, 2010.

[36] C. Vallaster, S. Kraus, N. Kailer, ve B. Baldwin, "Responsible entrepreneurship: outlining the contingencies", *Int. J. Entrep. Behav. Res.*, c. 25, sayı 3, ss. 538–553, 2019.

[37] S. A. Zahra, "Entrepreneurial risk taking in family firms", *Fam. Bus. Rev.*, c. 18, sayı 1, ss. 23–40, 2005.

[38] L. A. Zampetakis, K. Kafetsios, N. Bouranta, T. Dewett, ve V. S. Moustakis, "On the relationship between emotional intelligence and entrepreneurial attitudes and intentions", *Int. J. Entrep. Behav. Res.*, c. 15, sayı 6, ss. 595–618, Oca. 2009.

[39] M. Kobia ve D. Sikalieh, "Towards a search for the meaning of entrepreneurship", *J. Eur. Ind. Train.*, c. 34, sayı 2, ss. 110–127, 2010.

[40] N. V Loc, "Entrepreneurship-The basis for building the cultural value system of Vietnamese entrepreneurs", *Econ. Bus. Mag.*, c. 27, ss. 232–239, 2011.

[41] J. A. Katz, S. R. Safranski, ve O. Khan, "Virtual Instant Global Entrepreneurship", *J. Int. Entrep.*, c. 1, ss. 43–57, 2003.

[42] V. Dutot ve C. Van Horne, "Digital Entrepreneurship Intention in a Developed vs. Emerging Country: An Exploratory Study in France and the UAE", *Transnatl. Corp. Rev.*, c. 7, sayı 1, s. 85, 2015.

[43] F. Zhao ve A. Collier, "Digital Entrepreneurship: Research and Practice", içinde *9th Annual Conference of the EuroMed Academy of Busines*, 2016, s. 2173.

[44] N. Hair, L. R. Wetsch, C. E. Hull, V. Perotti, ve Y. T. C. Hung, "Market orientation in digital entrepreneurship: Advantages and challenges in a web 2.0 networked world", *Int. J. Innov. Technol. Manag.*, c. 9, sayı 6, 2012.

[45] C. E. Hull, Y.-T. C. Hung, N. Hair, V. Perotti, ve , Richard DeMartino, "Taking advantage of digital opportunities: a

typology of digital entrepreneurship", *Int. J. Netw. Virtual Organ.*, c. 4, sayı 3, ss. 290–303, 2007.

[46] S. Kieger, "An Exploration of Entrepreneurship in Massively Multiplayer Online Role-Playing Games: Second Life and Entropia Universe", *J. Virtual Worlds Res.*, c. 2, 2010.

[47] R. D. Hof, "A journey into a place in cyberspace where thousands of people have imaginary lives. Some even make a good living. Big advertisers are taking notice", *Business Week*, 2006. [Çevrimiçi]. Available at: http://large.stanford.edu/publications/coal/references/hof/.

[48] Commission of The European Communities, "Green Paper Entrepreneurship in Europe". ss. 7–9, 2003.

[49] L. Szerb, E. Lafuente, G. Márkus, ve Z. Acs, "Global Entrepreneurship Index 2019". 2020.

[50] D. Buhalis ve N. Karatay, "Mixed Reality (MR) for Generation Z in Cultural Heritage Tourism Towards Metaverse", içinde *ENTER 2022: Information and Communication Technologies in Tourism 2022*, 2022, ss. 16–27.

[51] D. Y. Aharon ve E. Demir, "NFTs and asset class spillovers: Lessons from the period around the COVID-19 pandemic", *Financ. Res. Lett.*, s. 102515, 2021.

[52] Meta, "The Metaverse and How We'll Build It Together - Connect 2021", *Youtube*, 2021. [Çevrimiçi]. Available at: https://www.youtube.com/watch?v=Uvufun6xer8.

[53] J. Lopez-Diez, "Metaverse: Year One. Mark Zuckerberg's video keynote on Meta (October 2021) in the context of previous and prospective studies on metaverses", *Pensar la Publicidad. Rev. Int. Investig. Public.*, c. 15, sayı 2, ss. 299–303, 2021.

[54] M. Zuckerberg, "Founder's Letter, 2021", *Meta*, 2021. [Çevrimiçi]. Available at: https://about.fb.com/news/2021/10/founders-letter/.

[55] U.-K. Lee, "Tourism Using Virtual Reality: Media Richness and Information System Successes", *Sustainability*, c. 14, sayı 7, s. 3975, 2022.

[56] R. Lang, "Try before you buy: A theory of dynamic information acquisition", *J. Econ. Theory*, c. 183, ss. 1057–1093, 2019.

[57] Y. Kang, "Metaverse Framework and Building Block", *J. Korea Inst. Inf. Commun. Eng.*, c. 25, sayı 9, ss. 1263–1266, 2021.

[58] P. Geethan, P. Jithin, T. Naveen, K. V. Padminy, J. Shruthi Krithika, ve S. K. Vasudevan, "Augmented reality X-ray vision with gesture interaction", *Indian J. Sci. Technol.*, c. 8, sayı April, ss. 43–47, 2015.

[59] E. Ayiter, "(Re) Building Proun #5A in the Metaverse", içinde *2014 International Conference on Cyberworlds*, 2014, ss. 403–406.

[60] T. G. Pittz, "A model for experiential entrepreneurship education", *J. Bus. Entrep.*, c. 26, sayı 1, ss. 179–192, 2014.

[61] L. P. Berg ve J. M. Vance, "Industry use of virtual reality in product design and manufacturing: a survey", *Virtual Real.*, c. 21, sayı 1, ss. 1–17, 2017.

[62] J. Lee, "A Study on Metaverse Hype for Sustainable Growth", *Int. J. Adv. smart Converg.*, c. 10, sayı 3, ss. 72–80, 2021.

[63] V. Ma, "5 Futuristic Jobs of The Metaverse", 2021. [Çevrimiçi]. Available at: https://hackernoon.com/5-futuristic-jobs-of-the-metaverse.

[64] C. Flavián, S. Ibáñez-Sánchez, ve C. Orús, "User Responses Towards Augmented Reality Face Filters: Implications for Social Media and Brands", içinde *Augmented Reality and Virtual Reality*, 2021, ss. 29–42.

[65] B. Ryskeldiev, Y. Ochiai, M. Cohen, ve J. Herder, "Distributed Metaverse: Creating Decentralized Blockchain-based Model for Peer-to-peer Sharing of Virtual Spaces for Mixed Reality Applications", içinde *The 9th Augmented Human International Conference*, 2018, ss. 1–3.

[66] Z. Zhang *vd.*, "Artificial intelligence in cyber security: research advances, challenges, and opportunities", *Artif. Intell. Rev.*, c. 55, sayı 2, ss. 1029–1053, 2022.

[67] B. Falchuk, S. Loeb, ve R. Neff, "The Social Metaverse: Battle for Privacy", *IEEE Technol. Soc. Mag.*, c. 37, sayı 2, ss. 52–61, 2018.

[68] G. Boldureanu, A. M. Ionescu, A. M. Bercu, M. V. Bedrule-Grigoruţă, ve D. Boldureanu, "Entrepreneurship education through successful entrepreneurial models in higher education institutions", *Sustain.*, c. 12, sayı 3, ss. 1–33, 2020.

[69] M. Rimmington, C. Williams, ve A. Morrison, *Entrepreneurship in the Hospitality, Tourism and Leisure Industries*. Routledge, 2009.

[70] D. Shin, "The actualization of meta affordances: Conceptualizing affordance actualization in the metaverse games", *Comput. Human Behav.*, c. 133, sayı April, s. 107292, 2022.

[71] D.-I. D. Han, Y. Bergs, ve N. Moorhouse, "Virtual reality consumer experience escapes: preparing for the metaverse", *Virtual Real.*, 2022.

[72] G. Bienasz, "4 Innovations That Give a Sneak Peek Into the Metaverse", *Inc.*, 2022.

[73] A. Alexander, A. De Smet, M. Langstaff, ve D. Ravid, "What employees are saying about the future of remote work", *McKinsey Co.*, sayı April, ss. 1–13, 2021.

[74] BEIS, "Making Flexible Working the Default", *Dep. Business, Energy Ind. Saf.*, sayı September, 2021.

[75] International Labor Organization, Teleworking during the COVID-19 pandemic and beyond: A Practical Guide. 2020.

[76] K. Mackenzie, S. Buckby, H. Irvine, "Business research in virtual worlds: Possibilities and practicalities", *Accounting, Audit. Account. J.*, c. 26, sayı 3, ss. 352–373, 2013.

[77] H. Treiblmaier, "Beyond blockchain: How tokens trigger the internet of value and what marketing researchers need to know about them", *J. Mark. Commun.*, c. 27, sayı 8, ss. 1–13, 2021.

[78] R. Williams, "Gucci's Robert Triefus on Testing Luxury's Allure in the Metaverse", *The Business of Fashion*, 2021. [Online]. Available at: https://www.businessoffashion.com/articles/luxury/the-state-of-fashion-2022-bof-mckinsey-gucci-robert-triefus-metaverse-virtual-nft-gaming/.

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Caribbean Metaverse Development: A Literature Review Perspective

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Abstract - The Caribbean's metaverse evolution accelerated due to the Covid-19 pandemic. This paper focuses on the metaverse, XR, and NFT and emphasises the Caribbean's contribution to the virtual environment. A bibliometric analysis of metaverse-themed research identified the rapid increase in publications in 2021 and 2022 and that titles with XR (AR, VR or MR) occurred three times more than blockchain (including NFT). An evolving dataset was created based on a continuous scoping literature review of Industry 4.0 and its enabling technologies. This enables the creation of a new definition of the metaverse, understanding the UX benefits of XR and its applications' areas of foci, highlighting investment in XR-based projects, and illustrating the Caribbean-themed NFT and XR projects. This dataset revealed that UX benefits are linked to XR element features that are relevant, contextual, customised, hands-free and intuitive. It also revealed that XR applications have areas of foci that can enable machine control or data interface, designing and testing, remote support, education, customer engagement, remote collaboration or entertainment and escapism. Analysis of 54 XR papers revealed that the most popular area of focus was education (including training, learning and understanding). An evaluation of global investments in XR development showed funding ranged from USD 70K to USD 100M, and there needs to be focused financial support for Caribbean projects. This justifies continued research into factors influencing funding and encouraging Caribbean XR development. In addition, this research promotes regionally developed XR projects and NFTs. The paper's originality is the reductionist definition of the metaverse: a space designed for users by users, which can satisfy whomever, whatever, however, wherever and whenever. It manifests the user's extended reality, facilitated through XR technologies that enable Industry 4.0 (I4.0). As such, the metaverse can be considered the practical implementation of I4.0.

Keywords: Caribbean, Metaverse, Industry 4.0 (I4.0), Extended Reality (XR)

I. INTRODUCTION

There is an existing gold rush to create and dominate virtual worlds (metaverse), of which extended reality (XR) technologies (augmented reality (AR), virtual reality (VR), and mixed reality (MR) play an essential role. However, the success of its adoption will be tempered by the perceptions and efficacy of the virtualised environment, which depend on the idea that the "objects will be versatile and scalable across different surfaces and use cases like commerce and shopping" [1]. This is highlighted by the importance of the digital transformation movement captured in the 2021 PricewaterhouseCoopers "Digital Readiness survey", in which AI (artificial intelligence), IoT (Internet of Things), RPA (Robotic Process Automation) and AR (augmented reality) make up the top four emerging technologies to be prioritised [2, p. 22].

These tools are used to develop "new revenue streams and grow existing ones" and "create new experiences and products" [3, p. 5] in a metaverse in which industry sectors such as gaming (Roblox signed partnerships with NFL, Ralph Lauren, Nike), media and entertainment (Imagine Dragons and Ariana Grande had VR concerts), e-commerce and retail (Shopify merchants using 3D images had a 94% increase in conversions), manufacturing (BMW tested changes in a virtual factory), architecture and engineering (Nvidia's Omniverse facilitates the remote collaboration of 3D assets) can benefit [4]. The emphasis on shaping the utility of these new environments is being placed on 3D development (creation of assets and tools to facilitate the process). It is already common in "product visualization such as 3D shopping (product models to spin & zoom on your desktop), or AR (the same thing overlayed in your space)" [5]. This development of new value demonstrates that "creativity is a critical competency that will be humans' distinctive asset in this current time where technology is ubiquitous." [6]. Quality content directly affects user adoption through better experiences [3, p. 15], [7].

Investments from technology companies are supporting the development of creatives to populate the new worlds [1], [8], which will enable users to be outfitted with and experience similarly designed and branded products used in the real world as clothing and cosmetics [9], [10]. This trend has expanded into big box retailers, such as Walmart, who will commercialise virtual products "ranging the gamut from electronics, home decorations, children's toys and games, sporting goods, personal care products to physical fitness training services and health and nutrition classes in augmented and virtual reality" [11], [12]. Another example is the partnership between Hyundai and Unity to create a meta-factory, which will be a digital twin of the physical plant's equipment and operations "will allow Hyundai to test numerous scenarios virtually, to assess, calculate and create optimal operation conditions, without employees needing to be onsite" [13]. The fashion and beauty industry has also entered the virtual marketing and engagement platform that enables brands to demonstrate new products. For example, Estée Lauder and Lottie London's nail collection, which the latter provided visitors with a "limited-edition free wearable avatar head" with "Mega Brow, Stamp Liner Wing Edition and Freckle Tint' as well as Valdé Beauty's NFT (non-fungible token) lipstick holders which also comes with

"virtual "armor" that the NFT owners could wear on Decentraland's platform" [14]. To support these developments, Deloitte provides "services and a studio to enable creators to build virtual and augmented environments"[15]. Virtual products, such as these, can offset the limitations of supply chain bottlenecks and uncertainties of the real world.

The Covid-19 pandemic highlighted the need to accelerate the adoption of digital transformation [16] to create virtualised systems such as AR and VR that would mitigate the adverse effects of required physical social distancing protocols. This prevented persons from engaging in many Caribbean activities such as tourism, Carnival, in-person meetings, and in-person educational classes. This perspective was emphasised by Senator Hassel Bacchus, Minister in the Ministry of Public Administration and Digital Transformation (Trinidad and Tobago), who stated that "the world of AR/VR has become a staple in many sectors because of COVID" and that "AR/VR is very important to the tourism sector which can add to the educational and cultural experience for visitors" as well as noting "AR/VR could be incorporated in Carnival and any sector." [17].

As such, the Caribbean Community (CARICOM) has recognised this need for digital skills and policies that guide the development of its people to meet the evolving needs of the new environment and which is being supported by funding from the 11th European Development Fund to "fast-track digital transformation" [18].

This drive is supported through initiatives such as the Caribbean Industrial Research Institute (CARIRI) AR/VR challenge, limited to participation by citizens of Trinidad and Tobago [19], identified XR projects that focused on areas of education, healthcare, agriculture and tourism. The top five projects selected were "Roam Reality", "Carnival Universe", "Explore Tobago – Underwater", "Planet Runner", and "Konnect the Kids" [20].

EON Reality provided a broader Caribbean focus through a USD 25M grant to The University of The West Indies (The UWI), which has physical campuses located in Jamaica, Trinidad and Tobago, Barbados, Antigua and Barbuda, as well as an online campus accessible to the entire Caribbean region [21]. This sponsorship was for the development of Caribbean capacities in "digital education and professional training" using their XR platform [22].

Meta (formerly Facebook), in their partnership with the Organization of American States (OAS), is supporting content development training throughout a larger region, in Latin America and the Caribbean, using their Spark AR platform as part of their global "XR Programs and Research Fund" [8], [23].

This development culminates in the creation of a virtual (digital) space that can offer Caribbean users (as well as visitors to the Caribbean) a realistic experience, which would be experienced as though it were a physical environment. A clear example of this approach is the Barbadian Ministry of Foreign Affairs and Foreign Trade developing an embassy in Decentraland [24]. This will require virtual assets to provide services to travellers, which will "open the door, using technology diplomacy, which then extends to cultural diplomacy – the trade of art, music, and culture." [25]. Another Caribbean country, St. Vincent and the Grenadines, is exploring developing a virtual Carnival for access in the metaverse [26].

The Jamaican Member of Parliament, Lisa Hanna, has advocated the importance of Caribbean-generated digital content and licensing opportunities through NFTs. She specifically noted the need for adequate infrastructures to support these developments. She also drew a comparison to the successes of the Jamaican athletic environment as a result of investments in sports training and development [27]. This would enable the Caribbean "artists, musicians, and content creators to monetise their content by leapfrogging their minds to this new reality of digital ownership, management, and sale" [28].

The Caribbean's evolution into the metaverse is being promoted by the Government of Barbados, the Caribbean Telecommunications Union (CTU) and Meta [29], [30], through the first public virtual forum, in February 2022, in which content creation was a key highlight as identified by the following statements [31]:

- Professor Avinash Persaud, Chairman of the CARICOM Commission on the Economy, stated, "Barbados is also providing opportunities for its citizens to be content creators for the digital space by providing them with the appropriate tools."
- "Presenters agreed that many opportunities exist for a variety of content creators in the sector"
- Rodney Taylor, CTU Secretary General, noted, "One thing we must never do in the region is to relinquish all technological innovation to the developed countries and simply be consumers of technology products and services residing in a distant cloud. We have too much regional talent for that to be the case. Yes, we must build global relationships and collaborate, but we must also take ownership for and be craftsmen and women of our destiny."

Thus, the ability to lower the entry barrier and give content creators greater freedom to develop and publish novel and customisable intellectual property-protected virtual assets [32] can increase the competitive advantage in the Caribbean region. This paper aggregates the Caribbean-focused work in metaverse-related areas such as NFT and XR and clearly indicates the progress made within this space.

II. Methodology

A. Bibliometric analysis of metaverse research

a) Selection of Web of Science as the bibliometric tool

A bibliometric analysis of metaverse-themed research performed on the 2nd of August 2022 identified the trend in published research [33] as there is a focused interest in the topic in the Caribbean. Web of Science (WoS) was selected as the source of data as it is "one of the world's premier scientific citation search, discovery, and analytical information platforms" [34, p. 2] and "still considered to be the most reliable sources of bibliographic data, both for the

most analyses and research evaluations and for daily tasks."[35, p. 4]. Neither Scopus nor Google Scholar was utilised. The author did not have academic access to the former platform as it is not included in the university's library subscription. The latter was omitted as it "lacks the quality control needed for its use as a bibliometric tool" [36, p. 343].

b) Identification of metaverse-themed research

The keyword (appended with the asterisk wildcard) "metaverse*" was used to capture any variations of the word [37] in two different searches (topic and title) to discover any patterns in the priority placement of the word metaverse. The topic search returns documents with the keyword in any of the following: title, abstract, author keywords, and Keyword Plus. The title search only identifies the presence of the keyword in the title.

An exhaustive search of the available WoS databases (KCI-Korean Journal Database, Web of Science Core Collection and SciELO Citation Index) was performed to identify the maximum number of documents that matched the criteria. A limitation in the number of results will occur if metaverse-themed research is present in other databases [38] to which the author's university library does not subscribe. Although WoS deduplicates data using the "All Database" search option [39], the author visually verified that the results contained unique records.

c) Priority of keywords (NFT, blockchain, AR, VR, MR and XR) within titles of metaverse-themed research

The quantities of keywords (NFT, blockchain, AR, VR, MR and XR) within the titles of the metaverse search results were identified to determine their priority. This would determine the technologies that authors frequently associate with the term metaverse in the titles. The terms selected were the digital tools identified in the Caribbean's metaverse journey. Blockchain was included as it is the platform for NFT [144, p. 3]. The following terms (and their variations) were searched within the titles: NFT (and fungible), Blockchain (and block, chain), Virtual Reality (and VR), Augmented Reality (and AR), Mixed Reality (and MR), Extended Reality (and XR).

d) Caribbean focused research

No titles contained the term "Caribbean" in the WoS dataset. This illustrated the lack of focused research on the Caribbean metaverse.

B. Exploration of Industry 4.0 and its enabling technologies

A scoping literature review [40], [41] using Google Scholar [42], [43] was used as the primary database for an exploratory search as it provided the researcher with a larger dataset (as compared to WoS) from a wide array of sources [44, p. 61], [45]. This research into Industry 4.0 and its enabling technologies, including those related to XR and blockchain (including NFT), began in 2016. This focus was to not deliberately omit or search for a specific element linked to the various technologies. Instead, these search results were continuously recorded, analysed and segmented based on thematic elements (such as the metaverse, Industry 4.0, XR, NFT, the Caribbean, and other categories). The growing dataset also included documents that matched the criteria from other sources such as websites, magazine subscriptions, newspapers (and news posts), blogs, reports, research papers, theses, references, and article suggestions from reference managers. This analysis highlights the relationship between the metaverse, XR and Industry 4.0. It also identifies the various benefits that can be achieved by implementing XR.

a) Understanding user experience (UX) benefits of XR and its applications' areas of foci

. The XR-themed documents (in the growing segmented dataset) were evaluated for UX benefits and its applications' areas of foci. A review of a sample of 54 academic sources (papers, conference publications) and 109 non-academic sources (websites, magazines, newspapers, blogs, reports, research papers) was performed to categorise the various types of applications. The latter was omitted from this paper due to its length. The aim was not to perform a gap analysis or an exhaustive search. The purpose was to categorise the types of foci present in XR-related work from selected documents and to determine a priority focus.

b) Investment in XR-based projects

The recorded data of various forms of investments into XR-themed projects were reviewed to identify the monetary value, the priority of the funding and the source of the funds. This demonstrated funding availability (and criteria) to develop virtual projects.

c) Caribbean-themed NFT and XR projects

The specific data on Caribbean-themed NFT and XR projects were extracted from the dataset. Caribbean NFT projects were evaluated to determine the product category types that creatives produced. Caribbean XR projects were evaluated and mapped with XR applications' areas of foci. These highlighted the region's progression in developing aspects of the metaverse through its application of the technologies. This work would show future researchers the contributions to the field made in the Caribbean.

III. DISCUSSION

A. The Metaverse

a) Origin of the metaverse term

The origin of the word "metaverse" has been credited to the descriptive world created in Neal Stephenson's 1992 novel "Snow Crash" [46, p. 492], [47, p. 3], [48, p. 56], [49, p. 4211], [50, p. 17], [51, p. 1]. However, there is currently no consensus on a specific definition, although there are recognised technologies and features that are being adopted, such as XR (a form of human-machine interface or HMI) and blockchain that facilitate the integration of and interoperability with decentralised systems, through real-time analytics of Big Data, to create realistic, immersive virtual worlds and experiences that are accessible by anyone and by any number of concurrent users [46], [49]–[53].

b) A new definition of the metaverse

Thus, conceptually, the metaverse is an evolving state machine that can mimic the physical world as well as the variety of human-centric interactions, such that it will become

impossible to distinguish between the "created" (virtual) environment and the "natural" (real) environment. It is shaped by the specific needs of the user(s) (as engaging in life-like remote collaborations across geographies). It relies upon emerging technologies to support its various requirements (such as verifying a digital object was created by a specific person or guaranteeing the success of a financial transaction between two entities) [47], [49], [54]. Therefore, as a reductionist definition, it can be thought of as:

A space designed for users, by users (that can satisfy whomever, whatever, however, wherever and whenever). It manifests their extended reality, which is facilitated through XR technologies.

c) Metaverse themed research

Metaverse-themed research collated using WoS between 1995 and 2022 identified 644 documents (as of the 2nd August 2022). This comprised 403 documents that contained the word metaverse directly in the title and 241 that contained it in the abstract or keywords. The annual variation in the publication per year data revealed a minimal interest in the area up to 2020 (Fig. 1) as there were 56 papers (approximately 9% of the total) produced during the first 25 years (Fig. 2). This increased by a factor of 10.5 to a total of 588 (approximately 91% of the total) over two years (2021-2022) (Fig. 1).

The graphs illustrated that there was no consistent pattern in the placement of the term metaverse within the title of the article (Title: Metaverse Paper Count) or within abstracts as well as keywords (Topic (No Title): Metaverse Paper Count). However, there is a clear shift in this focus in 2021 and 2022, with the majority having metaverse directly in the title.

The citation per year data (Fig. 3) also demonstrated no annual consistency. However, unlike the publication per year data, only 2022 produced the most significant number of citations of 220, which was approximately five times the annual average between 2008 and 2021.

The data revealed a significant inverse relationship between the number of papers and the number of citations Fig. 4), such that the lowest quantity of citations (either 1 or 2) was from 44 documents. Only one paper had the highest citation (116). Those without citations accounted for most of the papers (560). This pattern was similar for papers with metaverse in the title alone and those with metaverse located in the abstract or keywords. However, a key difference was that the highest citation of a paper with metaverse in the abstract or keywords is 73, whereas the paper with metaverse in the title has 116 citations.

d) Keyword evaluation of NFT, blockchain and XR

Fig. 5 illustrates the priority of keywords (NFT, blockchain, VR, AR, MR and XR) within the titles of the metaverse publication dataset. This demonstrated a strong association with extended reality technologies (including VR, AR, MR and XR) compared to the blockchain (including NFT). The XR group occurred three times more than blockchain and NFT combined. VR was the preferred keyword amongst the group accounting for almost 64% of the XR group's total (80). The data also revealed a lower occurrence of the metaverse and any of the keywords (except MR) being in the title together. MR and metaverse are present in the titles of three out of four documents.

e) Conclusion of metaverse-focused research

Based on the bibliometric analysis and keyword evaluation of the term metaverse, it is clear that there is a rapidly increasing interest in the subject (as shown in the change in trends in 2021 and 2022). It also revealed XR is the technology most frequently associated with developing this new space. As such, this paper will focus on XR as a critical element to the metaverse development in the Caribbean. It is, therefore, essential to outline the benefits of XR.

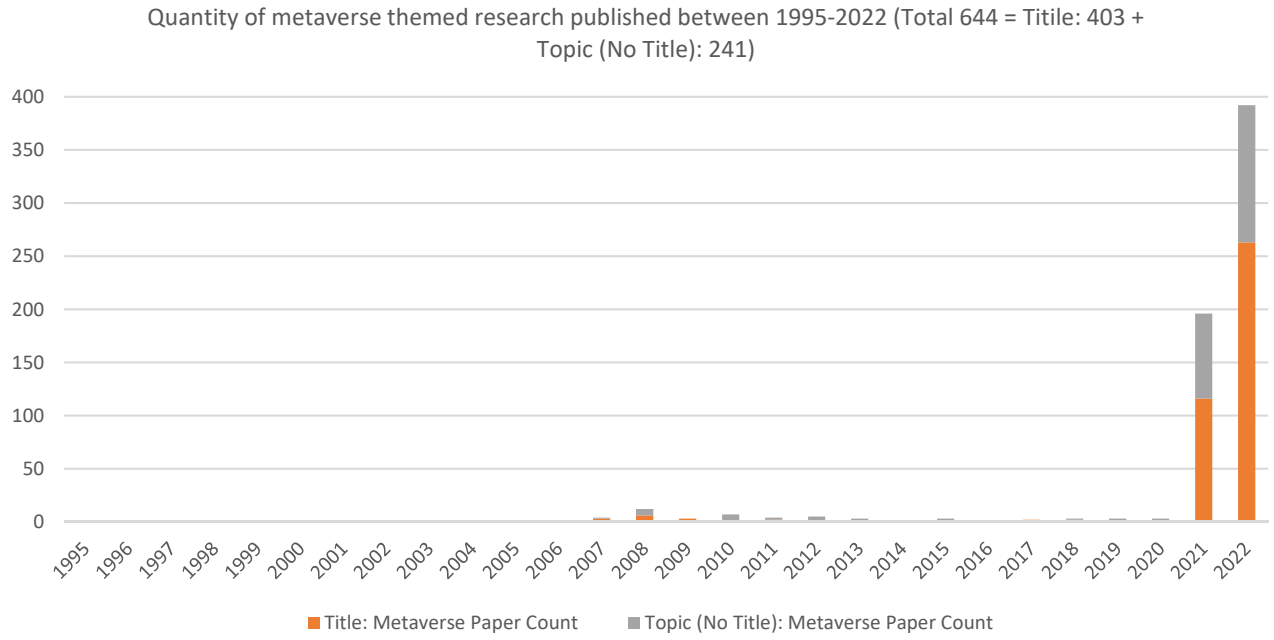

Fig. 1: Publication Per Year Data of Metaverse Themed Research Between 1995 and 2022

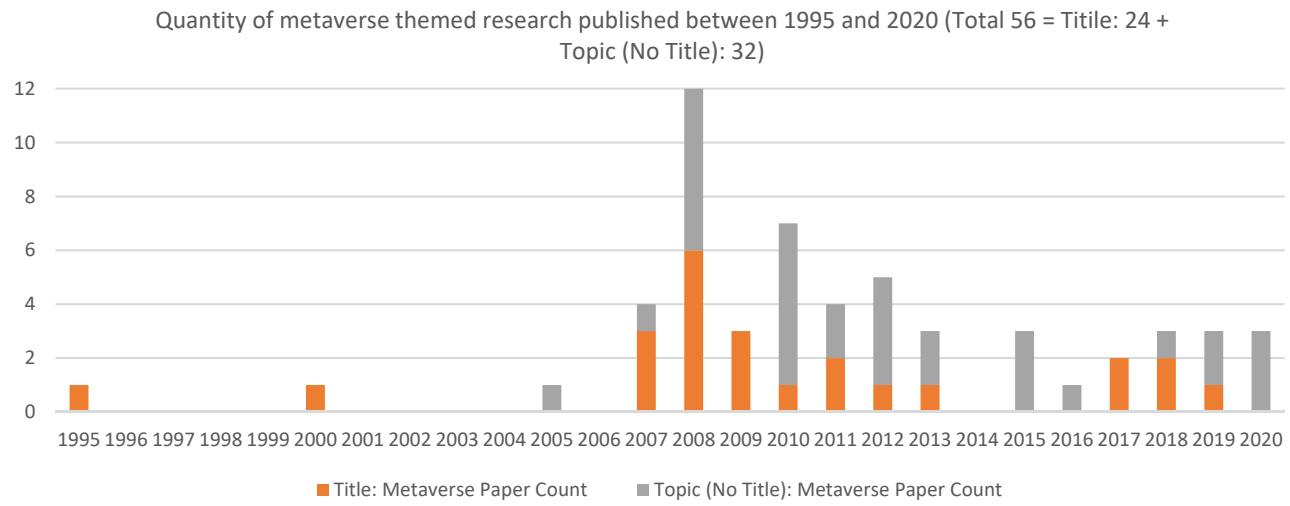

Fig. 2: Publication Per Year Data of Metaverse Themed Research Between 1995 and 2020

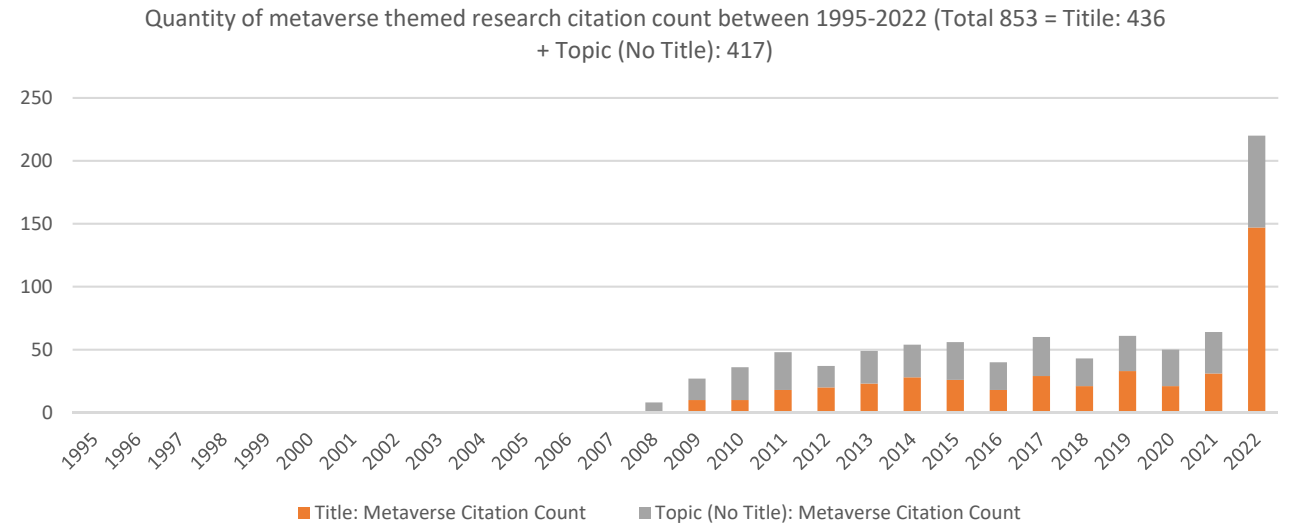

Fig. 3: Citation Per Year Data of Metaverse Themed Research Between 1995 and 2022

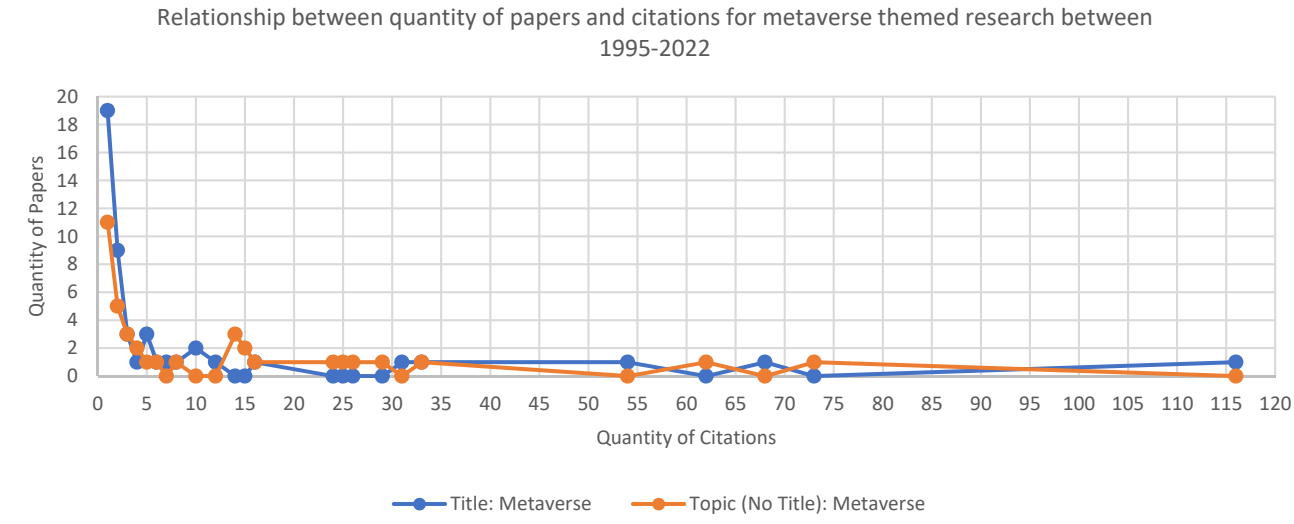

Fig. 4: Relationship Between Quantity of Papers Published and Quantity of Citations in Metaverse Themed Research Between 1995 and 2022

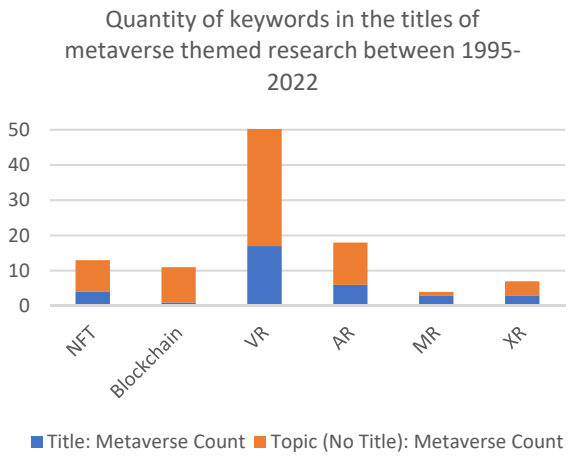

Fig. 5: Quantity of Keywords in Titles of Metaverse Themed Research Between 1995 and 2022

B. XR Enables the Benefits of Industry 4.0 to be Applied Across the Business-to-Customer Ecosystem

a) What is Industry 4.0?

Industry 4.0 (I4.0) is a strategy paradigm change first publicised in 2011 at the Hannover Fair in Germany [55]–[57]. That is the evolutionary change in industrial automation that utilises advancements in Information and Communication Technology (ICT) systems to incorporate and analyse large volumes of data from various disparate systems in real-time. The English term "Industry 4.0" is a translation of the original German moniker "Industrie 4.0", and these are often interchangeable with the phrase "Fourth Industrial Revolution" [58, pp. 17–18] coined in 2016 by Klaus Schwab [59].

Table I defined the features of each I4.0 key concept that could be implemented into any solution (as well as service or product), which would enable it to align either fully or partially with the strategy. The various benefits and opportunities available (Table II) identified the potential outcomes that could be realised throughout the Business-to-Customer (B2C) ecosystem when I4.0 was adopted.

b) XR as an Enabling Technology of I4.0

Concerns regarding the effective use of XR tools are addressed in its ability to virtually develop and evaluate proof of concepts [60], [61]. Companies that leverage these technological changes become successful [62, p. 2], and this can create "increased trust", "increased belief in its likely usability", "increased desire to purchase", and "reduced fear of operational failures" [63, p. 1018], which accelerates the digital transformation adoption into the virtual realm. These XR systems assist humans in "information visualization, remote collaboration, human-machine-interfaces, design tools and education and training" [64, p. 153] and apply to a wide range of disciplines, industries and activities [65]–[67], [68, p. 7].

Thus, human interventions are augmented by more comprehensive sources of data to aid in solving problems and making better decisions [62, p. 4]. Furthermore, these tools achieve the various I4.0 benefits by implementing various virtual applications in the business, process and customer segments. As such, AR, VR or MR technologies satisfy the "I4.0 key concepts of evolution, connected systems, decentralised, intelligent and integration of value chains" and are recognised as enablers of I4.0 as they can facilitate its core benefits of innovation, competitiveness and sustainability through the creation of and an increase in value [69].

A potential limitation of this achievement is an unsatisfactory user experience that can affect the adoption of XR applications within the B2C system. As such, it is essential to adequately develop XR projects that can satisfy the user's experience in various application environments.

TABLE I. I4.0 KEY CONCEPTS' DEFINITIONS (ABSTRACTED FROM [50, P. 371])

I4.0 Key Concept	Definition
Evolution	Changes and adapts to a variety of conditions as different users, tasks and environments
Connected systems	Links the user to other virtual or physical systems that provide additional data
Decentralised	Ability to function without a permanent physical or digital link to other systems
Intelligent	The system is self-reliant and understands the purpose, and makes decisions based on data
Integration of value chains	Create new revenues and reduce costs through linking complementary activities in different departments, companies and geographies

TABLE II. I4.0 BENEFITS AND OPPORTUNITIES ACHIEVED IN THE BUSINESS, PROCESS AND CUSTOMER SEGMENTS OF THE B2C ECOSYSTEM (SOURCE: [56, P. 577])

Business	Process	Customer
Information	Information	Information
Quality assurance	Quality assurance	Quality assurance
Time (real-time and reduced loss time)	Time (real-time and reduced loss time)	Time (real-time and reduced loss time)
Competitive	Efficiency	Loyalty
Quantity independent price model	Optimisation	Quantity independent price model
Value creation	Value creation	Satisfaction
Expense reduction or minimisation	Expense reduction or minimisation	Growth
Flexibility	Flexibility	
Improvement	Improvement	
Decentralisation	Decentralisation	
Easily influenced	Easily influenced	
Performance	Performance	
Transparency	Transparency	
Safety	Safety	
New businesses	Reliability	
New services		
Profit		

C. UX Benefits of XR and Its Applications' Areas of Foci

a) UX Benefits of XR and the Technology Platform Requirements

XR can be used to provide a digital version of the physical world. A feature of this digitalised representation or digital twin is that it "has a level of completeness and accuracy and includes context information that allows the user to understand its behavior and performance" [70, p. 3]. It can also mimic the real entity, including responses to real-time changes in conditions [61], [71, p. 242]. Another requirement is that "the interaction between a user and a virtual scene must register faster than a blink of an eye" [68, p. 6] through "low latency with a high rate of the frame" [72, p. 81]. As such, this technology can also be used to emulate life in gamified and experiential environments [73], [74].

Thus, real-time data influences how creators develop, modify, view and interact with virtual elements [75]–[77],

[78, pp. 55–56] to effectively emulate the physical world and provide the sensation of reality. This also requires "low-latency interactions" [65, p. 4]. However, as the real world involves many different systems interacting simultaneously, this depends upon collaboration across the various decentralised systems and feedback from various users to guide the development's evolution. Thus, this virtual platform can aggregate real-time data into virtualised changes in which users can experience the effects.

The ability to anchor a virtual simulation in reality without any real-time data (i.e. without a sensor to detect the changes in the physical world and relate them to the virtual domain) can be provided by incorporating physics engines [79]–[81] into the XR development platform to enable expected realistic interactions. Therefore, this technology can improve user productivity as relevant and content-specific information, skills and experience can be accessed anywhere and at any time via mobile devices [62, p. 3] and across various types of XR [82, p. 31].

TABLE III. UX BENEFITS OF XR PLATFORMS WITH THE CORRESPONDING XR ELEMENT FEATURE

UX Benefit	XR Element Feature	Cited Authors
Critical changes in the physical or digital worlds are automatically updated to alter the virtual object that informs the user	Relevant	[67], [72], [86], [87]
Virtual objects' and environments' design features change to suit the specific task requirements	Contextual	[67], [72, p. 82], [86], [87]
Designed to fit the requirement needs of each user in each specific task	Customised	[64], [67], [87], [88]
Hands-free to perform tasks	Hands-free	[89, p. 520]
Easy and fast to understand and use	Intuitive	[72, p. 82], [88, p. 5]

Multiple use XR elements reduce cost and time and provide design consistency by enabling the virtual object(s) to be applied in various applications. For instance, in a vehicle HMI control design [78], "Assets created by product design teams working on HMI can later be repurposed for use in marketing materials. Ultimately, this makes for more efficient use of company resources and keeps the designs consistent across an entire brand." [83]. This ability improves user engagement in both the virtual and physical worlds, as exemplified in the merging of e-Commerce with brick-and-mortar stores which created phygital (physical and digital) assets to provide immersive experiences in-store [84], [85].

A summary of the user benefits experienced in using XR platforms is summarised in Table III. This linked essential experiences a user would want within the virtual environment with those of the XR technology platform (element feature), which encompasses the hardware, software and application design. It provides a reference for the ability to develop and implement immersive experiences. As each experience depends on the specific task, it requires understanding the applications' areas of foci.

b) XR Applications' Areas of Foci

The benefits of using XR can be applied to core uses of "Gaming and Entertainment", "Education and Training", and "Enhanced Navigation, Smart Infrastructure, Communications" [90, pp. 10–14], which can be separated into areas of foci, as

- Machine control, Data interface (M) - ability to control equipment or vehicles or access information about them
- Design, Planning, Testing, Evaluation (D) - create new layouts or features of buildings, equipment, products
- Remote support (RS) - view information to guide the successful completion of tasks
- Training, Education, Learning, Understanding (T)
- Customer engagement (C) - demonstrations of new product ideas
- Remote collaboration (RC) - interact with people in different locations at the same time
- Entertainment, Escapism (E) - relaxing activities such as games, movies, art.

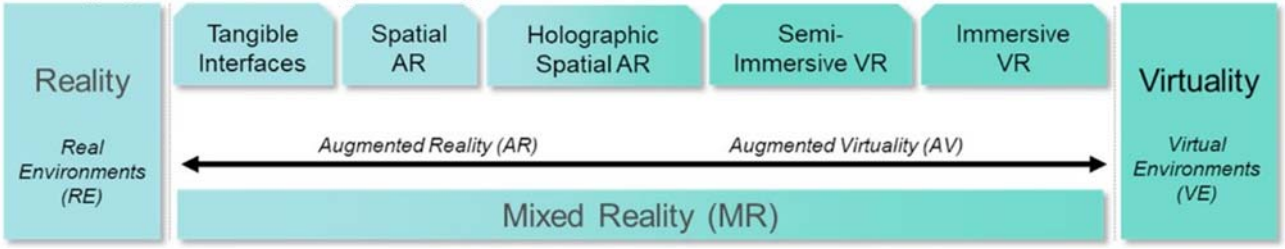

Fig. 6: Spectrum of the Transition from Real to Virtual Environments (source: [64, p. 154]*)*

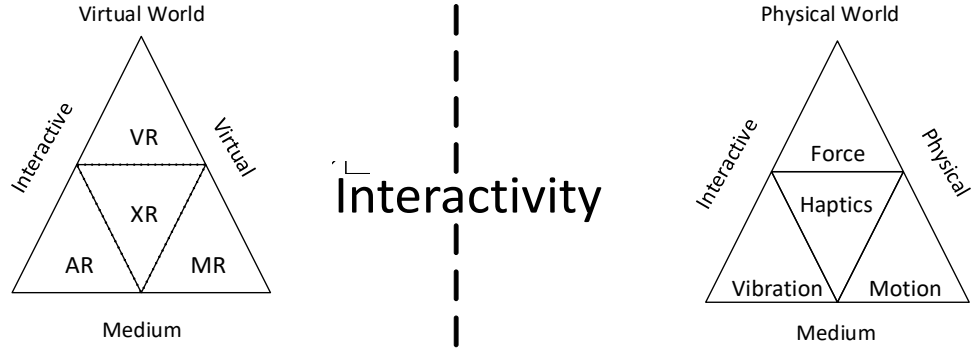

Fig. 7: Relationship of User Interactivity Transitioning Between the Real and Virtual Worlds (source: [92, p. 115]*)*

TABLE IV: XR APPLICATIONS' AREAS OF FOCI IDENTIFIED BASED ON SCOPING LITERATURE REVIEW OF SAMPLED JOURNAL PAPERS

Cited Authors	M	D	RS	T	C	RC	E
[93]				✓			✓
[94]				✓			
[72]	✓	✓		✓			✓
[95]				✓			
[86]	✓	✓	✓	✓			✓
[96]				✓			
[97]				✓			
[63]	✓						
[98]				✓		✓	
[89]	✓	✓	✓	✓			
[99]				✓			
[100]			✓				
[101]	✓		✓	✓			
[82]		✓	✓	✓		✓	
[102]			✓	✓	✓		
[103]				✓			
[104]				✓			
[105]		✓					
[106]				✓			
[61]		✓		✓			
[107]				✓			
[67]				✓			
[108]	✓						
[109]				✓			
[64]	✓	✓		✓	✓	✓	
[110]				✓			
[111]				✓			✓
[112]				✓		✓	✓
[113]				✓			
[114]				✓			
[115]				✓			
[116]				✓		✓	
[117]				✓			✓
[118]		✓					
[119]					✓	✓	
[120]		✓		✓		✓	
[78]		✓		✓	✓	✓	
[121]				✓			
[122]				✓			
[123]				✓			
[124]				✓			
[88]				✓			
[125]		✓		✓			
[126]				✓			
[76]				✓			
[87]				✓			
[71]	✓			✓			
[65]				✓		✓	✓
[127]				✓			
[128]				✓			
[129]			✓				
[130]				✓			
[131]				✓			
[132]				✓			
Total	8	11	7	47	4	9	7
Percentage	14.8	20.4	13.0	87.0	7.4	16.7	13.0

Table IV highlights the XR applications' areas of foci identified through a review of a sample of 54 academic journal papers. This determined that training, education, learning or understanding was a popular objective, thus identifying it as a core focus of an XR application. Different areas of foci may be better performed by a specific type of XR technology. As the range of XR applications' areas of foci is varied, it is essential to understand the scope of the terms AR, VR and MR [91] as they apply across the spectrum of transition from the real to the virtual worlds (Fig. 6) and the interactivity that a user experience in moving between them (Fig. 7). This would determine the specific XR application feature set that is required for various environments and tasks.

Therefore, XR application parameters depend on the UX benefits needed, XR applications' areas of foci of the specific task, the type of XR user interface being used, and the level of interactivity required between the real and digital worlds. Furthermore, the level of immersion depends upon the user, environment (or location) and task (or purpose). Thus, XR content development becomes an essential factor in this process.

D. XR Content Development

There is an ever-growing demand for innovative and creative content for the virtual space. This is demonstrated in the competitive space amongst meetings and other remote collaborative XR-based software environments constructed from various virtual elements to form exciting digital spaces [133]. These assets can be created as 2D or 3D objects. However, the choice between development in 2D vs 3D must be related to the context in which the information will be accessed, understood and applied to the task [134]–[136].

Content development of XR elements usually requires complex and expensive programming skills, and there is a need to democratise this process, expand the user accessibility base, and be platform-agnostic [137], [138]. Thus, the benefit is that XR immersive environments can be created by and experienced by anyone, anywhere and using any device. Furthermore, it will "make XR acceptable and available to larger audience at affordable cost" [65, p. 3].

As part of this approach, Seek developed "a system for converting "any type" of a 3D model into a platform-agnostic augmented reality asset", which will enable 3D content to be created and modified using their technology and then democratise the publishing and viewing of AR content on any platform [139]. The core benefit is the production cost and time saved in converting assets into formats that specific AR platforms can read. However, this will make Seek a critical link in the create-modify part of the development chain.

Thus, development platforms such as Unity [140], Unreal Engine [141], Blender [142] and Roblox [143] are some examples that have a low barrier to entry. This is either through being free or having a free commercial tier, which would be an essential component for developers and would encourage novices to enter this domain to start creating.

As such, these summarised lessons in developing virtual worlds can be applied within the development process [144]:

- Proper selection of content development platform based on technology limitations for accessibility, ease of customising existing templates or creating new 3D assets
- Design considerations to determine the look and "feel" of the virtual space as whether it should be a digital twin (replica of a physical asset) or based on limitless imagination ("castle in the sky")
- Focus on human-centred UX/UI features "abilities, goals and expectations of the intended users"

They can be used to identify core features of a democratised development platform that are:

- Easy to use in developing (including creating or modifying) 2D or 3D assets
- Low cost or zero capital investment (free application tools, free tiers of platform use or costs applied only when minimum sales level is achieved)
- Fast development (from concept idea to implementation of a minimum viable product (MVP))
- Low technical requirement (enable anyone to develop 2D or 3D assets without the need for high-level programming skills)
- Can be integrated into and used on various platforms (develop content for AR, VR or MR applications and published on various systems)

E. Financial Sources to Support XR Development

Although there are low-cost or free software development platforms (as noted in Section 0: Table IV *highlights* the XR applications' areas of foci identified through a review of a sample of 54 academic journal papers. This determined that training, education, learning or understanding was a popular objective, thus identifying it as a core focus of an XR application. Different areas of foci may be better performed by a specific type of XR technology. As the range of XR applications' areas of foci is varied, it is essential to understand the scope of the terms AR, VR and MR [91] as they apply across the spectrum of transition from the real to the virtual worlds (Fig. 6) and the interactivity that a user experience in moving between them (Fig. 7). This would determine the specific XR application feature set that is required for various environments and tasks.

Therefore, XR application parameters depend on the UX benefits needed, XR applications' areas of foci of the specific task, the type of XR user interface being used, and the level of interactivity required between the real and digital worlds. Furthermore, the level of immersion depends upon the user, environment (or location) and task (or purpose). Thus, XR content development becomes an essential factor in this process.

XR Content Development), finances are required to procure hardware, Internet access, and developers' time. As such, monetising virtual assets and investments are two options.

a) *NFTs as a mechanism to monetise Virtual Assets*

Creatives can generate both active and passive revenue by selling virtual assets to consumers who utilise them for various foci (such as collaborations, entertainment, data interface and training). It provides a symbiotic relationship between producer and consumer which encourages the adoption and permanent use of the "metaverse where creators can earn a living and people can purchase digital goods, services, and experiences" [145], [146].

NFTs are a mechanism to facilitate this process via their unique digitalised smart contracts that enable secure transactions based on the blockchain protocol [147, p. 3], [148]–[150]. The NFT of the virtual asset is permanently linked to the creator. Moreover, it contains rules of sale to enable both active incomes (direct development of the asset for sale to a user) and passive income (NFT-linked virtual assets can be resold by various entities with the creator receiving a percentage based on the specifics of the smart contract) [151], [152, p. 3].

The popularity of NFTs is demonstrated by companies expanding their customer engagement through customisation and delivery of unique or limited experiences or products through this platform. One example is Gap's use of the Tezos platform to create NFTs designed by Brandon Sines to embed "community, creativity, and self-expression" into the retailer's marketing strategy [153]. Another example is Perfect Corp which developed NFT AR assets to facilitate "beauty and fashion brands with new revenue stream opportunities, while providing customers with an interactive and personalised element" [154].

Various Caribbean creatives have entered this realm to generate revenue and engage customers through unique art, music, fashion and various collectables. A sample of these products is summarised in Table V to demonstrate that regional entities can accomplish it. This drive to facilitate creators' development of NFTs could be accomplished by connecting consumers into this ecosystem that enables a supply-demand relationship and thus provide sustainability for the innovators [146].

TABLE V: CARIBBEAN THEMED NFT PRODUCTS

Caribbean Creative Works	NFT Product Category	Cited Authors
Jamaican Bay-C's reggae music	Art, music, collectables	[155], [156]
Art auction of works by Jamaican-born-Caymanian Shane Aquârt 'dready'	Art	[157]
Barbadian Haleek Maul record sale	Music	[158]
Barbadian Shain "Rudy Vuitton" Clarke's artistic piece "Mojos Dome"	Art	[158]
"Views from 6 Roads" Digital Artwork meme	Art	[158]
NFT platform for Caribbean artists	Art, music, collectables	[159]
Barbadadian Shontelle Layne NFTs comprised customised artwork, a cameo in the music video, and a dubplate that would include a shout-out to the top buyers, among other exclusive opportunities	Art, music, collectables	[156]
Caribbean fashion NFT WYLD TING	Art, music, fashion	[156]

b) XR Investment

Funding directly applied to XR projects would alleviate creators' need to consistently engage with potential buyers and reduce the financial uncertainty of selling their virtual assets based on a global supply-demand marketplace. In addition, this would enable them to focus on developing the application.

A sample of various global investment initiatives is identified in Table VI to illustrate the availability and range of funds and the variety of the critical criteria for awarding monetary support. These programmes will help to develop the metaverse, various XR applications and developer competencies. However, there are a few shortcomings: they do not all focus directly on the creator; they may be platform specific and not allow an agnostic development; funding may be geographic specific.

CARIRI addressed many of these issues through an investment competition launched in 2020 to assist XR developers in commercialising their projects, with first place receiving TTD 40,000 (approximately USD 5,890 on the 19th

of February 2021 [160]) to complete the project and other prizes being TTD 20,000 (approximately USD 2,945 on the 19th February 2021 [160]) worth of devices [161]. However, this programme only focused on the citizens of Trinidad and Tobago. As such, there is a need to support XR developers throughout the Caribbean and provide a higher capital investment into AR, VR or MR-based projects.

The potential access to funding from global or regional sources raises the following concerns: Is it possible for regional XR developers to compete for global XR funding? Is a better strategy a focused regional investment? Will more significant opportunities exist through a combination of the two options? This question would focus future research on Caribbean XR developers to understand their needs and factors that affect their XR project development. It is, therefore, useful to identify the types of Caribbean XR applications that have already been developed.

TABLE VI: GLOBAL INVESTMENT IN METAVERSE AND XR DEVELOPMENT

Value ($USD)	Fund Focus	Funder	Cited Authors
100M	Approximately 31 XR projects (out of 390 recipients) focusing on "games to simulation to education" were able to access parts of the Epic MegaGrants program fund using Epic Games' development platform Unreal Engine	Epic Games	[162]
100M	Snapdragon Metaverse Fund will support projects that use the Qualcomm Snapdragon platform ecosystem to focus on "building unique, immersive XR experiences, as well as associated core augmented reality (AR) and related artificial intelligence (AI) technologies"	Qualcomm	[163], [164]
50M	Meta's various platforms will be utilised through partnerships "with organizations like Women in Immersive Tech, Africa No Filter, Electric South, and the Organization of American States" to develop elements of the metaverse to provide "compatibility with other services, as well as inclusivity, privacy, safety, and "economic opportunity""	Meta	[8]
50M	The fund focuses on global investments in "virtual reality games and related areas like the metaverse"	Tower 26 venture fund	[165]
27.5M	Total of FOV's first fund will "focus on Europe-based metaverse startups" "working specifically in the areas of 'Avatars & Identity', 'Retail & Digital Commerce', 'Immersive Social', 'Future of Work', and 'Tools & Infrastructure'."	FOV Ventures	[166]
25M	"Caribbean digital education and professional training" using EON Reality's EON-XR platform	EON Reality	[22]
20M	Niantic's Lightsight AR Development Kit (ARDK) for Unity will be used to "accelerate the growth of AR applications and experiences"	Niantic	[167]
15M	Fund provided "seed investments in gaming VR and AR"	GC Tracker Fund	[165]
10M	Meta's Horizon VR platform (Horizon Worlds) will be used to "build "the very best worlds"; "give people from diverse backgrounds an advanced crash course in Horizon Worlds creation"; and "making "experiences""	Meta	[168]
0.7M	Meta's Spark AR and Presence Platform will be used to "build something cool and useful" with user privacy in mind	Meta	[169]
0.5M	Meta's Horizon Worlds will be used for "creating unique, innovative, and engaging worlds"	Meta	[170]
0.07M	NASA MarsXR Challenge "to create new assets and scenarios to create realistic research, development, and testing environments" using the Epic Games' Unreal Engine 5 platform	HeroX	[171]

F. Caribbean XR Projects

Table VII highlights some XR projects developed for use within the Caribbean or focusing on a Caribbean element (such as marketing a locally produced product or experiencing a tour of part of a country). This sampled variety demonstrates the importance of Caribbean creatives to develop content and applications that will attract, engage and retain users. This ability to extend Caribbean-centric products and services to the global market using virtual domains can strengthen its economic viability using XR as a mechanism for diversification which will be unaffected by disruptions to the physical supply chain infrastructure.

These projects are part of the evolving Caribbean metaverse and can advance the region's innovative and sustainable competencies that improve its sustainability. As such, a system must be developed to encourage the continued development of various virtual and immersive environments that can be linked together and satisfy various applications' areas of foci.

IV. CONCLUSION

A bibliometric analysis of metaverse-themed research illustrated the rapid increase in interest during the 2021-2022 period, which accounted for 91% of the 644 documents. Furthermore, analysis of the titles revealed that the XR group (AR, VR and MR) occurred three times more than blockchain and NFT combined. It infers an association between the development of the metaverse and the application of XR technology platforms.

Thus, the metaverse will become an extension of human interactivity that bridges the gap between the physical and virtual environments. It is facilitated through emerging technologies that enable the integration, visualisation and manipulation of Big Data generated within the real and virtual worlds. This exchange of information between the two decentralised systems is provided through various user interfaces (such as XR and haptics) that interconnect people with anything to do anything. Thus, the metaverse can be thought of as the practical implementation of I4.0, defined as "the evolutionary change in decentralised connected systems

to enable the intelligent integration of the horizontal and vertical value chains of an organisation" [69, p. 370].

As an enabling technology of I4.0, XR becomes a key component in this strategy which develops innovation, competitiveness and sustainability by providing benefits in the business, process and customer segments. Therefore, the metaverse will be shaped by XR. It highlights the importance of a democratised developmental platform that lowers the barrier to entry to allow anyone to create AR, VR or MR applications. Furthermore, its adoption can be encouraged through direct investments in XR projects and competency development.

XR application element features as relevant, contextual, customised, hands-free and intuitive are applied across various focus areas such as machine control and data interface; design and testing; remote support; education; customer engagement; remote collaboration; and entertainment and escapism. These create respective UX benefits as critical changes in the virtual or physical world updated in the user's virtual object; virtual design features adaptable to specific tasks; fit the user needs in each specific task; free hands to perform tasks; as well as easy and fast to understand and use. The popularity of implementing the core focus area of education (including training, learning and understanding) infers that most developers include this feature in their XR projects. However, a future survey would be needed to validate the importance of this area of focus before it is considered for inclusion as part of a reference guide to aid developers in determining the goal(s) of their XR project.

TABLE VII: SAMPLE OF CARIBBEAN XR APPLICATIONS WITH THEIR XR APPLICATIONS' AREAS OF FOCI

Caribbean XR Examples	XR Applications' Areas of Foci	Cited Authors
Augmented reality web series accessed through scanning the QR code on Shandy Carib labels	Entertainment, Escapism; Customer engagement	[172]
Virtual reality experience of a Caesar's Army Carnival atmosphere	Entertainment, Escapism; Customer engagement; Remote collaboration	[173]
Augmented Reality gaming tourism and advertising app	Entertainment, Escapism; Customer engagement	[17]
Virtual tour of industrial estates and ports	Entertainment, Escapism; Customer engagement	[174]
Virtual reality steel pan	Entertainment, Escapism; Training, Education, Learning, Understanding	[175]
Virtual reality experience "of Prime Minister Eric Williams delivering his first Independence Day address to the T&T Parliament at the Red House in 1962"	Entertainment, Escapism; Training, Education, Learning, Understanding	[176]
Augmented reality steelpan	Entertainment, Escapism;	[177]
AR filter to wear virtual team kits and hats in Republic Bank -Caribbean League Tournament	Entertainment, Escapism;	[177]
AR filter to wear Carnival headpiece	Entertainment, Escapism;	[177]
Central Bank museum virtual art exhibition	Entertainment, Escapism;	[178]
Virtual Reality recreation of Plymouth, Montserrat	Training, Education, Learning, Understanding; Entertainment, Escapism;	[179], [180]
Marriott tourism promotions of Caribbean vacations spots	Entertainment, Escapism; Customer engagement	[181]
Haiti AR virtual tours	Training, Education, Learning, Understanding; Entertainment, Escapism;	[181], [182]
Grenada AR tourism marketing advert via Stylist magazine	Entertainment, Escapism; Customer engagement	[181]
CocoBay, Bahamas AR and VR marketing	Entertainment, Escapism; Customer engagement	[181]
Diving with sharks	Entertainment, Escapism;	[181]
Exploring Havana, Cuba	Entertainment, Escapism;	[181]
Experience Bahamas culture and heritage	Training, Education, Learning, Understanding; Entertainment, Escapism;	[181]
Experiencing 360-degree views of beaches of Pinel Island, St. Maarten & St. Barts	Entertainment, Escapism;	[181]
Caribbean Coconut Industry Development Project (CCIDP) uses AR to raise awareness of all coconut products	Training, Education, Learning, Understanding;	[183]
"Tropic Shades" "Island Life" AR filter for Instagram	Entertainment, Escapism;	[184]
AR mural	Entertainment, Escapism;	[185]
AR brings art to life	Entertainment, Escapism;	[186]
VR experience of "walking down Frederick Street as a woman and being heckled"	Training, Education, Learning, Understanding;	[187]
VR ""Behind The Wheel," where you drive and have to deal with distractions and end up in an accident"	Training, Education, Learning, Understanding;	[187]
Maracas Beach experience	Entertainment, Escapism;	[187]
Hope for Haiti VR world "social VR platform to hold events and guided tours through some of the projects, people, and stories of people working for their non-profit"	Training, Education, Learning, Understanding; Remote collaboration	[188]

The Caribbean has demonstrated an interest in the utility of the metaverse, a history of XR project development and encouragement in creating and using virtual elements. It is manifested through the various Caribbean-themed XR projects (such as wearing a Carnival headpiece, visiting islands' beaches and heritage sites or playing the steelpan). EON Reality and Meta investments increase regional XR competencies using their platforms (EON-XR and Spark AR).

Generation and sale of NFTs that monetise creatives' fashion, art, music and collectables. The launch of the CARIRI AR/VR challenge.

This review paper raises the question: What factors of influence will encourage the development of XR projects in the Caribbean to advance their metaverse development? Future research on a survey of Caribbean XR developers would answer this question.

There is an insufficient amount of literature explicitly focused on the Caribbean metaverse. This research illustrates the impact the Caribbean is having on its evolution in areas of XR and NFT. It adds to the literature to encourage future research in this area as a mechanism to develop strategies that promote the region's innovation, competitiveness and sustainability.

REFERENCES

[1] D. Takahashi, "Facebook unveils Horizon Home social VR, Messenger VR calls, and fitness VR on road to metaverse," VentureBeat, Oct. 28, 2021. https://venturebeat.com/2021/10/28/facebook-unveils-horizon-home-social-vr-messenger-vr-calls-and-fitness-vr-on-road-to-metaverse/ (accessed Oct. 31, 2021).

[2] PwC, "Caribbean Digital Readiness Survey 2021 Hello tomorrow. From transforming to transcending," Port-of-Spain, 2021. [Online]. Available: https://www.pwc.com/cb/en/issues/assets/digital-readiness-survey-2021.pdf

[3] PwC, "Seeing is believing How virtual reality and augmented reality are transforming business and the economy," London, UK, 2019. [Online]. Available: https://www.pwc.com/gx/en/technology/publications/assets/how-virtual-reality-and-augmented-reality.pdf

[4] M. Adair, "Five Industries That Will Be Transformed By The Metaverse," Forbes, Mar. 22, 2022. https://www.forbes.com/sites/forbestechcouncil/2022/03/22/five-industries-that-will-be-transformed-by-the-metaverse/ (accessed Mar. 27, 2022).

[5] M. Boland, "Is AR Shopping a Metaverse Precursor?," AR Insider, Jan. 19, 2022. https://arinsider.co/2022/01/19/is-ar-shopping-a-metaverse-precursor/ (accessed Jan. 20, 2022).

[6] N. Nixon, "The most in-demand soft skill has an ROI," Fast Company, Dec. 07, 2021. https://www.fastcompany.com/90702629/3-reasons-soft-skills-have-roi (accessed Dec. 12, 2021).

[7] M. E. Porter and J. E. Heppelmann, "Why Every Organization Needs an Augmented Reality Strategy AR will become the new interface between humans and machines," Harvard Business Review, Nov. 2017. https://hbr.org/2017/11/why-every-organization-needs-an-augmented-reality-strategy (accessed May 14, 2021).

[8] M. Clark, "Facebook is spending $50 million to 'responsibly' build the metaverse," The Verge, Sep. 27, 2021. https://www.theverge.com/platform/amp/2021/9/27/22696578/facebook-metaverse-ar-vr-fund-research-definition (accessed Oct. 31, 2021).

[9] J. Golden, "Nike is quietly preparing for the metaverse," CNBC, Nov. 02, 2021. https://www.cnbc.com/2021/11/02/nike-is-quietly-preparing-for-the-metaverse-.html (accessed Nov. 04, 2021).

[10] J. Wray, "Connected packaging: A door to new worlds," Cosmetics Business, Oct. 25, 2021. https://cosmeticsbusiness.com/news/article_page/Connected_packaging_A_door_to_new_worlds/180119/cn5392 (accessed Nov. 24, 2021).

[11] J. Kelly, "Walmart Plans Launch Of NFTs Cryptocurrency And Tokens As It Dives Into The Metaverse And Virtual Reality," Forbes, Jan. 17, 2022. https://www.forbes.com/sites/jackkelly/2022/01/17/walmart-plans-launch-of-nfts-cryptocurrency-and-tokens-as-it-dives-into-the-metaverse-and-virtual-reality/ (accessed Jan. 17, 2022).

[12] L. Thomas, "Walmart is quietly preparing to enter the metaverse," CNBC, Jan. 16, 2022. https://www.cnbc.com/2022/01/16/walmart-is-quietly-preparing-to-enter-the-metaverse.html (accessed Jan. 29, 2022).

[13] M. Tao, "Unity and Hyundai partner to build virtual twin of automotive manufacturing facility," Robotics & Automation News, Jan. 11, 2022. https://roboticsandautomationnews.com/2022/01/11/unity-and-hyundai-partner-to-build-virtual-twin-of-automotive-manufacturing-facility/ (accessed Jan. 18, 2022).

[14] J. Mueller, "Decentraland: Beauty's Metaverse Partner," Global Cosmetic Industry, Mar. 23, 2022. https://www.gcimagazine.com/brands-products/news/news/22131673/lottie-london-previews-new-nail-collection-on-decentraland (accessed Mar. 27, 2022).

[15] E. Ajao, "Deloitte launches new metaverse services and studio," SearchEnterpriseAI, Jan. 13, 2022. https://www.techtarget.com/searchenterpriseai/news/252511950/Deloitte-launches-new-metaverse-services-and-studio (accessed Jan. 18, 2022).

[16] J. R. Rameshwar, "COVID-19 Can Create Opportunity for IoT in the Caribbean: A Necessary Digital Transformation," IIC J. Innov., vol. November, p. 30, 2020, [Online]. Available: https://www.iiconsortium.org/news/joi-articles/2020_November_JoI_COVID-19_Can_Create_Opportunity_for_IoT_in_the_Caribbean.pdf

[17] S. Boodan, "Inventor shows how tech can boost tourism," Trinidad & Tobago Guardian, Feb. 20, 2021. https://www.guardian.co.tt/news/inventor-shows-how-tech-can-boost-tourism-6.2.1291815.4053b980c6 (accessed Mar. 03, 2021).

[18] "Digital skills are vital now," CARICOM Today, Sep. 28, 2021. https://today.caricom.org/2021/09/22/digital-skills-are-vital-now/ (accessed Nov. 06, 2021).

[19] L. V Williams, "CARIRI launches augmented reality/virtual reality challenge," Trinidad and Tobago Newsday, Nov. 09, 2020. https://newsday.co.tt/2020/11/09/cariri-launches-augmented-reality-virtual-reality-challenge/ (accessed Jun. 18, 2021).

[20] CARIRI, "AR/VR Challenge – -changethegame," 2020. https://www.cariri.com/Challenge/ (accessed Apr. 26, 2022).

[21] The UWI, "About The UWI." https://www.uwi.edu/about.php (accessed Apr. 28, 2022).

[22] J. Loutoo, "UWI secures US$25 million technology grant," Trinidad and Tobago Newsday, Apr. 05, 2021. https://newsday.co.tt/2021/04/05/uwi-secures-us25-million-technology-grant/ (accessed Apr. 26, 2022).

[23] OAS, "OAS and Meta Partner to Train Thousands of Latin American and Caribbean Creators in Augmented Reality," Dec. 15, 2021. https://www.oas.org/en/media_center/press_release.asp?sCodigo=E-116/21 (accessed Apr. 27, 2022).

[24] H. Hope, "Barbados in the Metaverse," NationNews, Jan. 06, 2022. https://www.nationnews.com/2022/01/06/barbados-in-the-metaverse/ (accessed Jan. 08, 2022).

[25] A. Thurman, "Barbados to Become First Sovereign Nation With an Embassy in the Metaverse," CoinDesk, Nov. 15, 2021. https://www.coindesk.com/business/2021/11/15/barbados-to-become-first-sovereign-nation-with-an-embassy-in-the-metaverse/ (accessed Nov. 20, 2021).

[26] M. Wong, "St Vincent wants to be first island to host Carnival in the Metaverse," Loop Caribbean News, Jan. 18, 2022. https://caribbean.loopnews.com/content/st-vincent-wants-be-first-island-host-carnival-metaverse-587786 (accessed Jan. 31, 2022).

[27] L. Hanna, "In a digital world content is king!," Jamaica Observer, Apr. 11, 2021. https://www.jamaicaobserver.com/the-agenda/in-a-digital-world-content-is-king-_218743 (accessed Mar. 23, 2022).

[28] L. Hanna, "Let's brand the metaverse with J'can NFT lifestyle?," Jamaica Observer, Jan. 30, 2022. https://www.jamaicaobserver.com/the-agenda/let-s-brand-the-metaverse-with-j-can-nft-lifestyle-_242609 (accessed Mar. 23, 2022).

[29] CTU, "Traversing the Metaverse – A Caribbean Perspective," Jan. 31, 2022. https://ctu.int/event/traversing-the-metaverse-a-caribbean-perspective-2/ (accessed Jan. 23, 2022).

[30] M. Lyndersay, "The metaverse in the Caribbean: What it is and why it's important," Trinidad and Tobago Newsday, Feb. 10, 2022. https://newsday.co.tt/2022/02/10/the-metaverse-in-the-caribbean-what-it-is-and-why-its-important/ (accessed Feb. 11, 2022).

[31] CTU, "THE METAVERSE: A NEW OPPORTUNITY FOR WEALTH GENERATION FOR CARIBBEAN CITIZENS㊊," https://ctu.int/the-metaverse-a-new-opportunity-for-wealth-generation-for-caribbean-citizens㊊/ (accessed Feb. 02, 2022).

[32] S. Hall and R. Takahashi, "Augmented and virtual reality: The promise and peril of immersive technologies," Oct. 03, 2017. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/augmented-and-virtual-reality-the-promise-and-peril-of-immersive-technologies (accessed May 14, 2021).

[33] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," J. Bus. Res., vol. 133, pp. 285–296, Sep. 2021, doi: 10.1016/j.jbusres.2021.04.070.

[34] K. Li, J. Rollins, and E. Yan, "Web of Science use in published research and review papers 1997–2017: a selective, dynamic, cross-domain, content-based analysis," Scientometrics, vol. 115, no. 1, pp. 1–20, Apr. 2018, doi: 10.1007/S11192-017-2622-5/TABLES/8.

[35] R. Pranckutė, "Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World," Publications, vol. 9, no. 1, p. 12, Mar. 2021, doi: 10.3390/publications9010012.

[36] I. F. Aguillo, "Is Google Scholar useful for bibliometrics? A webometric analysis," Scientometrics, vol. 91, no. 2, pp. 343–351, May 2012, doi: 10.1007/s11192-011-0582-8.

[37] Clarivate, "Web of Science: Definition and Use of Wildcards," Jun. 10, 2022. https://support.clarivate.com/ScientificandAcademicResearch/s/article/Web-of-Science-Definition-and-Use-of-Wildcards (accessed Aug. 06, 2022).

[38] Clarivate, "Web of Science: Display of All Databases Search and Results Precedence," May 26, 2022. https://support.clarivate.com/ScientificandAcademicResearch/s/article/Web-of-Science-Display-of-All-Databases-Search-and-Results-Precedence (accessed Aug. 06, 2022).

[39] Clarivate, "Web of Science Core Collection: Duplicate records in different editions are de-duplicated," Aug. 02, 2022. https://support.clarivate.com/ScientificandAcademicResearch/s/article/Web-of-Science-Core-Collection-Duplicate-records-in-different-editions-are-de-duplicated (accessed Aug. 04, 2022).

[40] A. C. Tricco et al., "A scoping review of rapid review methods," BMC Med., vol. 13, no. 1, Sep. 2015, doi: 10.1186/s12916-015-0465-6.

[41] J. Peterson, P. F. Pearce, L. A. Ferguson, and C. A. Langford, "Understanding scoping reviews," J. Am. Assoc. Nurse Pract., vol. 29, no. 1, pp. 12–16, Jan. 2017, doi: 10.1002/2327-6924.12380.

[42] M. Gusenbauer, "Google Scholar to overshadow them all? Comparing the sizes of 12 academic search engines and bibliographic databases," Scientometrics, vol. 118, no. 1, pp. 177–214, Jan. 2019, doi: 10.1007/S11192-018-2958-5/TABLES/4.

[43] C. Cole, A. R. Davis, V. Eyer, and J. J. Meier, "Google Scholar's Coverage of the Engineering Literature 10 years Later," J. Acad. Librariansh., vol. 44, no. 3, pp. 419–425, May 2018, doi: 10.1016/J.ACALIB.2018.02.013.

[44] A. W. K. Harzing and R. van der Wal, "Google Scholar as a new source for citation analysis," Ethics Sci. Environ. Polit., vol. 8, no. 1, pp. 61–73, Jun. 2008, doi: 10.3354/ESEP00076.

[45] J. C. F. de Winter, A. A. Zadpoor, and D. Dodou, "The expansion of Google Scholar versus Web of Science: a longitudinal study," Sci. 2013 982, vol. 98, no. 2, pp. 1547–1565, Aug. 2013, doi: 10.1007/S11192-013-1089-2.

[46] S. Mystakidis, "Metaverse," Encyclopedia, vol. 2, no. 1, pp. 486–497, Feb. 2022, doi: 10.3390/encyclopedia2010031.

[47] S.-V. Rehm, L. Goel, and M. Crespi, "The Metaverse as Mediator between Technology, Trends, and the Digital Transformation of Society and Business," J. Virtual Worlds Res., vol. 8, no. 2, Oct. 2015, doi: 10.4101/jvwr.v8i2.7149.

[48] Y. Zhao et al., "Metaverse: Perspectives from graphics, interactions and visualization," Vis. Informatics, vol. 6, no. 1, pp. 56–67, Mar. 2022, doi: 10.1016/j.visinf.2022.03.002.

[49] S.-M. Park and Y.-G. Kim, "A Metaverse: Taxonomy, Components, Applications, and Open Challenges," IEEE Access, vol. 10, pp. 4209–4251, 2022, doi: 10.1109/ACCESS.2021.3140175.

[50] N. G. Narin, "A Content Analysis of the Metaverse Articles," Journal of Metaverse, vol. 1, no. 1, pp. 17–24, 2021, Accessed: May 08, 2022. [Online]. Available: https://dergipark.org.tr/en/pub/jmv/issue/67581/1051382

[51] M. Damar, "Metaverse Shape of Your Life for Future: A bibliometric snapshot," Journal of Metaverse, vol. 1, no. 1, pp. 1–8, 2021, Accessed: May 08, 2022. [Online]. Available: https://dergipark.org.tr/en/pub/jmv/issue/67581/1051371

[52] S. B. Hall and M. Baier-Lentz, "3 technologies that will shape the future of the metaverse – and the human experience," World Economic Forum, Feb. 07, 2022. https://www.weforum.org/agenda/2022/02/future-of-the-metaverse-vr-ar-and-brain-computer/ (accessed May 01, 2022).

[53] J. D. N. Dionisio, W. G. Burns III, and R. Gilbert, "3D Virtual worlds and the metaverse: Current status and future possibilities," ACM Comput. Surv., vol. 45, no. 3, pp. 1–38, Jun. 2013, doi: 10.1145/2480741.2480751.

[54] D. Owens, A. Mitchell, D. Khazanchi, and I. ZIgurs, "An empirical investigation of virtual world projects and metaverse technology capabilities," ACM SIGMIS Database DATABASE Adv. Inf. Syst., vol. 42, no. 1, pp. 74–101, Feb. 2011, doi: 10.1145/1952712.1952717.

[55] J. Qina, Y. Liua, and R. Grosvenora, "A Categorical Framework of Manufacturing for Industry 4.0 and Beyond," Procedia CIRP, vol. 52, no. 2016, pp. 173–178, 2016, doi: 10.1016/j.procir.2016.08.005.

[56] B. Sniderman, M. Mahto, and M. J. Cotteleer, "Industry 4.0 and manufacturing ecosystems Exploring the world of connected enterprises," New York, 2016. [Online]. Available: https://www2.deloitte.com/content/dam/insights/us/articles/manufacturing-ecosystems-exploring-world-connected-enterprises/DUP_2898_Industry4.0ManufacturingEcosystems.pdf

[57] B. Vogel-Heuser and D. Hess, "Guest Editorial Industry 4.0–Prerequisites and Visions," IEEE Trans. Autom. Sci. Eng., vol. 13, no. 2, pp. 411–413, Apr. 2016, doi: 10.1109/TASE.2016.2523639.

[58] T. Philbeck and N. Davis, "The Fourth Industrial Revolution: Shaping a New Era," J. Int. Aff., vol. 72, no. 1, pp. 17–22, 2019, [Online]. Available: http://search.proquest.com/docview/2290089757/

[59] K. Schwab, The fourth industrial revolution, First. New York: Crown Publishing Group, 2016.

[60] J. R. Rameshwar and G. S. King, "Case Studies in Engineering and Technology Innovation in the Caribbean: A focus on EduColCom and BevCom," in Proceedings of the International Conference on Emerging Trends in Engineering & Technology (IConETech-2020), 2020, pp. 574–584. doi: 10.47412/EBWB6632.

[61] D. Grube, A. A. Malik, and A. Bilberg, "SMEs can touch Industry 4.0 in the Smart Learning Factory," Procedia Manuf., vol. 31, pp. 219–224, 2019, doi: 10.1016/j.promfg.2019.03.035.

[62] A. Dhaliwal, T. Egan, and T. Shinbara, "The Value of Augmented Reality in Manufacturing Technology," McLean, Virginia, 2020. [Online]. Available: https://www.engineering.com/ResourceMain?resid=1029

[63] J. Brinkley, B. Posadas, I. Sherman, S. B. Daily, and J. E. Gilbert, "An Open Road Evaluation of a Self-Driving Vehicle Human–Machine Interface Designed for Visually Impaired Users," Int. J. Human–Computer Interact., vol. 35, no. 11, pp. 1018–1032, Jul. 2019, doi: 10.1080/10447318.2018.1561787.

[64] M. Juraschek, L. Büth, G. Posselt, and C. Herrmann, "Mixed Reality in Learning Factories," Procedia Manuf., vol. 23, pp. 153–158, Jan. 2018, doi: 10.1016/j.promfg.2018.04.009.

[65] A. Vasilchenko et al., "Collaborative learning & co-creation in XR," in Conference on Human Factors in Computing Systems - Proceedings, Apr. 2020, pp. 1–4. doi: 10.1145/3334480.3381056.

[66] H. Pozniak, "Virtual training: can technology come to the rescue?," E&T Magazine, May 18, 2020. https://eandt.theiet.org/content/articles/2020/05/virtual-training-can-technology-come-to-the-rescue/ (accessed Jan. 27, 2021).

[67] N. Ho, P.-M. Wong, M. Chua, and C.-K. Chui, "Virtual reality training for assembly of hybrid medical devices," Multimed Tools Appl, vol. 77, pp. 30651–30682, 2018, doi: 10.1007/s11042-018-6216-x.

[68] M. Walsh, W. Markow, and S. Bittle, "Visualizing the Future Demand for 3D Graphics andReal-time 3D Across the Economy," Boston, MA and Cary, NC USA, 2019. [Online]. Available: https://www.burning-glass.com/research-project/visualizing_future_3d_skills_workforce-old/

[69] G. S. King, J. R. Rameshwar, and C. S. Syan, "Industry 4.0 in a Small Commodity-Based Economy: A Vehicle for Stimulating Innovation," J. Ind. Integr. Manag., vol. 05, no. 03, pp. 365–391, Sep. 2020, doi: 10.1142/S242486222050013X.

[70] V. de Leeuw, "Creating and Deploying Digital Twins in the Process Industsry," Dedham, 2019. [Online]. Available:

https://www.smartindustry.com/assets/Uploads/EXTWP-ARC-Digital-Twins-Process-Industries-LTR-EN-LR.pdf

[71] B. Thiede, G. Posselt, S. Kauffeld, and C. Herrmann, "Enhancing Learning Experience in Physical Action-orientated Learning Factories Using a Virtually Extended Environment and Serious Gaming Approaches," Procedia Manuf., vol. 9, pp. 238–244, 2017, doi: 10.1016/j.promfg.2017.04.042.

[72] A. S. Alqahtani, L. F. Daghestani, and L. F. Ibrahim, "Environments and System Types of Virtual Reality Technology in STEM: a Survey," Int. J. Adv. Comput. Sci. Appl., vol. 8, no. 6, pp. 77–89, 2017, doi: 10.14569/IJACSA.2017.080610.

[73] T. Basu, "Why games like Animal Crossing are the new social media of the coronavirus era," MIT Technology Review, Apr. 16, 2020. https://www.technologyreview.com/2020/04/16/999944/coronavirus-animal-crossing-video-games-social-media/ (accessed Apr. 16, 2020).

[74] S. Lozé, "VR Perspectives brings inclusion and diversity through VR training," Aug. 11, 2020. https://www.unrealengine.com/en-US/spotlights/vr-perspectives-brings-inclusion-and-diversity-through-vr-training (accessed Sep. 03, 2020).

[75] K. Pimentel, "Cornell University partners with industry on a new approach to urban design and planning," Feb. 07, 2020. https://www.unrealengine.com/en-US/spotlights/cornell-university-partners-with-industry-on-a-new-approach-to-urban-design-and-planning (accessed Mar. 08, 2020).

[76] D. Sonntag, G. Albuquerque, M. Magnor, and O. Bodensiek, "Hybrid learning environments by data-driven augmented reality," Procedia Manuf., vol. 31, pp. 32–37, 2019, doi: 10.1016/j.promfg.2019.03.006.

[77] B. Lumsden, "Designing sets and action sequences on 'His Dark Materials' with virtual production," Apr. 27, 2020. https://www.unrealengine.com/en-US/spotlights/designing-sets-and-action-sequences-on-his-dark-materials-with-virtual-production (accessed May 07, 2020).

[78] M. Müller, T. Günther, D. Kammer, J. Wojdziak, S. Lorenz, and R. Groh, "Smart prototyping- Improving the evaluation of design concepts using virtual reality," in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2016, vol. 9740, pp. 47–58. doi: 10.1007/978-3-319-39907-2_5.

[79] I. Millington, Game Physics Engine Development, 1st ed. Boca Raton: CRC Press, 2007. doi: 10.1201/9781482267327.

[80] E. Todorov, T. Erez, and Y. Tassa, "MuJoCo: A physics engine for model-based control," IEEE Int. Conf. Intell. Robot. Syst., pp. 5026–5033, 2012, doi: 10.1109/IROS.2012.6386109.

[81] E. Weitnauer, R. Haschke, and H. Ritter, "Evaluating a Physics Engine as an Ingredient for Physical Reasoning," Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), vol. 6472 LNAI, pp. 144–155, Nov. 2010, doi: 10.1007/978-3-642-17319-6_16.

[82] Å. Fast-Berglund, L. Gong, and D. Li, "Testing and validating Extended Reality (xR) technologies in manufacturing," Procedia Manuf., vol. 25, pp. 31–38, Jan. 2018, doi: 10.1016/j.promfg.2018.06.054.

[83] Epic Games, "USA's largest car maker builds HMI systems in Unreal Engine," Oct. 07, 2020. https://www.unrealengine.com/en-US/blog/usa-s-largest-car-maker-builds-hmi-systems-in-unreal-engine (accessed Nov. 10, 2020).

[84] P. Prior, "Phygital — What Is It And Why Should I Care?," Forbes, Jun. 30, 2021. https://www.forbes.com/sites/forbesbusinesscouncil/2021/06/30/phygital---what-is-it-and-why-should-i-care/?sh=406359c7587a (accessed Oct. 21, 2021).

[85] G. Petro, "The 'Phygital' World: Reinventing The In-Store Experience Digitally," Forbes, Aug. 06, 2021. https://www.forbes.com/sites/gregpetro/2021/08/06/the-phygital-world-reinventing-the-in-store-experience-digitally/?sh=4d0370223863 (accessed Oct. 21, 2021).

[86] R. T. Azuma, "A Survey of Augmented Reality," Presence Teleoperators Virtual Environ., vol. 6, no. 4, pp. 355–385, Aug. 1997, doi: 10.1162/pres.1997.6.4.355.

[87] S. R. Sorko and M. Brunnhofer, "Potentials of Augmented Reality in Training," Procedia Manuf., vol. 31, pp. 85–90, 2019, doi: 10.1016/j.promfg.2019.03.014.

[88] T. Riemann, A. Kreß, L. Roth, S. Klipfel, J. Metternich, and P. Grell, "Agile Implementation of Virtual Reality in Learning Factories," Procedia Manuf., vol. 45, pp. 1–6, 2020, doi: 10.1016/j.promfg.2020.04.029.

[89] A. Ceruti, P. Marzocca, A. Liverani, and C. Bil, "Maintenance in aeronautics in an Industry 4.0 context: The role of Augmented Reality and Additive Manufacturing," J. Comput. Des. Eng., vol. 6, no. 4, pp. 516–526, Oct. 2019, doi: 10.1016/j.jcde.2019.02.001.

[90] J. Jerome and J. Greenberg, "Augmented Reality + Virtual Reality Privacy & Autonomy Considerations in Emerging, Immersive Digital Worlds," Washington DC USA, 2021. [Online]. Available: https://fpf.org/wp-content/uploads/2021/04/FPF-ARVR-Report-4.16.21-Digital.pdf

[91] P. Milgram and F. Kishino, "A Taxonomy of Mixed Reality Visual Displays," IEICE Trans. Inf. Syst., vol. E77-D, no. 12, pp. 1321–1329, Dec. 1994, Accessed: Jan. 31, 2021. [Online]. Available: https://search.ieice.org/bin/summary.php?id=e77-d_12_1321

[92] J. R. Rameshwar, "Transitioning to a Digital Educational Environment A Lecturer's Perspective on Migrating to Google Classroom During the COVID-19 Pandemic in Trinidad and Tobago," UWI Qual. Educ. Forum, vol. 25, pp. 96–119, 2021, [Online]. Available: https://journals.sta.uwi.edu/qef/index.asp?action=viewArticle&articleId=8131&galleyId=6924

[93] M. Ablyaev, A. Abliakimova, and Z. Seidametova, "Developing a Mobile Augmented Reality Application for Enhancing Early Literacy Skills," in Communications in Computer and Information Science, Jun. 2020, vol. 1175 CCIS, pp. 163–185. doi: 10.1007/978-3-030-39459-2_8.

[94] D. Allcoat and A. von Mühlenen, "Learning in virtual reality: Effects on performance, emotion and engagement," Res. Learn. Technol., vol. 26, Nov. 2018, doi: 10.25304/rlt.v26.2140.

[95] H. Altinpulluk, "Determining the trends of using augmented reality in education between 2006-2016," Educ. Inf. Technol., vol. 24, no. 2, pp. 1089–1114, 2019, doi: 10.1007/s10639-018-9806-3.

[96] S. Barteit, L. Lanfermann, T. Bärnighausen, F. Neuhann, and C. Beiersmann, "Augmented, Mixed, and Virtual Reality-Based Head-Mounted Devices for Medical Education: Systematic Review," JMIR Serious Games 2021;9(3)e29080 https//games.jmir.org/2021/3/e29080, vol. 9, no. 3, p. e29080, Jul. 2021, doi: 10.2196/29080.

[97] A. Berns, S. Reyes Sánchez, and I. Ruiz Rube, "Virtual reality authoring tools for teachers to create novel and immersive learning scenarios," in ACM International Conference Proceeding Series, Oct. 2020, pp. 896–900. doi: 10.1145/3434780.3436668.

[98] R. Bucea-Manea-Țoniș, R. Bucea-Manea-Țoniș, V. E. Simion, D. Ilic, C. Braicu, and N. Manea, "Sustainability in Higher Education: The Relationship between Work-Life Balance and XR E-Learning Facilities," Sustainability, vol. 12, no. 14, p. 5872, Jul. 2020, doi: 10.3390/su12145872.

[99] P. Chen, X. Liu, W. Cheng, and R. Huang, "A review of using Augmented Reality in Education from 2011 to 2016," in Lecture Notes in Educational Technology, no. 9789811024184, Springer International Publishing, 2017, pp. 13–18. doi: 10.1007/978-981-10-2419-1_2.

[100] R. De Amicis, A. Ceruti, D. Francia, L. Frizziero, and B. Simões, "Augmented Reality for virtual user manual," Int. J. Interact. Des. Manuf., vol. 12, no. 2, pp. 689–697, May 2018, doi: 10.1007/s12008-017-0451-7.

[101] M. Eder, M. Hulla, F. Mast, and C. Ramsauer, "On the application of Augmented Reality in a learning factory working environment," Procedia Manuf., vol. 45, pp. 7–12, 2020, doi: 10.1016/j.promfg.2020.04.030.

[102] Fei Wang, "Research on Virtual Reality Based on EON Studio," in 2010 Fourth International Conference on Genetic and Evolutionary Computing, Dec. 2010, pp. 558–561. doi: 10.1109/ICGEC.2010.143.

[103] J. M. M. Ferreira and Z. I. Qureshi, "Use of XR technologies to bridge the gap between Higher Education and Continuing Education," in 2020 IEEE Global Engineering Education Conference (EDUCON), Apr. 2020, vol. 2020-April, pp. 913–918. doi: 10.1109/EDUCON45650.2020.9125346.

[104] K. Fiedler, "Virtual Reality in the Cloud: Amazon Sumerian as a Tool and Topic," AMCIS 2019 Proc., Aug. 2019, Accessed: Apr. 15, 2021. [Online]. Available: https://aisel.aisnet.org/amcis2019/treo/treos/12

[105]L. Frajhof, J. Borges, E. Hoffmann, J. Lopes, and R. Haddad, "Virtual reality, mixed reality and augmented reality in surgical planning for video or robotically assisted thoracoscopic anatomic resections for treatment of lung cancer," J. Vis. Surg., vol. 4, pp. 143–143, Jul. 2018, doi: 10.21037/jovs.2018.06.02.

[106]J. Gott et al., "Virtual reality training of lucid dreaming," Philos. Trans. R. Soc. B, vol. 376, no. 1817, p. 20190697, Feb. 2021, doi: 10.1098/RSTB.2019.0697.

[107]T. Gutierrez, J. Rodriguez, Y. Velaz, S. Casado, A. Suescun, and E. J. Sanchez, "IMA-VR: A multimodal virtual training system for skills transfer in Industrial Maintenance and Assembly tasks," in 19th International Symposium in Robot and Human Interactive Communication, Sep. 2010, pp. 428–433. doi: 10.1109/ROMAN.2010.5598643.

[108]C. Hofmann, T. Staehr, S. Cohen, N. Stricker, B. Haefner, and G. Lanza, "Augmented Go & See: An approach for improved bottleneck identification in production lines," Procedia Manuf., vol. 31, pp. 148–154, 2019, doi: 10.1016/j.promfg.2019.03.023.

[109]N. I. Jaksic, "A Virtual Reality Course using EON Reality: Students' Experiences," in 2018 ASEE Annual Conference & Exposition June 24-28, Salt Lake City, UT, 2018, p. 17. [Online]. Available: https://www.asee.org/public/conferences/106/papers/23858/view

[110]S.-H. Lee and B.-S. Jung, "Development of electric vehicle maintenance education ability using digital twin technology and VR," Int. J. Adv. Cult. Technol., vol. 8, no. 2, pp. 58–67, 2020, doi: 10.17703/IJACT.2020.8.2.58.

[111]L. Li et al., "Application of virtual reality technology in clinical medicine," Am. J. Transl. Res., vol. 9, no. 9, p. 3867, 2017, Accessed: Sep. 17, 2021. [Online]. Available: /pmc/articles/PMC5622235/

[112]D. Lockwood and E. Kruger, "Using VR for Human Development in Africa," IEEE Comput. Graph. Appl., vol. 28, no. 3, pp. 99–103, May 2008, doi: 10.1109/MCG.2008.62.

[113]R. Lohre, J. C. Wang, K.-U. Lewandrowski, and D. P. Goel, "Virtual reality in spinal endoscopy: a paradigm shift in education to support spine surgeons," J. Spine Surg., vol. 6, no. S1, pp. S208–S223, Jan. 2020, doi: 10.21037/jss.2019.11.16.

[114]S. Marks, J. Windsor, and B. Wünsche, "Evaluation of game engines for simulated surgical training," in Proceedings - GRAPHITE 2007, 5th International Conference on Computer Graphics and Interactive Techniques in Australasia and Southeast Asia, 2007, pp. 273–280. doi: 10.1145/1321261.1321311.

[115]J. Martín-Gutiérrez, C. E. Mora, B. Añorbe-Díaz, and A. González-Marrero, "Virtual Technologies Trends in Education," EURASIA J. Math. Sci. Technol. Educ., vol. 13, no. 2, pp. 469–486, Jan. 2017, doi: 10.12973/eurasia.2017.00626a.

[116]D. Mavrikios, K. Alexopoulos, K. Georgoulias, S. Makris, G. Michalos, and G. Chryssolouris, "Using Holograms for visualizing and interacting with educational content in a Teaching Factory," Procedia Manuf., vol. 31, pp. 404–410, 2019, doi: 10.1016/j.promfg.2019.03.063.

[117]C. Meier, J. Saorín, A. Bonnet de León, and A. G. Cobos, "Using the Roblox Video Game Engine for Creating Virtual tours and Learning about the Sculptural Heritage," Int. J. Emerg. Technol. Learn., vol. 15, no. 20, pp. 268–280, Oct. 2020, Accessed: Feb. 01, 2021. [Online]. Available: https://www.learntechlib.org/p/218337/

[118]E. G. Milano et al., "Enhanced 3D visualization for planning biventricular repair of double outlet right ventricle: a pilot study on the advantages of virtual reality," Eur. Hear. J. - Digit. Heal., Oct. 2021, doi: 10.1093/ehjdh/ztab087.

[119]D. Mourtzis, V. Siatras, J. Angelopoulos, and N. Panopoulos, "An Augmented Reality Collaborative Product Design Cloud-Based Platform in the Context of Learning Factory," Procedia Manuf., vol. 45, pp. 546–551, 2020, doi: 10.1016/j.promfg.2020.04.076.

[120]D. Mourtzis, V. Zogopoulos, and E. Vlachou, "Augmented Reality supported Product Design towards Industry 4.0: a Teaching Factory paradigm," Procedia Manuf., vol. 23, pp. 207–212, Jan. 2018, doi: 10.1016/j.promfg.2018.04.018.

[121]S. X. Nelson et al., "Development of a 3D Interactive Training Platform for Assembly of Bogie Unit in the Railcar Learning Factory," Procedia Manuf., vol. 45, pp. 386–391, 2020, doi: 10.1016/j.promfg.2020.04.041.

[122]C. J. Ochoa Fenandez, "Special Session—XR Education 21th. Are We Ready for XR Disruptive Ecosystems in Education?," in 2020 6th International Conference of the Immersive Learning Research Network (iLRN), Jun. 2020, pp. 424–426. doi: 10.23919/iLRN47897.2020.9155215.

[123]F. Pilati, M. Faccio, M. Gamberi, and A. Regattieri, "Learning manual assembly through real-time motion capture for operator training with augmented reality," Procedia Manuf., vol. 45, pp. 189–195, 2020, doi: 10.1016/j.promfg.2020.04.093.

[124]F. Quint, K. Sebastian, and D. Gorecky, "A Mixed-reality Learning Environment," Procedia Comput. Sci., vol. 75, pp. 43–48, Jan. 2015, doi: 10.1016/j.procs.2015.12.199.

[125]J. A. Sánchez-Margallo, C. Plaza de Miguel, R. A. Fernández Anzules, and F. M. Sánchez-Margallo, "Application of Mixed Reality in Medical Training and Surgical Planning Focused on Minimally Invasive Surgery," Front. Virtual Real., vol. 0, p. 144, Oct. 2021, doi: 10.3389/FRVIR.2021.692641.

[126]S. Sandrone and C. E. Carlson, "Future of Neurology & Technology: Virtual and Augmented Reality in Neurology and Neuroscience Education," Neurology, vol. 97, no. 15, pp. 740–744, Oct. 2021, doi: 10.1212/WNL.0000000000012413.

[127]M. Wang, J. Ryoo, and K. Winkelmann, "Preface to the special issue on Cross Reality (XR) and Immersive Learning Environments (ILE) in education," Interact. Learn. Environ., vol. 28, no. 5, pp. 539–542, Jul. 2020, doi: 10.1080/10494820.2019.1696845.

[128]J. Wu et al., "Benefits of Virtual Reality Balance Training for Patients With Parkinson Disease: Systematic Review, Meta-analysis, and Meta-Regression of a Randomized Controlled Trial," JMIR Serious Games 2022;10(1)e30882 https//games.jmir.org/2022/1/e30882, vol. 10, no. 1, p. e30882, Mar. 2022, doi: 10.2196/30882.

[129]Y.-T. Yue, X. Zhang, Y. Yang, G. Ren, Y.-K. Choi, and W. Wang, "WireDraw: 3D Wire Sculpturing Guided with Mixed Reality," in Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, May 2017, vol. 2017-May, pp. 3693–3704. doi: 10.1145/3025453.3025792.

[130]X. Zhang, J. Liu, Q. Chen, H. Song, Q. Zhan, and J. Lu, "A 3D virtual Weft-knitting Engineering learning system based on Unreal Engine 4," Comput. Appl. Eng. Educ., vol. 26, no. 6, pp. 2223–2236, Nov. 2018, doi: 10.1002/cae.22030.

[131]H. Zhang et al., "Hotspots and Trends of Virtual Reality, Augmented Reality and Mixed Reality in Education Field," in 2020 6th International Conference of the Immersive Learning Research Network (iLRN), Jun. 2020, pp. 215–219. doi: 10.23919/iLRN47897.2020.9155170.

[132]M. Zhu et al., "Haptic-feedback smart glove as a creative human-machine interface (HMI) for virtual/augmented reality applications," Sci. Adv., vol. 6, no. 19, p. eaaz8693, May 2020, doi: 10.1126/sciadv.aaz8693.

[133]Tanya Basu, "Meetings suck. Can we make them more fun?," MIT Technology Review, Sep. 08, 2021. https://www.technologyreview.com/2021/09/08/1035081/facebook-horizons-oculus-zoom-fatigue (accessed Sep. 13, 2021).

[134]M. M. Sebrechts, J. V. Cugini, S. J. Laskowski, J. Vasilakis, and M. S. Miller, "Visualization of search results: a comparative evaluation of text, 2D, and 3D interfaces," in Proceedings of the 22nd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, Aug. 1999, pp. 3–10. doi: 10.1145/312624.

[135]M. Tory, A. E. Kirkpatrick, M. S. Atkins, and T. Moller, "Visualization task performance with 2D, 3D, and combination displays," IEEE Trans. Vis. Comput. Graph., vol. 12, no. 1, pp. 2–13, Jan. 2006, doi: 10.1109/TVCG.2006.17.

[136]M. Tavanti and M. Lind, "2D vs 3D, implications on spatial memory," in IEEE Symposium on Information Visualization, 2001. INFOVIS 2001., 2001, pp. 139–145. doi: 10.1109/INFVIS.2001.963291.

[137]J. Pike, "How augmented, virtual reality can reduce manufacturing skills gap," Control Engineering, Oct. 30, 2020. https://www.controleng.com/articles/how-augmented-virtual-reality-can-reduce-manufacturing-skills-gap/ (accessed Nov. 09, 2020).

[138]N. Saforrudin, H. Badioze Zaman, and A. Ahmad, "Technical skills in developing augmented reality application: Teachers' readiness," in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2011, vol. 7067 LNCS, no. PART 2, pp. 360–370. doi: 10.1007/978-3-642-25200-6_34.

[139]J. Horwitz, "Seek patents creation of cross-platform AR assets from 'any' 3D models," VentureBeat, Jun. 02, 2020. https://venturebeat.com/2020/06/02/seek-patents-creation-of-cross-platform-ar-assets-from-any-3d-models/amp/ (accessed Jun. 03, 2020).

[140]Unity Technologies, "Powerful 2D, 3D, VR, & AR software for cross-platform development of games and mobile apps." https://store.unity.com/#plans-individual (accessed Jan. 17, 2020).

[141]Epic Games, "Unreal Engine (UE5) licensing options." https://www.unrealengine.com/en-US/license (accessed Apr. 30, 2022).

[142]Blender Foundation, " Blender is Free Software ." https://www.blender.org/about/license/ (accessed Apr. 30, 2022).

[143]Roblox Corporation, "Roblox FAQ - Roblox." https://corp.roblox.com/faq/ (accessed Apr. 30, 2022).

[144]G. Burnett, "Bringing the metaverse to life: how I built a virtual reality for my students -- and what I've learnt along the way," The Conversation, Nov. 19, 2021. https://theconversation.com/bringing-the-metaverse-to-life-how-i-built-a-virtual-reality-for-my-students-and-what-ive-learnt-along-the-way-171760 (accessed Nov. 21, 2021).

[145]B. Lang, "Meta Begins Testing Selling Tools in Horizon Worlds," Road to VR, Apr. 11, 2022. https://www.roadtovr.com/meta-horizon-worlds-monetization-selling-tools-test/ (accessed Apr. 13, 2022).

[146]C. Fink, "Spatial Raises $25 Million, Pivots To NFTs," Forbes, Dec. 14, 2021. https://www.forbes.com/sites/charliefink/2021/12/14/spatial-raises-25-million-pivots-to-nfts/ (accessed Dec. 14, 2021).

[147]F. Regner, N. Urbach, and A. Schweizer, "NFTs in Practice – Non-Fungible Tokens as Core Component of a Blockchain-based Event Ticketing Application," in ICIS 2019 Proceedings, Nov. 2019, p. 18. Accessed: Apr. 30, 2022. [Online]. Available: https://aisel.aisnet.org/icis2019/blockchain_fintech/blockchain_fintech/1

[148]A. Arora, Kanisk, and S. Kumar, "Smart Contracts and NFTs: Non-Fungible Tokens as a Core Component of Blockchain to Be Used as Collectibles," in Cyber Security and Digital Forensics. Lecture Notes on Data Engineering and Communications Technologies, vol 73, K. Khanna, V. V. Estrela, and J. J. P. C. Rodrigues, Eds. Singapore: Springer Singapore, 2022, pp. 401–422. doi: 10.1007/978-981-16-3961-6_34.

[149]K. B. Wilson, A. Karg, and H. Ghaderi, "Prospecting non-fungible tokens in the digital economy: Stakeholders and ecosystem, risk and opportunity," Bus. Horiz., Oct. 2021, doi: 10.1016/j.bushor.2021.10.007.

[150]M. Nadini, L. Alessandretti, F. Di Giacinto, M. Martino, L. M. Aiello, and A. Baronchelli, "Mapping the NFT revolution: market trends, trade networks, and visual features," Sci. Rep., vol. 11, no. 1, p. 20902, Dec. 2021, doi: 10.1038/s41598-021-00053-8.

[151]L. Kugler, "Non-fungible tokens and the future of art," Commun. ACM, vol. 64, no. 9, pp. 19–20, Sep. 2021, doi: 10.1145/3474355.

[152]W. Rehman, H. e Zainab, J. Imran, and N. Z. Bawany, "NFTs: Applications and Challenges," in 2021 22nd International Arab Conference on Information Technology (ACIT), Dec. 2021, pp. 1–7. doi: 10.1109/ACIT53391.2021.9677260.

[153]Gap, "Gap Launches Gamified Collectible NFT Experience to Activate Community, Creativity and Self-Expression," Jan. 22, 2022. https://www.gapinc.com/en-us/articles/2022-1/01/gap-launches-gamified-collectible-nft-experience-t (accessed Jan. 29, 2022).

[154]M. Fahy, "Perfect Corp pioneers NFTs with AR try-on capabilities," Cosmetics Business, Mar. 10, 2022. https://www.cosmeticsbusiness.com/news/article_page/Perfect_Corp_pioneers_NFTs_with_AR_try-on_capabilities/199379 (accessed Mar. 10, 2022).

[155]Jamaica Observer, "Reggae NFT platform coming by year end," Jamaica Observer, May 16, 2021. https://www.jamaicaobserver.com/sunday-finance/reggae-nft-platform-coming-by-year-end_221534 (accessed Oct. 01, 2021).

[156]L. Dowrich-Phillips, "The Weekend Read: Caribbean creatives embracing benefits of NFTs," Loop Caribbean News, Oct. 24, 2021. https://caribbean.loopnews.com/content/weekend-read-caribbean-creatives-embracing-benefits-nfts-4 (accessed Oct. 25, 2021).

[157]Loop Cayman Islands, "Cayman's first NFT art auction Helps to raise funds for charitiy," Loop Cayman Islands, Jul. 21, 2021. https://cayman.loopnews.com/index.php/fr/node/554817 (accessed Oct. 01, 2021).

[158]"NFT Caribbean Art Mints Lucky Richard Hennessy," Mar. 15, 2021. https://bimvibes.com/2021/03/15/nft-caribbeans-mints-lucky-richard-hennessy/ (accessed Oct. 01, 2021).

[159]NFT Caribbean, "NFT Caribbean." https://nftcaribbeanart.com/ (accessed Oct. 01, 2021).

[160]Central Bank of Trinidad and Tobago, "Exchange Rates Daily." https://www.central-bank.org.tt/statistics/data-centre/exchange-rates-daily (accessed Apr. 26, 2022).

[161]CARIRI, "Challenge Info – AR/VR Challenge," 2020. https://www.cariri.com/Challenge/challenge-details/ (accessed Apr. 26, 2022).

[162]B. Lang, "31 XR Projects Received Grants from Epic MegaGrants in 2021," Road to VR, Jan. 14, 2022. https://www.roadtovr.com/epic-games-megagrants-xr-recipients-2021/ (accessed Jan. 16, 2022).

[163]S. Hayden, "Qualcomm Launches $100M Fund to Help Build the Metaverse," Road to VR, Mar. 21, 2022. https://www.roadtovr.com/qualcomm-launches-100m-fund-help-build-metaverse/ (accessed Mar. 22, 2022).

[164]Qualcomm Technologies, "Qualcomm Launches $100M Snapdragon Metaverse Fund," Mar. 21, 2022. https://www.qualcomm.com/news/releases/2022/03/21/qualcomm-launches-100m-snapdragon-metaverse-fund (accessed Mar. 22, 2022).

[165]D. Takahashi, "Tower 26 venture fund will invest $50M in VR games and the metaverse," VentureBeat, Apr. 20, 2022. https://venturebeat.com/2022/04/20/tower-26-venture-fund-will-invest-50m-in-vr-games-and-the-metaverse/ (accessed May 07, 2022).

[166]B. Lang, "FOV Ventures Raises $18 Million to Fund European Metaverse Startups," Road to VR, Mar. 22, 2022. https://www.roadtovr.com/fov-ventures-fund-raise-announcement/ (accessed Mar. 22, 2022).

[167]S. Hayden, "Niantic Kickstarts Its AR Metaverse with Release of Lightship SDK and $20M Developer Fund," Road to VR, Nov. 08, 2021. https://www.roadtovr.com/niantic-lightship-sdk-developer-fund/ (accessed Nov. 08, 2021).

[168]J. Peters, "Facebook's new $10 million fund for VR creators is hopefully just the beginning," The Verge, Oct. 07, 2021. https://www.theverge.com/2021/10/7/22714876/facebook-horizon-worlds-creators-fund-social-vr-platform-metaverse (accessed Nov. 08, 2021).

[169]S. Hayden, "Meta Hackathon This Month Challenges Devs to Use Its Latest XR Tools for $700,000 in Prizes," Road to VR, Nov. 05, 2021. https://www.roadtovr.com/meta-hackathon-xr-2021/ (accessed Nov. 08, 2021).

[170]S. Hayden, "Meta is Nudging VR Devs Towards 'Horizon Worlds' with Training, Funding & More," Road to VR, Mar. 23, 2022. https://www.roadtovr.com/meta-vr-devs-horizon-worlds-oculus-start/ (accessed Mar. 23, 2022).

[171]HeroX, "NASA MarsXR Challenge." https://www.herox.com/MarsXR/guidelines (accessed May 09, 2022).

[172]M. Haseley, "Carib Shandy augmented reality series, new label," Trinidad and Tobago Newsday, Sep. 17, 2019. https://newsday.co.tt/2019/09/17/carib-shandy-augmented-reality-series-new-label/ (accessed Jan. 22, 2021).

[173]M. Lyndersay, "Caesar's Army hosts a digital bashment," Tech News TT, Jan. 28, 2021. https://technewstt.com/antillea/?amp=1 (accessed Jan. 29, 2021).

[174]N. Fraser, "National Energy, Labidco launch virtual tours of facilities," Trinidad and Tobago Newsday, Mar. 23, 2021. https://newsday.co.tt/2021/03/23/national-energy-labidco-launch-virtual-tours-of-facilities/ (accessed Apr. 11, 2021).

[175]K. Corion, "Virtual Reality and Pan Collides in Trinidad and Tobago," HuffPost, Apr. 28, 2017. https://www.huffpost.com/entry/virtual-reality-and-pan-collides-in-trinidad-and-tobago_b_59038f90e4b05279d4edbbb4 (accessed May 11, 2021).

[176]M. Lyndersay, "The games are afoot | Snapshot," Caribbean Beat Magazine, Nov. 2017. https://www.caribbean-beat.com/issue-148/games-are-afoot#axzz50yaFuRCM (accessed Jun. 16, 2021).

[177]P. Christopher, "Royalty Club hopes for AR renaissance," Trinidad & Tobago Guardian, Port-of-Spain, p. SB5, Jun. 06, 2021.

[178] J. De Souza, "Central Bank launches virtual museum," Trinidad and Tobago Newsday, May 29, 2021. https://newsday.co.tt/2021/05/29/central-bank-launches-virtual-museum/ (accessed May 30, 2021).

[179] M. Marius, "ICTP 132: Virtual and augmented reality, and key opportunities for the Caribbean, with 4th Dymension," ICT Pulse, Nov. 18, 2020. https://www.ict-pulse.com/2020/11/ictp-132-virtual-and-augmented-reality-in-key-opportunities-for-the-caribbean-with-4th-dymension/ (accessed Sep. 17, 2021).

[180] 4th Dymension, "The Plymouth Recreation Project." https://www.4thdymension.com/the-plymouth-recreation-project/ (accessed Sep. 17, 2021).

[181] T. Panagopoulos, "Experience the Caribbean Through Augmented Reality & Virtual Reality," Ascape VR, Jan. 04, 2019. https://ascape.com/blog/2019/1/25/experience-the-caribbean-through-augmented-reality-amp-virtual-reality (accessed Sep. 19, 2021).

[182] HaitiLibre, "Haiti - Technology : Augmented reality and virtual tours of tourist sites," HaitiLibre, Jun. 12, 2018. https://www.haitilibre.com/en/news-24652-haiti-technology-augmented-reality-and-virtual-tours-of-tourist-sites.html (accessed Sep. 19, 2021).

[183] M. Nurse, "Region's coconut industry to be transformed via Augmented Reality," CARICOM Today, Jul. 17, 2018. https://today.caricom.org/2018/07/13/regons-coconut-industry-to-be-transformed-via-augmented-reality/ (accessed Jul. 29, 2020).

[184] Silicon Caribe, "Jamaican Travel Blogger launches Augmented Reality 'Island Life' filter on Instagram," Silicon Caribe, Jun. 27, 2019. https://www.siliconcaribe.com/2019/06/27/jamaican-travel-blogger-launches-augmented-reality-island-life-filter-on-instagram/ (accessed Sep. 19, 2021).

[185] Loop Jamaica, "Jamaica's first augmented reality mural unveiled in downtown Kingston," Loop Jamaica, Aug. 30, 2019. https://jamaica.loopnews.com/content/jamaicas-first-augmented-reality-mural-unveiled-downtown-kingston (accessed Sep. 19, 2021).

[186] Loop Jamaica, "Photos: Next Generation Creators bring art to life," Loop Jamaica, Apr. 10, 2018. https://jamaica.loopnews.com/content/photos-next-generation-creators-bring-art-life (accessed Sep. 19, 2021).

[187] J. Neaves, "CariGamers' got game," Trinidad and Tobago Newsday, Jul. 18, 2019. https://newsday.co.tt/2019/07/18/carigamers-got-game/ (accessed Oct. 06, 2021).

[188] Voices of VR Podcast, "#1024: Using VR for Non-Profit Outreach & Fundraising with Hope for Haiti," Nov. 29, 2021. https://voicesofvr.com/1024-using-vr-for-non-profit-outreach-fundraising-with-hope-for-haiti/ (accessed Nov. 30, 2021).