Investigating the Impact of Design and Security on Continued Intention to Engage with AI-Enhanced Metaverse among Generation Z

Dr. Shailja Tripathi
Assistant Professor,
IBS Hyderabad, the ICFAI Foundation for Higher Education
(Declared as Deemed-to-be University u/s 3 of the UGC Act, 1956)

Abstract

The metaverse constitutes a synthesis of both physical and digital realms, enabled through computational apparatus and enhanced by advanced technologies that create a wholly immersive experience. The intersection of artificial intelligence (AI) and the metaverse acts as a catalyst for swift and extensive transformation within the virtual domain. This study further investigates the dynamic relationship between AI and the metaverse, clarifying the significant roles that AI can play in augmenting and disseminating the metaverse. Notwithstanding its importance, this critical aspect is often overlooked, leading to a scarcity of academic exploration regarding the factors that influence user acceptance of AI-enhanced metaverse environments. To remedy the identified gap in the existing literature, the current research expands upon the technology acceptance model by integrating it with the expectancy confirmation model (ECM), while also incorporating additional variables such as confirmation, satisfaction, and intention to maintain usage. Data relevant to this investigation were gathered through an online survey instrument. A total of 541 responses were amassed from individuals who actively participate in the metaverse, resulting in a response rate of 89%. The information obtained from the survey was analyzed employing partial least squares structural equation modeling. The findings indicated that the security level within the metaverse does not exert a significant influence on perceived usefulness and ease of use; however, it plays a crucial role in determining the intention to continue utilizing the metaverse. The impacts of confirmation and perceived ease of use on the intention to persist in using the system were not evidenced to be statistically significant. These findings offer critical insights for developers and practitioners in the realms of design and security within the metaverse, aimed at promoting its widespread acceptance.

Keywords: Artificial Intelligence; Metaverse; Design, Security, Perceived Usefulness, Perceived Ease of Use, Satisfaction, Confirmation

1. Introduction

The notion of the 'metaverse' was first delineated in Neal Stephenson's speculative literary piece 'Snow Crash,' in which it was depicted as a collective reality comprising millions of participants (Stephenson, 1993). The metaverse represents an integrated digital realm that synthesizes the internet and virtual reality (VR), thereby enabling users to connect and interact with one another

as well as with virtual entities (Mozumder et al., 2022). This online sphere empowers individuals to construct and immerse themselves in their own digital identities and narratives, facilitating uninterrupted real-time interactions with others (Tukur et al., 2024). The function of artificial intelligence is pivotal within this virtual domain, as the interplay between these two technological spheres fosters a reciprocal enhancement that elevates the overall capabilities of both (Zohuri et al., 2023). The ability of AI to process and analyze vast datasets, coupled with its machine learning capabilities, positions it as an essential tool for empowering users and creators within the virtual environment (Khang et al., 2023). AI technologies can be employed to generate digital characters, digital humans, and non-player characters (NPCs) that can embody authentic and captivating avatars, thereby enhancing the immersive nature of the experience. The proficiency of AI in message interpretation enables seamless communication across linguistic barriers, thereby fostering collaborative endeavors on a global scale. The virtual environment is expected to create job opportunities akin to those established by the internet, thereby facilitating the emergence of new enterprises, job roles, and occupational descriptions requisite for the governance and administration of the virtual ecosystem (Fui-Hoon Nah et al., 2023).

Artificial intelligence systems demonstrate the capacity to perform tasks, adapt to changing environments, and autonomously acquire knowledge in accordance with the specified directives (Dubova, 2022). AI functions as a significant resource that can enhance user interactions and collaborations by enriching the overall experience within the metaverse. The incorporation of AI into the metaverse is transforming the ways in which individuals engage with the digital sphere. Illustrating AI-enabled capabilities, intelligent agents, personalization, and natural language processing serve to augment and elevate the user experience within the metaverse (Huynh-the et al., 2023, Bibri et al., 2023). The applications of artificial intelligence (AI) and the metaverse are being utilized across a multitude of sectors including gaming, education, and healthcare. This synergy offers innovative insights into the advancement of products within various industries.

According to the McKinsey report (2022), video gamers are acknowledged as the pioneers of participants within the virtual realm. Presently, there exists an estimated 3.2 billion players worldwide, and this number is continually increasing. These developments are anticipated to establish a solid consumer base and facilitate the sustainable progression of the metaverse, surpassing the current prevalent enthusiasm. Additionally, younger populations and novice users exhibit a notable ability to adapt to new websites and platforms. The digital environment is increasingly synchronized with the physical world, progressively evolving to become more intelligent and autonomous with the integration of artificial intelligence (AI) (Yang et al., 2023). The metaverse can actualize experiences in virtual reality, encompassing VR, AR, and mixed reality, through the amalgamation of supportive technologies such as artificial intelligence, blockchain, the internet of things (IoT), and 5G (Jagatheesaperumal et al., 2024).

2. Theoretical Background

2.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) has been extensively deployed in academic investigations to analyze the acceptance of emergent electronic technologies or digital services (Davis, 1989; Venkatesh and Davis, 1996). In alignment with the Theory of Reasoned Action

(TRA) articulated by Ajzen and Fishbein (1970), TAM is esteemed as one of the paramount contributions to the discipline. Empirical studies have elucidated a relationship between users' perceptions of a technology's utility, operational simplicity, attitudes, and their intent to engage with it. The theoretical construct is founded upon two essential dimensions: perceived usefulness (PU) and perceived ease of use (PEOU). PU signifies the extent to which a user believes that the utilization of a specific system would augment their job performance, while PEOU indicates the degree to which a user assesses the usability of a particular system as uncomplicated. Research findings suggest that perceived usefulness acts as a significant predictor of attitudes toward the engagement with the Metaverse, thus influencing users' intentions to interact with it across varied contexts, including eLearning and professional services (Wu & Yu, 2023; Alhalaybeh & Althunibat, 2023; Leo et al., 2023). Conversely, perceived ease of use intermittently exhibits a minimal effect on intention, signifying that users may prioritize the benefits derived rather than the user-friendliness of the platform (Ali et al., 2025; Alshammari & Alshammari, 2024).

Al-Adwan et al. (2023) investigate the fundamental factors that influence higher education students' intentions to adopt metaverse technology for educational purposes. This inquiry proposes an enhanced iteration of TAM to fulfill this objective. The research emphasizes perceived usefulness, personal innovativeness, and perceived enjoyment as crucial components that shape students' intentions to engage with the metaverse. Torman and Gecit (2023) utilized TAM to examine the adoption of metaverse technologies and non-fungible tokens (NFTs), discovering that perceived compatibility, enjoyment, and trust exert a considerable and positive impact on perceived usefulness. Misirlis et al. (2023) employed TAM to explore the interplay between students' intentions to utilize the metaverse in educational technologies (hereafter designated as meta education) alongside selected constructs of TAM, including attitude (ATT), perceived usefulness (PU), perceived ease of use (PE), self-efficacy (SE) regarding metaverse technologies in education, and subjective norm (SN).

2.2 Expectation-confirmation model (ECM)

The Expectation Confirmation Model (ECM) serves as a theoretical framework for analyzing the sustained engagement with technology, extending beyond the confines of the initial acceptance period (Bhattacherjee, 2001). The model comprises four essential elements: perceived usefulness, confirmation, satisfaction, and the intention to persist in the utilization of the system. Satisfaction is indicative of the emotional responses elicited during interactions with the service provider. This emotional state manifests subsequent to the experience of consumption. Confirmation refers to the degree to which users perceive that their initial expectations concerning the technology have been fulfilled during its practical application (Bhattacherjee, 2001). Confirmation encapsulates the user's foundational belief regarding the operational effectiveness of the technology, based upon their pre-existing expectations. Moreover, confirmation emphasizes the preliminary acceptance of the technology, considering the anticipated changes that will transpire over time (Bhattacharjee, 2001). Perceived usefulness evaluates the user's inclination to initially adopt a new technology and to persist in its usage thereafter. The perceived usefulness and confirmation resulting from initial interactions can substantially affect user adoption and satisfaction with the technology. When users identify the utility of a product and experience satisfaction from their interactions, they exhibit a greater propensity to continue its use.

The Expectation Confirmation Model (ECM) assumes a crucial role in the analysis of user satisfaction and the intention to persist in engaging with platforms in digital environments. It posits that users' ongoing engagement is influenced by their initial expectations and the subsequent experiences that unfold (Lai et al., 2016). In the context of the Metaverse, the ECM may be augmented by incorporating factors such as emotional attachment, perceived enjoyment, and social interaction, all of which significantly affect user perceptions and intentions (Wu & Yu, 2023).

Natale et al. (2024) implemented the extended expectation-confirmation model (EECM) as a theoretical framework to investigate the determinants influencing students' acceptance and their intention to continue utilizing integrated learning environments within educational frameworks. The EECM, which addresses the incongruence between pre-adoption expectations and post-adoption experiences, offers a holistic perspective for analyzing technology adoption in educational contexts. The authors discovered that factors such as performance expectancy and effort expectancy exerted minimal influence on expectancy confirmation. Nonetheless, when students' initial expectations aligned with their actual experiences, their evaluations of the technology's usefulness, satisfaction, and confidence in its application were positively impacted, subsequently affecting their intention to further integrate these tools into their educational methodologies.

3. Literature Review

The progressions in artificial intelligence related to generative content (AIGC) have precipitated the emergence of fundamental technologies, with ChatGPT exemplifying a product originating from the metaverse engine layer, thereby enhancing the generation of valuable assets within the metaverse (Cao et al., 2023). At present, the virtual environment is lacking in critical attributes necessary to meet user expectations, accompanied by exorbitant costs associated with its development, thus limiting accessibility to a restricted number of enterprises. Nevertheless, should artificial intelligence enable a reduction in costs for developers, such as by delivering analogous events with elucidations, the financial implications involved in the establishment of a metaverse environment could be considerably alleviated (Reis and Ashmore, 2022; Godwin-Jones, 2023; Lyu, z., 2023). The significance of content within the metaverse has escalated to unparalleled heights, consequently revitalizing sectors such as augmented reality (AR) and virtual reality (VR) (Lyu, z., 2023).

Virtual reality represents the vanguard of the metaverse, incorporating advanced apparatus such as head-mounted displays. Artificial intelligence constructs an imaginative and engaging domain within the metaverse. As a result, it provides users with a seamless virtual reality experience. Artificial intelligence can facilitate the content generation process, as illustrated by NVIDIA's GANverse3D, which enables developers and creators to capture an image and subsequently produce a virtual artifact.

In scenarios where discrepancies arise among users in the virtual domain, one of the functionalities of artificial intelligence is "decision-making." For instance, in a virtual reality gaming context, challenges may emerge (Cossich et al., 2023). Consequently, determinations must be made to ascertain the victor and the vanquished, which will ultimately influence the concluding outcome. Another prospective functionality of artificial intelligence modules is "simulation." For example,

when users engage in activities such as agriculture or animal husbandry, there should exist a mechanism that simulates the growth or development of flora or fauna over time (Huynh-the et al., 2023).

A crucial aspect of utilizing the "simulation" capability afforded by AI technology is that it enables non-player characters (NPCs) to mimic human behaviors within the metaverse. Naturally, artificial intelligence modules must also possess the capability to make determinations based on the parameters established by the designer, such as ascertaining outcomes in accordance with predetermined rules upon the occurrence of specific events (Hwang et al., 2023). This technology provides caregivers with a self-directed learning experience that enhances their competencies and bolsters their confidence in remotely managing patients. ChatGPT is adept at generating simulated patient interactions that reflect real-life scenarios, whereas the metaverse can offer virtual reality experiences and situations for caregivers to practice and learn in a real-time, secure, and controlled environment (Sharma and Sharma, 2023). Within the metaverse, digital assets resemble AI-driven NPCs in video games that can react to actions within a virtual reality milieu rather than functioning as representations of actual individuals (Johri et al., 2024). All digital assets within the virtual realm were conceived using advanced technological means and play a critical role in the operational dynamics of the ecosystem (Ersoy and Gürfidan, 2023).

Numerous organizations, including Soul Machines, have made significant financial investments in this sector due to the vast array of potential applications, which include non-playable characters within video games and the enhancement of individual engagement in the virtual professional environment (Vero, 2023). Within the virtual realm, users will interact with each other through virtual embodiments of themselves, commonly referred to as avatars. It is essential that these avatars demonstrate dynamism and authenticity, as there will be avatars capable of recognizing users within the virtual landscape. The application of artificial intelligence can facilitate the development of realistic virtual entities by employing computer vision to produce authentic images of users, utilizing natural language processing to generate realistic vocalizations for virtual characters, and implementing virtual reality to construct a genuine environment for these entities (Massaro et al., 2023).

For instance, users are granted the opportunity to create an avatar that closely resembles themselves or to select from a collection of pre-designed avatars. These avatars will engage in conversations as they are equipped with the capability to communicate via chat interfaces. Such functionality is critical in enhancing the accessibility of the metaverse. AIOps represents a domain within artificial intelligence that employs machine learning methodologies to assist organizations in managing their IT infrastructures. The implementation of AIOps can facilitate the anticipation and prevention of cyber-attacks, the identification of critical system issues, and the efficient allocation of resources (Remil, 2023). The characteristics of robustness, reliability, and scalability are highly sought after within the context of metaverse platforms. As a result, AIOps can contribute to the more effective distribution of resources and the ongoing monitoring of operational processes. For example, should a corporation's integration of the metaverse persist, AIOps can aid in the identification and resolution of issues before they escalate into malicious activities (Pattam, 2022).

Digital twins will serve to represent objects within the digital domain in the context of the metadata environment. Artificial intelligence can facilitate the creation of authentic digital twins by employing computer vision to model physical objects, utilizing deep learning to cultivate trust in these digital representations, and leveraging virtual reality to construct a lifelike setting. For instance, an organization may develop a virtual replica of its manufacturing facility within the metaverse. The "digital twin" of the factory can monitor its operational processes and predict potential future complications. This technological innovation empowers users to construct virtual environments that authentically mirror the real world. Users' expertise lies in the development of virtual environments and the execution of simulations within these contexts to explore various subjects, including advanced speech technology and autonomous robotic systems. NVIDIA technology exemplifies the convergence of artificial intelligence and the metaverse in the creation of immersive virtual environments designed for social engagement (Guo et al., 2022; Bibri et al., 2023).

Generation Z demonstrates a significant propensity for the integration of technology, a strong valuation of individual identity, an observable prevalence of depressive manifestations, and a pronounced inclination towards a variety of products and services (Slepian et al., 2024). This generational cohort has developed during a period distinguished by swift technological progress, enabled by the widespread availability of the internet. In contrast to millennials (individuals born between 1981 and 1996), Generation Z has interacted with the internet and virtual technologies from an early stage in life, experiencing a continuously 'connected' milieu (Wilson, 2021; Buhalis et al., 2023).

4. Research Model

The research framework is formulated through the integration of the Technology Acceptance Model (TAM) alongside the Expectation Confirmation Model (ECM). This framework incorporates the variables relevant to both theoretical constructs, encompassing Perceived Usefulness, Perceived Ease of Use, Confirmation, Satisfaction, and the Continued Intention to Use Metaverse.
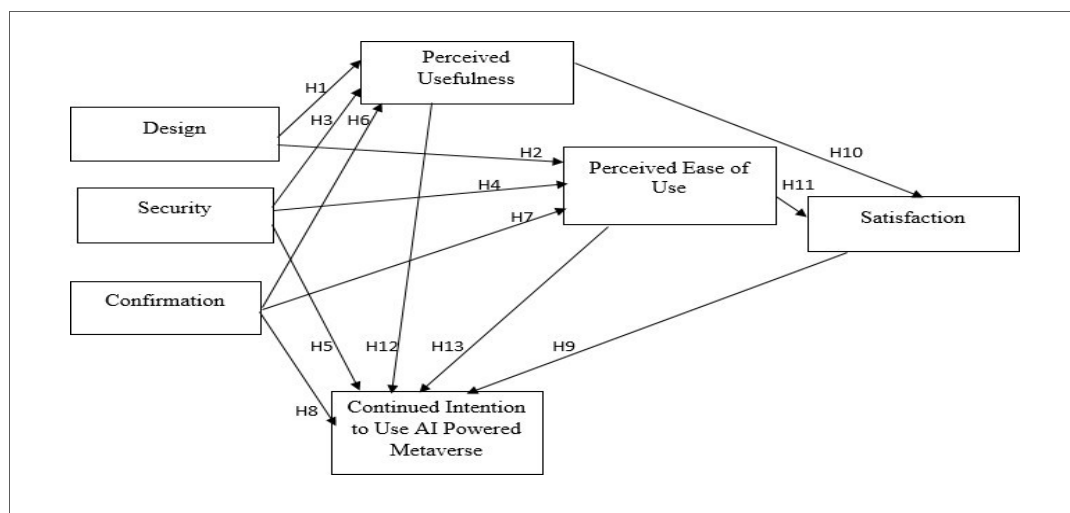

Figure 1. Research Model

5. Hypothesis Development

Davis (1987) asserted that the design attributes of a system significantly affect its perceived utility. The technological or product design may enhance its perceived utility by cultivating an individual's conviction that it will augment their tasks or obligations. Koch et al. (2011) emphasized that the design attributes of a system directly impact its perceived usefulness and user-friendliness. Balakrishnan et al. (2024) contended that the vibrancy and color palettes of metaverse design improve the overall experiential quality and utility. The information embedded within the metaverse can facilitate navigational efficacy, thus streamlining the process for users to achieve their goals while reducing the effort required (Balakrishnan et al., 2024). Kim and Lee (2023) and Ibili et al. (2023) recognized that the characteristics of the Metaverse, namely telepresence, interoperability, and concurrence, exert a favorable influence on perceived usefulness. These technological features significantly enhance users' perceptions of the utility of the Metaverse, thereby reinforcing their intention to engage with it. Moreover, it has been evidenced that perceived usefulness exhibits a positive correlation with perceived value, indicating that a thoughtfully conceived Metaverse design can profoundly influence user behavior and acceptance. Consequently, the design elements of the Metaverse assume a pivotal role in shaping users' perceptions of its utility. In consideration of the arguments articulated in the preceding discourse, the following hypothesis is posited.

H1: Metaverse design has a positive effect on perceived usefulness

H2: Metaverse design has a positive effect on perceived ease of use

Nikou (2019) conducted an empirical study aimed at clarifying the influence of security and privacy, alongside various supplementary factors, on users' perceptions of smart home technologies. Security risk is defined as the potential loss of control over personal information, which can lead to a multitude of detrimental consequences. The outcomes of the study indicated that security risks had a harmful effect on users' perceptions of usability and utility. This research highlighted the crucial importance of security risks in shaping users' perceptions. This investigation emphasized the necessity of comprehending data usage and security as a fundamental aspect of risk perception, particularly in relation to a smart home application intended to bolster safety. The same theoretical framework is applicable to the metaverse (Al-kfairy et al., 2023), including the emerging metaverse marketplace, which is presently characterized by a significant user base that remains predominantly unaware of the pertinent security and privacy issues. As a result, this lack of awareness contributes to a decline in users' perceived utility, ease of use, and an overarching sense of apprehension (Al-Adaileh et al., 2024). Therefore, it is hypothesized that security risks within the metaverse will negatively impact both perceived usefulness and perceived ease of use.

H3: Security risks in Metaverse has a negative effect on perceived usefulness

H4: Security risks in Metaverse has a negative effect on perceived ease of use.

Security represents a critical issue within the metaverse, primarily due to the potential cyber threats that include identity theft, fraud, and data breaches. The metaverse exemplifies a continuously evolving and interconnected digital landscape wherein individuals are afforded the opportunity to interact, transact, and generate value in the absence of stringent security protocols. Such imminent threats possess the capacity to impact a significant demographic of users and virtual assets (Zhao et al., 2022; Hwang, 2023). The metaverse serves as a quintessential representation of an advanced evolution of digital technologies. While the metaverse encapsulates substantial prospects for expansion, it remains vulnerable to similar security threats linked to intelligent computing, cloud-network integration, terminal access, and digital assets (Li et al., 2024). Oleksy et al. (2023) elucidated the potential detrimental effects of metaverse integration, such as privacy concerns and the unpredictable consequences on individuals' connections with the physical world. Consequently, it is asserted that the presence of security vulnerabilities within the metaverse acts as a deterrent for individuals contemplating its frequent engagement.

H5: Security risks in Metaverse has a negative effect on Continued Intention to Use Metaverse

Confirmation pertains to the extent to which an individual's expectations align with their actual experiences while engaging with a product or service. The concept of confirmation plays a crucial role in assessing user satisfaction in relation to a product or service, as well as in predicting the likelihood of continued usage (Bhattacherjee, 2001). In circumstances where users discern a harmony between their experiences and their anticipations, the dimensions of perceived usefulness, perceived ease of use, and the intention to persist in utilizing the system are significantly enhanced (Natale et al., 2024). Consequently, it is asserted that confirmation will have a substantial impact on perceived usefulness, perceived ease of use, and the likelihood of sustained involvement with the metaverse.

H6: Confirmation has a positive effect on Perceived Usefulness

H7: Confirmation has a positive effect on *Perceived Ease of Use*

H8: Confirmation has a positive effect on Continued Intention to Use Metaverse

Users' satisfaction is defined as the positive emotional responses generated during the engagement with technological systems, which align with their expectations and typical usage behaviors. Teng et al. (2022) examined the factors influencing the acceptance of an educational metaverse through the implementation of an augmented UTAUT model. Their findings indicated that users' satisfaction demonstrated a favorable association with their likelihood to continue utilizing the system. A study conducted by Almarzouqi et al. (2022) emphasized that user satisfaction plays a crucial role in determining users' readiness to interact with the metaverse in the context of medical education. Natale et al. (2024) asserted that the perceived usefulness of the technology, the level of satisfaction derived from its utilization, and self-efficacy are essential elements that affect their decision to repeatedly engage with the technology. In consideration of these factors, it is suggested that satisfaction will significantly influence the intention to maintain usage of the service.

H9: Satisfaction has a positive effect on Continued Intention to Use Metaverse

According to Lestari et al. (2024), the consumer's perception of utility can lead to an enhanced level of satisfaction derived from a specific service. Maghaydah et al. (2024) and Lestari et al. (2024) underscored that the perceived ease of use can significantly elevate user satisfaction during interactions with online services, including those associated with the metaverse. Mandal et al. (2024) contended that both perceived utility and perceived ease of use concerning the metaverse exert a substantial impact on the engagement and satisfaction experienced by individuals belonging to Generation Z. In light of these considerations, it is posited that both perceived utility and perceived ease of use exert a positive influence on overall satisfaction.

H10: Perceived Usefulness has a positive effect on Satisfaction

H11: Perceived Ease of Use has a positive effect on Satisfaction

As individuals incorporate technology into their daily routines, their inclination to continue its use is substantially shaped by its practical applicability (Venkatesh et al., 2012). The propensity of users to sustain their engagement with technology is molded by positive experiences, ease of use, and the technology's efficacy in addressing their increasing requirements. The extent of usability, convenience, and perceived worth significantly influences consumers' decisions to remain involved with the metaverse (Chakraborty et al., 2024). In light of these factors, it is asserted that perceived usefulness and perceived ease of use positively impact the intention to sustain utilization of the metaverse.

H12: Perceived Usefulness has a positive effect on Continued Intention to Use Metaverse

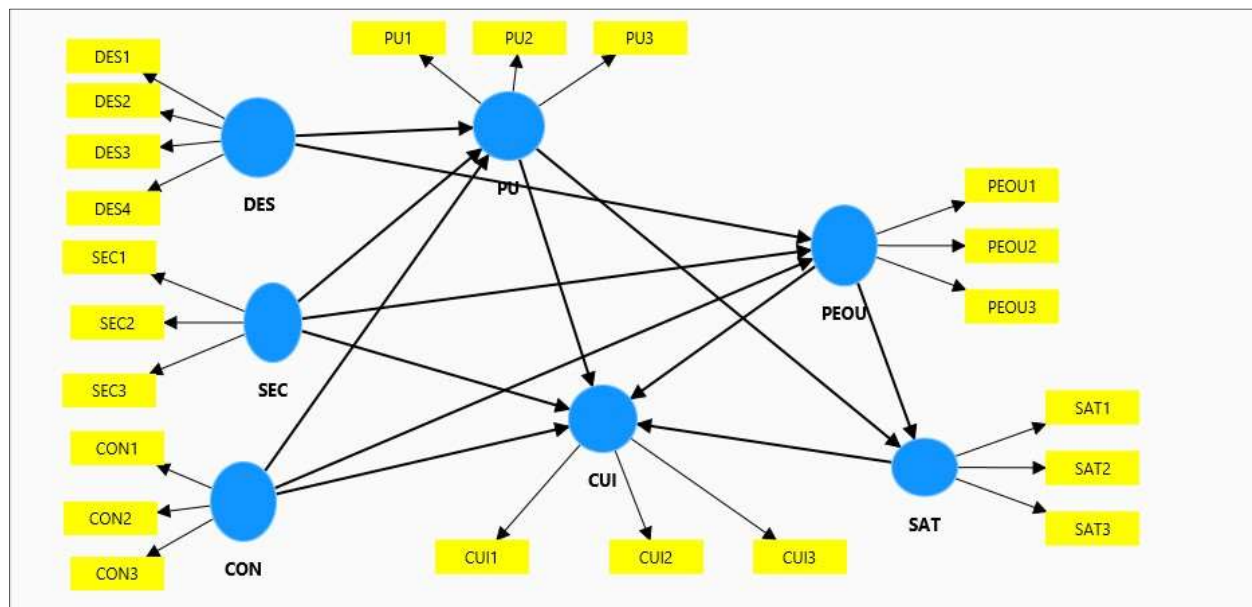*H13: Perceived Ease of Use has a positive effect on Continued Intention to Use Metaverse*

Figure 2. PLS Measurement Model

6. Research Methodology

6.1 Instrument Development

A survey-based questionnaire methodology is employed for the purpose of systematic data collection. The survey instrument underwent a preliminary assessment with qualified experts (faculty members) prior to the initiation of the principal research study. The faculty members were consulted for their evaluations regarding the survey's linguistic precision, substantive relevance, and organizational structure. Following the implementation of several minor revisions, the questionnaire was considered finalized for the principal analysis. The inquiries are evaluated utilizing a Likert scale that ranges from 1 to 5, where 1 signifies strong disagreement, 2 denotes mild disagreement, 3 represents a neutral position, 4 indicates mild agreement, and 5 reflects strong agreement. In this study, a five-point Likert scale is utilized, as it facilitates straightforward responses from participants. The initial section of the survey is crafted to collect data pertaining to the demographic attributes of the participants. The subsequent segment encompasses inquiries related to seven constructs, namely perceived usefulness (PU), perceived ease of use (PEOU), design (DES), security (SEC), confirmation (CON), satisfaction (SAT), and the intention to continue utilizing the metaverse (CUI).

The survey consists of a total of 22 items. Four design elements derived from Zallio et al. (2023) are incorporated into the metaverse framework. Three items associated with the construct of continued usage intention (CUI) and three items pertaining to the construct of satisfaction (SAT) are extracted from the scales developed by Teng et al. (2022) and Dwivedi et al. (2024). Four dimensions of the construct referred to as 'security' (SEC) are adapted from the measurement scale established by Zibarzani et al. (2024). Three items concerning perceived usefulness (PU) and three items regarding perceived ease of use (PEOU) are sourced from the scale formulated by Yu et al. (2024). Additionally, three items related to confirmation (CON) are appropriated from the scale devised by Thong et al. (2006).

6.2 Data Collection

This research has identified the Generation Z cohort as the focal demographic due to their significant propensity toward engagement with the metaverse. Generation Z is defined as individuals born between 1997 and 2012, who currently range from their mid-twenties to younger ages (Slepian et al., 2024). A survey-based questionnaire methodology is employed to facilitate the process of data collection. Data are obtained from students enrolled in higher education institutions, specifically those aged between 15 and 25 years. The convenience sampling method is utilized for participant selection, wherein the sample consists of individuals who are readily accessible. A total of 541 responses were garnered through the survey, yielding a notable response rate of 89%.

6.3 Sample Description

The sample comprised 54.5% male participants and 45.5% female participants; 77.8% of the respondents were classified within the age bracket of 20 to 24 years. A total of 49% of the respondents indicated that they engaged with the metaverse for a duration of 1-2 hours on a daily

basis. The majority of respondents reported utilization of metaverse platforms, specifically Minecraft (42.7%) and Fortnite (23.5%).

Table 1. Sample Demographics

Age	Count	Percentage
15 to19 years	41	7.6
20 to 24 years	421	77.8
25 to 30 years	79	14.6
Metaverse Platform	**Count**	**Percentage**
Minecraft	231	42.7
Fortnite	127	23.4
Roblox	55	10.17
Zepeto	41	7.58
Second Life	35	6.47
Sandbox	27	4.99
Others	25	4.62
Frequency of Usage	**Count**	**Percentage**
1-2 hours	265	49.0
2-3 hours	148	27.4
3-4 hours	65	12.0
	35	6.5
>5 hours	28	5.2
Gender	**Count**	**Percentage**
Male	295	54.5
Female	246	45.5

7. Data Analysis

7.1 Assessing Data Validity

The analysis of the normality of variance represents the initial phase in the data analytical procedure. The results revealed that all metrics pertaining to skewness and kurtosis were within the acceptable limits (Tabachnic and Fidell, 2007), thus corroborating the integrity of the items. A significant issue is the occurrence of common source variance (CSV). The findings of the study demonstrated that common method variance (CMV) was predominantly managed in accordance with the protocols established by Podsakoff et al. (2003). In order to assess the potential risk linked with CMV, a comprehensive collinearity analysis as recommended by Kock (2015) was performed, which indicated that the internal variance inflation factor (VIF) did not exceed 3.3. The outcomes of the analysis indicated that all internal VIF values remained beneath the predetermined threshold. This result affirms that the model is not influenced by the repercussions of multicollinearity.

7.2 Confirmatory Factor Analysis

Two consecutive and interconnected methodologies were employed during the data analysis phase. Initially, the unidimensionality, reliability, and validity of each measurement scale were meticulously examined. Subsequently, the thirteen hypotheses (H1 to H13) were systematically assessed. The results of the confirmatory factor analysis are delineated in Table 2.

Table 2. PLS algorithm Results

Constructs (Items)	Loadings (λ)	Mean/SD	Cronbach's alpha (α)	Composite reliability (rho_a)	Average variance extracted (AVE)	VIF
Perceived Usefulness (PU1)	0.883	3.375/0.938	0.882	0.882	0.809	2.177
PU2	0.916	3.461/0.851				2.989
PU3	0.898	3.489/0.843				2.579
Perceived ease of Use (PEOU1)	0.880	3.572/0.823	0.867	0.869	0.789	2.124
PEOU2	0.884	3.502/0.834				2.291
PEOU3	0.901	3.613/0.841				2.383
Design (DES1)	0.750	3.264/0.874	0.819	0.844	0.664	1.645
DES2	0.831	3.727/0.929				1.761
DES3	0.855	3.290/0.907				1.867
DES4	0.771	3.210/0.980				1.718
Security (SEC1)	0.831	3.618/0.890	0.768	0.795	0.639	2.267
SEC2	0.867	3.373/0.999				2.324
SEC3	0.723	3.530/0.983				1.252
Confirmation (CON1)	0.818	3.392/0.902	0.807	0.810	0.689	1.584
CON2	0.860	3.682/0.903				1.892
CON3	0.871	3.789/0.917				1.901

Satisfaction (SAT1)	0.891	3.625/0.973	0.865	0.865	0.787	2.350
SAT2	0.875	3.784/0.947				2.065
SAT3	0.895	3.838/0.961				2.332
Continued Usage (CUI1)	0.877	3.492/0.988	0.801	0.807	0.715	1.925
CUI2	0.803	3.306/1.017				1.559
CUI3	0.855	3.287/0.967				1.797

As evidenced in Table 2, all primary-order factors exhibit considerable factor loadings that are statistically significant and exceed the recommended threshold (Hair et al., 2006). Due to the insufficient loading (less than 0.70), one component of the construct 'security,' specifically SEC4, was excluded from the analytical model. To evaluate the composite reliability and convergent validity, the researchers calculated the values of Cronbach's alpha, rho_a, composite reliability, and average variance for all factors (refer to Table 2). The composite reliability and Cronbach's alpha for the factors surpass the recommended threshold levels of 0.70 and 0.80, respectively (Hair et al., 2006). This finding signifies that the internal consistency of the measurement model is deemed satisfactory. Given that the average variance extracted for each item exceeded the .50 criterion, convergent validity was confirmed (Hair et al., 2006). Table 3 delineates the discriminant validity for each construct, wherein the square root of the average variance extracted (AVE) surpasses the correlations with other components, in accordance with the recommendations of Fornell and Larcker (1981). Furthermore, the HTMT (heterotrait-monotrait ratio criterion) was evaluated (see Table 4) as proposed by Heseler et al. (2015), indicating that discriminant validity is established when all HTMT values remain below 0.85. In the context of this research, the HTMT values for all items were found to be less than 0.85.

In the present study, the R square values for continuance intention, satisfaction, perceived usefulness, and perceived ease of use are 0.60, 0.301, 0.452, and 0.475, respectively, $p < 0.01$, all of which surpass 0.10 (Falk & Miller, 1992), thereby elucidating an adequate variance of endogenous variables accounted for by exogenous variables such as security, design, and confirmation (SEC, DES, and CON). The q square values for metaverse adoption, physical health, mental health, privacy and security, satisfaction, and continuance intention are 0.566, 0.086, 0.185, 0.167, 0.33, and 0.318, respectively. Q values exceeding zero signify the predictive relevance of a model as per the recommendations articulated by Hair et al. (2017). When an exogenous variable is removed from the model, the effect size (f square) illustrates the modifications in the R square value (Chin, 2010; Cohen, 1988). The range of values is delineated as 0.02 for a weak effect, 0.05 for a moderate effect, and 0.35 for a substantial effect. As indicated in Table 3, confirmation (0.211), design (0.194), perceived ease of use (0.109), perceived usefulness (0.071), and security (0.021) in the present study exhibited moderate effect sizes, while satisfaction demonstrated a significant effect size (0.486), with all other components reflecting small effect sizes.

Table 3. Discriminant validity

	CON	CUI	DES	PEOU	PU	SAT	SEC	R-Square	Q-Square	F-Square (Effect Size)
CON	0.85									0.211
CUI	0.582	0.846							0.382	
DES	0.649	0.559	0.803							0.194
PEOU	0.603	0.459	0.643	0.888					0.465	0.109
PU	0.647	0.521	0.549	0.585	0.899				0.441	0.071
SAT	0.61	0.742	0.571	0.501	0.474	0.887			0.372	0.486
SEC	0.485	0.45	0.412	0.374	0.396	0.422	0.83			0.021

Note n=540; Square root values of AVE for all the constructs are located on the diagonal; inter-construct correlations are found at lower diagonal values.

Table 4. HTMT Matrix

	CON	CUI	DES	PEOU	PU	SAT
CUI	0.723					
DES	0.776	0.676				
PEOU	0.718	0.552	0.745			
PU	0.766	0.616	0.622	0.669		
SAT	0.729	0.89	0.658	0.579	0.543	
SEC	0.598	0.567	0.51	0.456	0.479	0.513

8. Hypotheses Results and Discussion

8.1 Test of Hypotheses (H1-H13)

In the realm of this scholarly inquiry, the SmartPLS 4.0 software enabled the implementation of the partial least squares-based structural equation modeling (PLS-SEM) approach to rigorously evaluate the proposed research hypotheses. Given the characteristics, complexity, and sampling parameters of the study, the PLS-SEM approach is regarded as appropriate (Hair et al., 2021). Within the parameters of this examination, the identified exogenous variables comprised design (DES), security (SEC), and confirmation (CON), while the endogenous constructs included perceived usefulness (PU), perceived ease of use (PEOU), continuance usage intention (CUI), and satisfaction (SAT). The constructs PU, PEOU, and SAT were classified as both exogenous and endogenous variables within the analytical framework. All hypotheses, with the exception of H3, H4, H8, and H13, exhibited statistically significant coefficients (p-values < 0.01), as depicted in Figure 3 and Table 5. The empirical results revealed that metaverse design has a positive effect on perceived usefulness ($\beta = 0.42$, $p < 0.001$) and perceived ease of use ($\beta = 0.25$, $p < 0.001$). Security was observed to have a detrimental effect on the continuance usage intention of the metaverse (β

= 0.086, p < 0.05), yet it did not significantly influence perceived usefulness or perceived ease of use. Confirmation was found to positively affect perceived usefulness (β = 0.464, p < 0.001) as well as perceived ease of use (β = 0.299, p < 0.001). Moreover, perceived usefulness (β = 0.278, p < 0.001) and perceived ease of use (β = 0.313, p < 0.001) were shown to positively influence satisfaction. Satisfaction (β = 0.608, p < 0.001) was demonstrated to have a positive impact on the continuance usage intention of the metaverse. However, both confirmation and perceived ease of use did not manifest a significant influence on the continuance usage intention. The outcomes of the hypotheses, inclusive of p-values and a 95% confidence interval, are comprehensively presented in Table 5. The Standardized Root Mean Square Residual (SRMR) acts as an indicator of the model's congruence with the data (Hair et al., 2021); in this specific investigation, the SRMR value was ascertained to be 0.05, which remains below the threshold of 0.08 as recommended by Hu and Bentler (1999) and Hair et al. (2021).
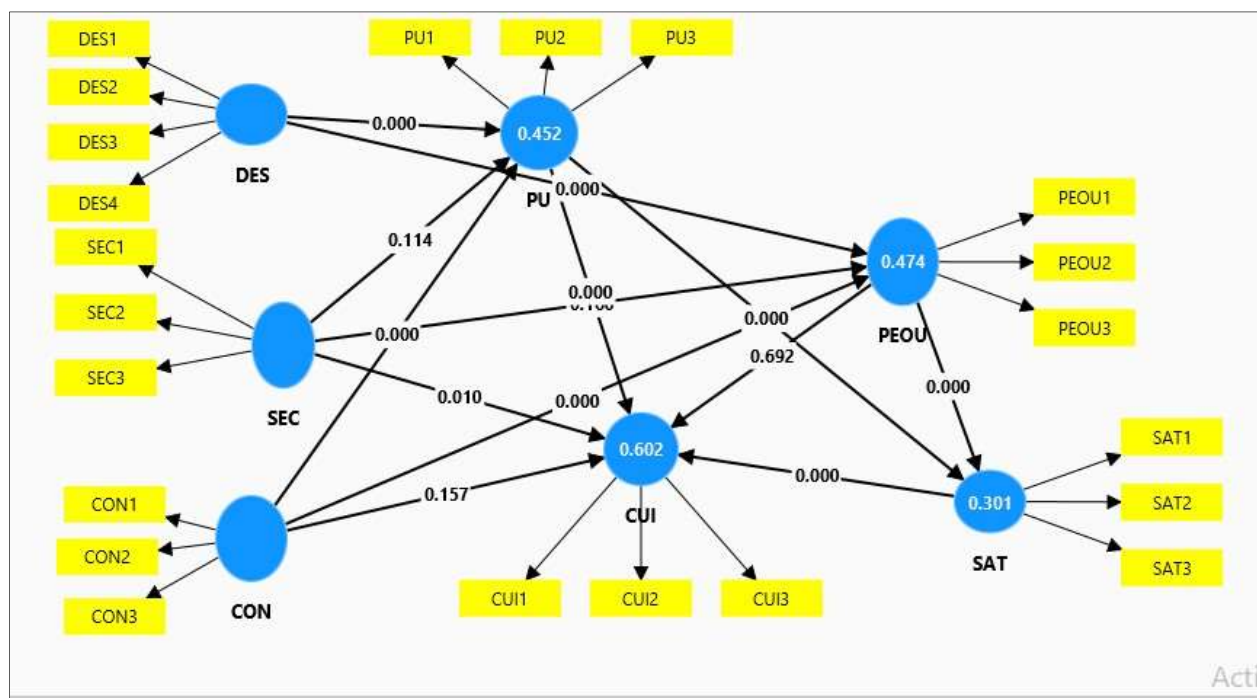

Figure 3. PLS Structural Model

Table 5. Hypotheses Result

Hypotheses	Paths	Path Coefficients	T Statistics	P values	2.5% CI	97.5% CI
H1	**DES -> PU**	0.210	3.593	0.000	0.095	0.326
H2	**DES -> PEOU**	0.424	8.599	0.000	0.327	0.521
H3	**SEC -> PU**	-0.082	1.58	0.114	-0.017	0.185

H4	SEC -> PEOU	-0.052	1.407	0.160	-0.021	0.126
H5	SEC -> CUI	-0.108	2.573	0.010	0.027	0.192
H6	CON -> PU	0.471	10.004	0.000	0.376	0.56
H7	CON -> PEOU	0.302	5.353	0.000	0.192	0.411
H8	CON -> CUI	0.084	1.415	0.157	-0.029	0.204
H9	SAT -> CUI	0.577	11.555	0.000	0.472	0.666
H10	PU -> SAT	0.275	4.458	0.000	0.155	0.398
H11	PEOU -> SAT	0.340	5.12	0.000	0.201	0.466
H12	PU -> CUI	0.159	3.63	0.000	0.073	0.245
H13	PEOU -> CUI	-0.015	0.396	0.692	-0.088	0.062

8.2 Specific Indirect effects

To initiate the mediation analysis, the significance of the indirect effects was examined employing the bootstrapping methodology. Indirect effects pertain to the influences that arise when the relationship between two variables is moderated by one or more intermediary variables. More explicitly, this signifies a condition in which the effect of one variable on another is not direct, but rather facilitated by additional factors that intervene within the process. As demonstrated in Table 6, the indirect effects of design (DES) on continuous intention (CUI) via perceived usefulness (PU) and satisfaction (SAT) (β= 0.033, p < 0.05) and through perceived ease of use (PEOU) and satisfaction (SAT) (β= 0.083, p < 0.01) were considered statistically significant. Correspondingly, the indirect effects of confirmation (CON) on CUI through PU and SAT (β= 0.075, p < 0.05) and through PEOU and SAT (β= 0.059, p < 0.01) were also determined to be statistically significant. These indirect effects suggest that the relationships between design (DES) and continuous intention (CUI) as well as between confirmation (CON) and continuous intention (CUI) were entirely mediated by PU (perceived usefulness) and SAT (satisfaction) in conjunction with PEOU (perceived ease of use) and SAT (satisfaction), respectively. In contrast, the indirect effects of security (SEC) on CUI through PU and SAT (β= 0.013, p > 0.05) and through PEOU and SAT (β= 0.01, p > 0.01) were not found to be statistically significant.

Table 6. Specific Indirect Effects

Path	Path Coefficients	T Statistics	P values
CON -> PU -> SAT	0.13	4.095	0.00
CON -> PEOU -> SAT	0.103	3.464	0.001

DES -> PU -> SAT	0.058	2.42	0.01
SEC -> PU -> CUI	0.013	1.338	0.18
DES -> PEOU -> SAT	0.144	4.294	0.00
SEC -> PEOU -> CUI	-0.001	0.323	0.74
SEC -> PU -> SAT	0.022	1.542	0.123
SEC -> PEOU -> SAT	0.018	1.282	0.20
SEC -> PEOU -> SAT -> CUI	0.01	1.301	0.193
SEC -> PU -> SAT -> CUI	0.013	1.555	0.12
CON -> PEOU -> SAT -> CUI	0.059	3.365	0.001
CON -> PU -> SAT -> CUI	0.075	3.709	0.00
DES -> PU -> SAT -> CUI	0.033	2.302	0.021
DES -> PEOU -> SAT -> CUI	0.083	4.193	0.00
CON -> PU -> CUI	0.075	3.582	0.00
CON -> PEOU -> CUI	-0.005	0.378	0.705
DES -> PU -> CUI	0.033	2.556	0.011
PEOU -> SAT -> CUI	0.196	4.959	0.00
DES -> PEOU -> CUI	-0.006	0.398	0.691
PU -> SAT -> CUI	0.159	4.05	0.00

9.   Discussions and Implications

This academic inquiry employed the Technology Acceptance Model (TAM) alongside the Expectation-Confirmation Model (ECM) to investigate the myriad factors that affect both the initial adoption and the sustained intention to engage with AI-enhanced metaverse environments. In addition to design and security considerations, the theoretical framework encompasses these pivotal elements. The results demonstrated that the architectural features of the metaverse

positively impact perceived utility and user-friendliness. These findings are consistent with the assertions made by Davis (1987) and Koch (2011), as well as Ibili et al. (2023), who contended that system design characteristics can favorably affect individuals' perceptions of usefulness and ease of use by fostering the belief that a specific technology will augment their task performance. Furthermore, Balakrishnan et al. (2024) underscored that the information available within the metaverse can enhance navigational efficiency within the virtual realm, consequently reducing the effort necessary to achieve user goals. The research further revealed a significant and positive relationship between perceived usefulness and the intention to sustain usage, corroborating prior studies (Teng et al., 2022; Lee et al., 2023; Alshammari et al., 2024), which indicated that users demonstrate a greater propensity to persist in their engagement with the metaverse when they perceive it as beneficial and instrumental in fulfilling their educational and personal aspirations.

The study's findings indicated that perceived ease of use does not exert a significant influence on the adoption of the metaverse, as asserted by Alshammari et al. (2024). The authors suggested that students, as digital natives proficient in technological utilization, do not face substantial challenges in navigating such platforms. Since engagement with the metaverse does not require additional effort, perceived ease of use does not considerably affect the probability of continued utilization of the metaverse. Moreover, the results indicated that security concerns related to the metaverse adversely impact the intention to persist in using the platform, which is consistent with the observations made by Oleksy et al. (2023), who noted that the negative ramifications of adopting the metaverse include privacy risks and the unpredictable consequences of displacing individuals from physical environments, thereby impeding sustained usage in the future. The findings further illustrated that confirmation has a constructive effect on both perceived usefulness and perceived ease of use of the metaverse. These results align with Natale et al. (2014), who asserted that when users' initial expectations of the metaverse coincide with their actual experiences, their perceptions of the metaverse's utility, satisfaction, and confidence in its application are positively enhanced.

The investigation also established that confirmation does not significantly influence the intention to continue utilizing the metaverse, which is consistent with Natale et al. (2024), who posited that a confluence of factors including perceived usefulness, perceived ease of use, and overall satisfaction dictates users' intentions to persist in their utilization of the technology. Thus, it is evident from this study that confirmation lacks a direct impact on the ongoing engagement with the metaverse.

The empirical evidence revealed that both perceived utility and perceived simplicity of use exert a positive influence on user satisfaction within the metaverse, thereby affirming the assertions made by Maghaydah et al. (2024), Mandal et al. (2024), and Lestari et al. (2024), which underscored that perceived simplicity of use has the capacity to elevate user satisfaction in digital services such as the metaverse, and that the perceived utility of the metaverse significantly affects the engagement and satisfaction levels of Generation Z users interacting with this digital environment. The outcome of this investigation concerning a notable correlation between user satisfaction and the ongoing intention to utilize the metaverse is in accordance with the claims advanced by Natale et al. (2024), which suggest that the extent of satisfaction derived from

participation in the metaverse is crucial in shaping the user's decision to persistently engage with the technology.

10. Limitations and Contribution

This investigation is characterized by distinct limitations that may warrant further exploration by future scholarly pursuits. Primarily, the current study is situated within the geographical framework of India; hence, subsequent researchers may direct their attention towards a variety of nations to acquire a more comprehensive array of findings. Furthermore, this research assessed the ongoing application of metaverse technology based on factors such as user satisfaction, perceived ease of use, perceived utility, design aesthetics, and security considerations; thus, future inquiries might incorporate additional parameters including technology-related costs, technological awareness, self-efficacy, among others. It is impractical to encapsulate all dimensions within the limits of this manuscript. This study predominantly concentrates on the adoption of metaverse technology within the educational sector, while future investigations will also extend to encompass other domains such as manufacturing, healthcare, tourism, retail, and beyond. A significant limitation of this research is its exclusive focus on participants from Generation Z; consequently, future studies will also integrate millennials into their analytical frameworks.

These findings elucidate pivotal considerations for developers and practitioners engaged in the design and security of the metaverse, with the aim of facilitating its widespread adoption. This research contributes to the limited body of knowledge regarding the adoption of metaverse technology within the educational sector and investigates the determinants influencing its acceptance in this context. The insights derived from this study hold considerable significance for policymakers, developers, and researchers, thereby substantially advancing the field of metaverse adoption. The potential implications of metaverse integration underscored in this research may assist system designers in fostering a more inclusive and less detrimental virtual environment.

Declaration of conflict of interest

This manuscript is devoid of any conflicts of interest pertaining to its publication.

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