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Uncovering the critical drivers of Blockchain sustainability in higher education using a deep learning-based hybrid SEM-ANN approach

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Abstract

The increasing popularity of Blockchain technology has led to its adoption in various sectors, including higher education. However, the sustainability of Blockchain in higher education is yet to be fully understood. Therefore, this research examines the determinants affecting Blockchain sustainability by developing a theoretical model that integrates the protection motivation theory (PMT) and expectation confirmation model (ECM). Based on 374 valid responses collected from university students, the proposed model is evaluated through a deep learning-based hybrid structural equation modeling (SEM) and artificial neural network (ANN) approach. The PLS-SEM results confirmed most of the hypotheses in the proposed model. The sensitivity analysis outcomes discovered that users' satisfaction is the most important factor affecting Blockchain sustainability, with 100% normalized importance, followed by perceived usefulness (58.8%), perceived severity (12.1%), and response costs (9.2%). The findings of this research provide valuable insights for higher education institutions and other stakeholders looking to sustain the use of Blockchain technology.

Keywords: drivers; Blockchain; sustainability; higher education; deep learning; SEM-ANN.

1. Introduction

Organizations use technological advancements to establish their strategic aims for gaining market domination. Disruptive technologies have forced firms to reevaluate and reinvent their operational processes and technology infrastructure in response to changing market conditions. Blockchain is regarded as the disruptive technology of the current decade, forcing market leaders to review their business strategies (Bhatt et al., 2021). Blockchain has gained a lot of attention and recognition in recent years as a transformative technology that has the potential to disrupt and revolutionize various industries (S. Wong et al., 2021). Blockchain is a decentralized, distributed ledger technology that enables the secure and transparent recording of transactions without the need for a central authority or intermediaries (Moll & Yigitbasioglu, 2019). Blockchain technology holds the potential to revolutionize digital transaction security and trust (Omrani et al., 2022). The advantages of Blockchain technology includes decentralization, transparency, security, and immutability. Even though Blockchain may provide a solution to several issues such as a lack of trust and information security, there are still many obstacles that must be overcome before a procedure can be adopted and implemented (Scherer et al., 2019). Infrastructure, people's perspectives, and procedures all need to be changed fundamentally to support the adoption process. These variables can be separated into institutional, market, and technical variables (Salim et al., 2022).

Blockchain uses advanced cryptography to ensure the integrity and immutability of the records, making it resistant to tampering and fraud (Al-Amri et al., 2021). First implemented in 2008, it is a public ledger maintained de-centrally as a single data record in blocks on network nodes (Rakshit et al., 2022). According to Zhang et al. (2021), Blockchain supports automated and secure transactions between many actors, as well as enhancing the balancing of supply and demand. Blockchain technology was initially developed to be used in the financial sector, but it has since been applied in various industries, including supply chain management (Kumar et al., 2022; Zhang et al., 2022; Ghode et al., 2020; Abeyratne & Radmehr P. Monfared, 2016), healthcare (Alzahrani et al., 2022; Massaro, 2021; Pham et al., 2018), hospitality and tourism (Sharma et al., 2021), agriculture (Sharma et al., 2022; Garrard and Fielke, 2020), energy (Sahebi et al., 2022), construction (Xu et al., 2023), national governments, and academic communities (Cerchione et al., 2023). It has strong cybersecurity capabilities (Bhaskar et al., 2021) and the potential to streamline processes, increase transparency, and reduce the risk of errors and fraud (Angelis & Ribeiro, 2019; Harris & Wonglimpiyarat, 2019).

According to Garcia-Perez (2022), the global economy and society have both been greatly impacted by new technologies. Today, people use digital technologies in all aspects of daily life, including work, education, entertainment, transportation, and communication (Al-Emran, 2023). Smart education driven by Blockchain has gained a lot of attention in recent years, and relevant system frameworks and important technologies have been described (Gong et al., 2019). According to Zhang et al. (2022), the primary benefit of Blockchain is its potential to address problems with disclosure and accountability between people and institutions, where the parties' interests are not always congruent. As a result, each network member can gain better and more timely visibility into the network's operations at any time. On the other hand, it arranges for real-time updating of the data that is crucial to all parties, doing away with the need for lengthy and error-prone reconciliation procedures with each party's internal records. It is important to understand both the benefits and the potential complications of implementing Blockchain in education and identify any issues that may arise during the transformative process (Ullah et al., 2021).

Higher education institutions should strive to increase their awareness and understanding of Blockchain, and use it to improve the skills and capabilities of the educational sector (Shah et al., 2021). Blockchain can be used in educational settings for issuing, confirming, and exchanging certificates (Bhaskar et al., 2021). However, concerns about scalability, security, and regulatory issues, as well as a lack of awareness, can make it difficult for the educational sector to sustain its use. A recent systematic review revealed that the influence of security aspects on the sustainable utilization of Blockchain is overlooked (AlShamsi et al., 2022). In this study, "Blockchain sustainability" is defined as the ongoing use of Blockchain technology within higher education. This definition emphasizes the technology's relevance, adaptability, and utility, ensuring its users consistently engage with it over extended periods. The term "sustainability" underscores the ongoing nature of Blockchain adoption in the academic sphere, advocating for its sustained application beyond just short-term integration. This notion of sustainability in the context of technology adoption aligns with previous studies in various domains. For example, Al-Sharafi, Al-Emran, et al. (2022) explored the sustainable use of AI-based chatbots in education, emphasizing the continuity and relevance of technology from a user engagement perspective. Despite the numerous studies on the adoption of Blockchain technology in various industries, there remains a shortage of knowledge regarding what affects its sustainable application in higher education (Loukil et al., 2021; Yumna et al., 2019). While it has the potential to revolutionize secure transactions in education, there are also challenges to its sustainability (Loukil et al., 2021; Raimundo, 2021).

To bridge the previously mentioned gaps, this research aims to deepen our understanding of the factors that drive the sustainable use of Blockchain in higher education. To achieve this, we proposed a theoretical model by integrating the expectation confirmation model (ECM) (Bhattacherjee, 2001) with the protection motivation theory (PMT) (R. W. Rogers, 1975; R. W. Rogers & Prentice-Dunn, 1997). The ECM can be used to understand how individuals' expectations about a technology, such as Blockchain, influence their behavior toward it. It suggests that people's preconceptions about technology play a role in their willingness to adopt and utilize it. Their personal experiences with the technology either confirm or contradict their initial expectations. On the other side, the PMT theory can be used to examine the perceived threats or risks associated with adopting Blockchain and the motivations that drive individuals to embrace it, such as the potential benefits or rewards they expect to receive. By grasping the underlying principles behind the formation of individuals' expectations, the impact of their experiences with technology, and its associated threats, we can accurately anticipate and comprehend the sustainable use of Blockchain technology within higher education.

2. Blockchain in higher education

Blockchain technology has the potential to transform various industries, including higher education. Universities not only contribute to education and research but also to local development by involving both public and private partners, transferring knowledge to the market, and promoting creative solutions. To achieve this, universities use an interdisciplinary, multi-stakeholder approach that increases the impact of their research findings and enhances the social, cultural, and environmental development of their local communities (Compagnucci et al., 2022). Colleges and universities frequently allocate resources toward technological solutions as a crucial component of their strategic planning and community outreach initiatives (Y. A. Qasem et al., 2021; Y. A. M. Qasem et al., 2020). Since educational institutions could verify the certificates directly on the Blockchain, the nature of Blockchain technology can assist them in reducing unnecessary costs in terms of time and resources associated with transactions to confirm the validity of their certificates issued to third parties (Cheng et al., 2018). On the other hand, university transcript data can be kept in blocks, and smart contracts can be used to enable transcript functionality (Arndt and Guercio, 2020).

The goal of Blockchain technology is to set up smart networks for data mobility, which can significantly increase the efficiency and transparency of sustainable supply chain management (Zhang et al., 2022). Likewise, the higher education sector requires more development and enhancement to effectively utilize Blockchain technologies and achieve better results (Vidal et al., 2020). Blockchain technology can potentially enhance higher education in several ways (Raimundo, 2021). For example, it can be used to verify and store educational credentials, streamline the admission process, improve the delivery of online courses, facilitate research collaboration, and enhance student engagement. In addition, Blockchain can create a secure and immutable record of educational credentials, such as degrees and certifications, helping to prevent fraud and to ensure that academic achievements are accurately represented. Moreover, Blockchain can be used to verify the identity of students and to ensure that they receive credit for completing online courses. It can also facilitate collaboration between researchers by creating a secure and transparent record of research contributions. Additionally, Blockchain can be used to create a personalized learning experience for students by tracking their progress and providing them with relevant resources and support. Blockchain technology can also be utilized to handle various educational administration and data management tasks using shared ledgers. This includes using smart contracts for hiring school staff, promoting ongoing professional development, and overseeing performance objectives and payments (J. Park, 2021). Two emerging application areas that involve multiple, distributed actors and that naturally lend themselves to the use of Blockchain as a component of a system are the transfer of credits between highly mobile students crossing international borders and the consolidation of new, diverse educational credentials (certificates, badges, etc.) in higher (Arndt and Guercio, 2020).

Blockchain technology has the potential to revolutionize education by efficiently managing data (Yumna et al., 2019). Role-based access, records management, and data transfer can be greatly improved by Blockchain (Zhang et al., 2022). The foundation for data notarization and certification applications, such as those targeted at recording, tracing, and certifying the stages of a productive process in the supply chain, is the immutable storage of data, which is supported by all Blockchain infrastructures (Pólvora et al., 2020). On the other hand, implementing a Blockchain model in education involves securing data, establishing system trust, handling a global database, and conducting a formative evaluation. There have been several initiatives implemented by educational institutions to utilize Blockchain technologies. For example, the University of Nicosia has implemented technology for managing student databases and tracking certificates. The Massachusetts Institute of Technology (MIT) has also developed a new machine learning technology based on the structure of Blockchain to monitor student records. Implementing Blockchain technology in higher education can involve significant changes to existing procedures and processes. Some educational institutions may be hesitant to share their data on a Blockchain network. and may have difficulty deciding which data and services to offer through the network (Sharples & Domingue, 2016).

The unchanging characteristic of Blockchain technology can pose difficulties for educational institutions in implementing new data storage regulations or correcting inaccurate information (Mitchell et al., 2019). Furthermore, Blockchain technology still struggles with low usability and complicated configurations, and its transactions lack privacy as the information and values associated with each public key are publicly accessible (Kosba et al., 2016). The widespread interest in Blockchain technology highlights the need for organizations to embrace change and be prepared for the radical transformation of their operations (L. W. Wong et al., 2020). A study that examined the literature on Blockchain technology and sustainability found that there is a scarce amount of evidence on Blockchain sustainability, and the existing data do not provide detail on the execution of the technology (Abeyratne & Radmehr P. Monfared, 2016). In addition, a recent systematic review indicated limited research on how threat appraisal and coping appraisal affect Blockchain sustainability (AlShamsi et al., 2022).

3. Research model and hypotheses development

This research integrates two theories, the protection motivation theory (PMT) and the expectation confirmation model (ECM), to propose a theoretical model to predict the drivers of Blockchain sustainability. This research adopts the “continuous intention” concept from the ECM to define Blockchain sustainability as its persistent application in higher education beyond mere short-term implementation. This approach to sustainability in technology adoption resonates with findings in other fields. For instance, Arpaci (2023) examined the sustainability of chatbots and their impact on social sustainability by integrating the PMT with cybersecurity concerns. In a related vein, Park and Lee (2023) delved into chatbot sustainability by augmenting the ECM with AI features and chatbot traits. In addition, Al-Sharafi, Al-Emran, et al. (2022) examined chatbot sustainability by enriching the ECM with knowledge management factors. Furthermore, the enduring use and social sustainability of emerging technologies like the Metaverse have been highlighted, emphasizing their continued adaptability and focus on the user (Arpaci et al., 2022). Thus, our definition aligns with these viewpoints, emphasizing Blockchain’s long-term role in the educational sector.

PMT involves several constructs categorized under "threat appraisal" and "coping appraisal" (R. W. Rogers, 1975; R. W. Rogers & Prentice-Dunn, 1997), while ECM is characterized by continuous intention (Bhattacherjee, 2001). The choice of these two theories is based on their respective focus. PMT is utilized to assess the influence of security factors, whereas ECM is commonly employed for post-acceptance investigation. PMT aims to investigate the cognitive mechanisms that influence behavior when faced with a threat (Hassandoust & Techatassanasoontorn, 2019). PMT discusses how people react defensively to a threatening occurrence that is about to happen or has already happened. The theory consists of two methods that people employ to stay motivated: threat assessment and coping evaluation (Singh et al., 2022).

ECM is a psychological model that explains how individuals form and revise their expectations about a product or service based on their experiences. The ECM is an extension of expectation confirmation theory (ECT), which suggests that individuals have certain expectations about the performance of a product or service before they use it. Their level of satisfaction with the product or service is determined by whether or not those expectations are met (Bhattacherjee, 2001). According to the ECM, an individual's intention to continue using technology mainly depends on the degree of the user's confirmation of expectations, the level of the user's satisfaction with the technology, and post-adoption expectations. The ECM has been widely used to study the continuance use and technology sustainability (Al-Sharafi et al., 2022, 2019; Chen et al., 2012; Joo et al., 2017; Lin et al., 2012), and has been found to be a valuable framework for understanding and predicting consumer behavior, particularly in the context of information systems.

PMT is a psychological theory that aims to understand the cognitive processes that influence behavior in response to perceived threats, and to identify factors that influence an individual's intention to take preventive actions or engage in maladaptive behaviors (R. W. Rogers & Prentice-Dunn, 1997). PMT has been used as a valuable framework for understanding human behavior toward accepting or rejecting technology, including Blockchain technology. PMT states that in response to a threatening situation, individuals undergo two appraisals: threat appraisal and coping appraisal. Threat appraisal evaluates the factors that contribute to the potential danger of the situation, such as the rewards and consequences of the action, the danger's severity, and one's vulnerability. Coping appraisal evaluates one's self-efficacy and the effectiveness of potential responses concerning the costs of protective behavior. PMT can be used to understand how security concerns can impact an individual's intention to continue using Blockchain technology. Additionally, PMT can be used to understand the motivations that drive individuals to adopt Blockchain technology, such as the potential benefits or rewards they expect to receive. Understanding these factors can help researchers better predict and understand the adoption and sustainability of Blockchain technology in higher education and other industries. The proposed theoretical model is presented in Figure 1.

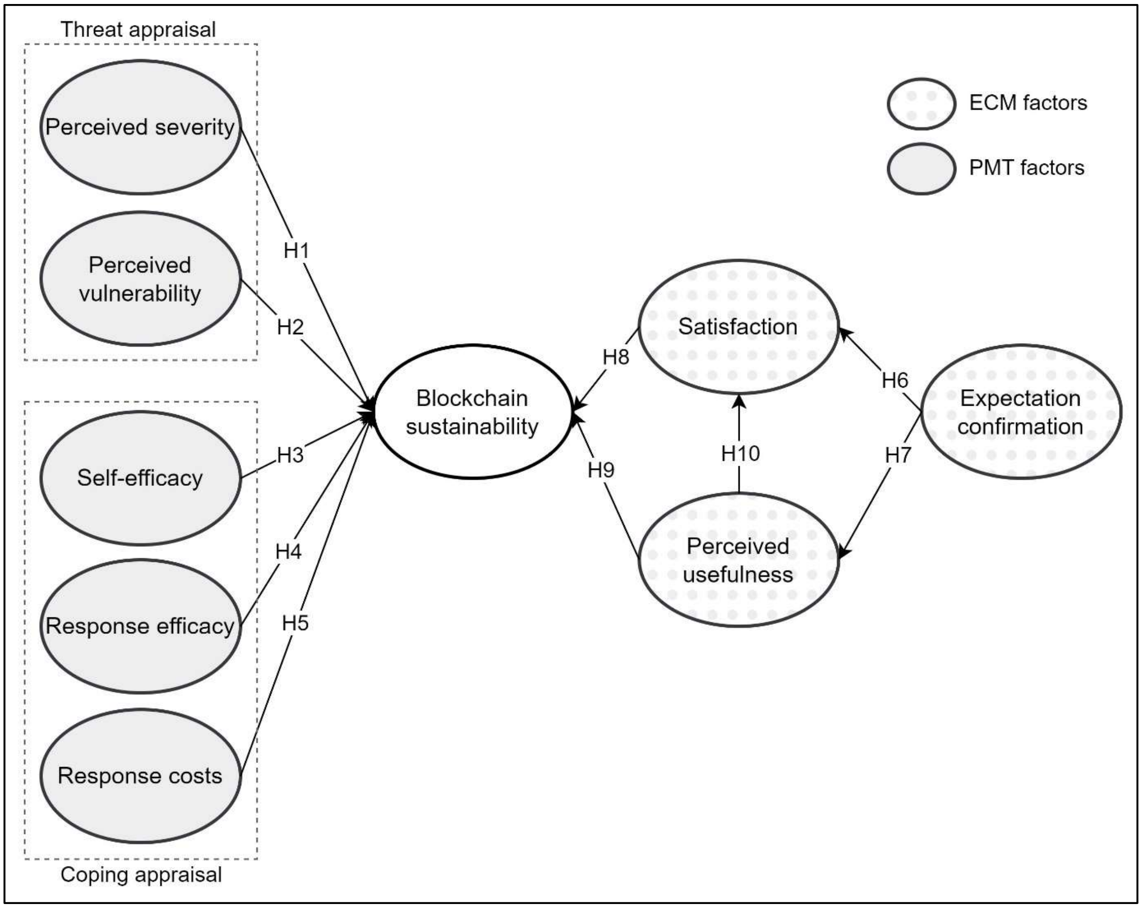

Figure 1. Proposed research model.

3.1 Perceived severity

Perceived severity refers to an individual's assessment of the danger or harm that a threat poses. This can encompass evaluations of economic damage, social hazards, and psychological and physical harms (R. W. Rogers, 1975). The severity of inhibitors may have a significant impact on how an organization adopts new technology and uses it (King & Teo, 1996; Teo et al., 2006). PMT states that perceived severity is one of the two major cognitive components that reflects a user's evaluation of the perceived threat's seriousness. Individuals' responses to threats, whether adaptive or maladaptive, are influenced by their appraisal of the threat and their coping mechanisms (Ronald W. Rogers & Rippetoe, 1987). Fear appeals can also play a

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role in shaping voluntary behavior in a systematic manner (Sommestad et al., 2015). Adopting new technologies can often be challenging due to psychological anxiety, which PMT can address.

Studies have consistently shown that perceived severity is significantly related to an individual's intention to adopt new technologies, including smartwatches (Al-Emran et al., 2021), cyberspace (Wu, 2020), anti-plagiarism software (Ifinedo, 2012), and phishing (Shahbaznezhad et al., 2020). Similarly, it can be hypothesized that Blockchain sustainability depends on the perceived severity of the problem among the participants. Complying with perceived severity procedures is expected to lead to a stronger motivation for Blockchain sustainability. Therefore, the following hypothesis is proposed:

H1: Perceived severity is significantly related to Blockchain sustainability.

3.2 Perceived vulnerability

Perceived vulnerability is "the conditional probability that the threatening event will occur provided that no adaptive behavior is performed or there is no modification of an existing behavioral disposition" (R. W. Rogers & Prentice-Dunn, 1997; Ronald W. Rogers, 2010). Perceived vulnerability is recognized for its framework that highlights uncertainty and consequences (Conchar et al., 2004; Nicolaou & McKnight, 2006). Threats associated with technology use can include monetary losses, misuse of private data, or identity theft during online transactions. There is a definitive relationship between behavior and perceived vulnerability (Marikyan et al., 2022). An individual is likely to assess potential security threats and consider ways to mitigate them if they perceive a high vulnerability risk. To grasp the interaction and threat mitigation of new technology, it's crucial to comprehend one's own perception of their vulnerability to it. Human behavior still affects human interaction and risk mitigation, even though digital technologies that can be utilized proactively and in real-time are being increasingly utilized. Many studies have demonstrated a correlation between perceived vulnerability and an individual's intention to adopt various technologies, such as smartwatches (Al-Emran et al., 2021), cyberspace (Wu, 2020), and phishing (Shahbaznezhad et al., 2020). On the other hand, the role of threat severity will be important in encouraging adoption of Blockchain technology. This may be particularly true given that the deployment of privacy-preserving technologies is motivated by the possibility that unauthorized parties could obtain personal data and use it improperly. Such repercussions are out of one's control. In contrast, the impact of threat intensity may be substantially less significant when people have a high level of behavioral control, are aware of the hazards, and have personal efficacy in connection to protective actions (Menard et al., 2017). According to Tsai et al. (2016), in these circumstances, the perception of coping effectiveness may lessen the impact of threat severity on the decision to implement security measures. Adopting the Blockchain is crucial in higher education as it's associated with sensitive data, such as educational and personal records. Therefore, understanding how to deal with vulnerability issues will lead to sustaining the use of Blockchain. Accordingly, the following is formulated:

H2: Perceived vulnerability is significantly related to Blockchain sustainability.

3.3 Self-efficacy

Self-efficacy is "the degree to which an individual has confidence that he or she will be able to carry out the coping behavior" (Sergueeva & Shaw, 2017). Self-efficacy is the concept that someone can act in a way that will effectively deal with the threat. The intention to participate in adaptive behavior, such as the adoption of Blockchain-enabled services, grows with increased confidence in one's own talents. Self-efficacy influences behavior in both direct and indirect ways. Examples include using software for email authentication and bogus website identification (Johnston & Warkentin, 2010). As a result, it is anticipated that the intention to embrace Blockchain-based apps will connect with an individual's capacity to participate in protective behaviors (Marikyan et al., 2022). Services with high output quality depending on the demands and tasks of users should be offered to increase innovative structure, flexibility, and diversity so that users can improve their self-efficacy (Kimiagari & Baei, 2022). Blockchain is able to provide services with high output quality. In PMT, self-efficacy refers to an individual's belief in their ability to take effective action to cope with a perceived threat (R. W. Rogers, 1975; Woon et al., 2005). Higher levels of self-efficacy can increase the intention to engage in adaptive behavior, such as adopting Blockchain technology. The belief in one's abilities, or self-efficacy, can directly or indirectly affect the decision to participate in activities such as using email authentication and fake website detection systems. Numerous research studies have been conducted to assess individuals' self-efficacy. In the fintech domain, self-efficacy and its effects are well-documented, both online (Alalwan et al., 2015; Marakarkandy et al., 2017) and in mobile banking (Jeong & Yoon, 2013; Zhou, 2012). For example, a study by (Gao et al., 2016) discovered that individuals who do not use bitcoin believe they do not possess the necessary proficiency, which is their primary justification for not engaging in its use. It has also been suggested that self-efficacy is essential in understanding fear appeals (Johnston & Warkentin, 2010). Based on these conclusions, the same can be suggested when

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understanding the sustainability of Blockchain for educational activities. Therefore, we propose the following:

H3: Self-efficacy is significantly related to Blockchain sustainability.

3.4 Response efficacy

Response efficacy refers to an individual's belief that adaptive behavior can prevent or avoid a threat (Lee, 2011). Previous research suggests that technology effectively facilitates responses and that Blockchain offers privacy and security benefits when utilized (Janssen et al., 2020). Individuals are expected to view technology as a means of securing their personal data from unauthorized access by others. Upon recognizing the potential threat, they evaluate the available options to address it. If they feel that adjusting their behavior will increase their ability to confront the threat, their intention to adopt the technology will become stronger. A certain amount of resistance enters the picture, subsequently serving as the user's initial reaction to a threat. It offers them a feeling of security that helps them judge the situation and determine how best to take action. Self-efficacy, perceived severity, and response efficacy are all highly impacted by users' perceptions of security (Kimiagari & Baei, 2022; Hanus & Wu, 2016). According to Marikyan et al. (2022), response efficacy is the strongest cognitive aspect underpinning purpose, it is crucial for customers to have faith that Blockchain-based services will be successful in fending off cyber threats. Response efficacy was found to have a considerable positive impact on individuals' behavioral intentions to adopt smartwatches (Al-Emran et al., 2021), cyberspace (Wu, 2020), and phishing (Shahbaznezhad et al., 2020). When considering the sustainability of the Blockchain, the following hypothesis is proposed:

H4: Response efficacy is significantly related to Blockchain sustainability.

3.5 Response costs

Response costs refer to the perceived costs an individual may incur to engage in adaptive behavior (Lee, 2011). These costs may include the time, money, and effort required to adopt and use a particular technology (R. W. Rogers & Prentice-Dunn, 1997). Response costs are frequently viewed as a detrimental aspect of any subject evaluation. In the context of this study, response costs may include the time and effort required to learn how to use Blockchain technology in education, as well as any financial costs associated with its adoption. According to Zhao et al. (2021), since data collection frequently needs to be used for more than one query, the level of privacy protection could deteriorate as more queries are resolved. Thus, it is essential to monitor privacy budget expenditure, which should not go beyond the allotted amount. Response costs were found to negatively influence the sustainability of various technologies like smartwatches (Al-Emran et al., 2021), cyberspace (Wu, 2020), and phishing (Shahbaznezhad et al., 2020). We, therefore, propose the following:

H5: Response costs are significantly related to Blockchain sustainability.

3.6 Expectation confirmation

Expectation confirmation refers to the degree to which an individual's expectations about a product, service, or technology are met or exceeded after using it (Bhattacherjee, 2001). The psychological attribute of a user during interaction with an entity is determined by their perception of quality following the occurrence of an event (Spreng et al., 1996). Expectations predict future product attributes and are directly proportional to performance perceptions and confirmation (Churchill & Surprenant, 1982). Confirming expectations can result in post-purchase or post-adoption satisfaction through its mediational connection with the expectation confirmation construct (Jiang & Klein, 2009). In this context, expectation confirmation can refer to the extent to which students feel that Blockchain meets or exceeds their expectations in terms of performance, ease of use, and ability to support their educational activities. This aligns with previous research that demonstrated the value of ECM in explaining the expectation-confirmation behaviors of information system users in organizations (Gupta et al., 2020; Wang et al., 2019; Wu, 2020). Ambalov (2021) found that confirmation affects both perceived usefulness and satisfaction. Furthermore, he found that perceived usefulness has a positive effect on satisfaction. The ECM involves looking at the long-term elements that encourage their system reuse (Hong et al., 2006). According to Jumaan et al. (2020), the confirmation, perceived usefulness, satisfaction, and continuance intention attitudinal elements make the ECM. On the other hand, the ECM has been tested and expanded in numerous applications, such as online shopping and healthcare, demonstrating its effectiveness as a robust framework for comprehending the persistence and sustainability of technology (Al-Emran et al., 2020; E. Park, 2020). Hence, the following hypotheses are suggested:

H6: Expectation confirmation is significantly related to satisfaction.

H7: Expectation confirmation is significantly related to perceived usefulness.

3.7 Satisfaction

Adopting new technology is a critical strategic decision. Technology adoption is an important process that provides a competitive advantage for organizations. Technology adoption can

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increase a company's process capabilities and it affects satisfaction (Bolatan et al., 2022). According to Kaur et al. (2022), Blockchain is a potential technology that aims to increase operational effectiveness and competitive advantage in supply chain financing transactions by enabling a higher level of transparency and visibility (Chen et al., 2022). The positive feeling of end users toward a specific technology is known as satisfaction (Doll et al., 1998). Satisfaction is an essential factor that can influence the sustainability of Blockchain technology.

Transparency in action has a big impact on customer satisfaction because it enables businesses to analyze data more quickly, which increases customer satisfaction. Transparency in transactions means that every step of the transaction process is visible to the customer. Additionally, transparency permits some entities to flow through transparent materials, which increases customer satisfaction (Chen et al., 2022). As a result, Blockchain can increase satisfaction because it can provide transparency.

According to (Joo et al., 2016), learners who are more satisfied with technology are more likely to continue using it in future learning situations. The ECM suggests that satisfaction is influenced by confirmation, perceived performance, and expectations (Bhattacherjee, 2001). The psychological approach of ECM can address any threats or barriers to adopting new technologies, such as Blockchain, and facilitate user satisfaction (Wamba, 2019). In the context of Blockchain technology, satisfaction is related to its ability to provide security, transparency, and efficiency in business networks (Shin & Hwang, 2020; Sumit et al., 2022; Kaur et al., 2022; Chen et al., 2022), which can boost the user experience and increase trust in the technology. Several studies found that satisfaction significantly impacts the continued use of technology (Dai et al., 2020; E. Park, 2020). Thus, satisfaction with Blockchain technology can contribute to its sustainability. Therefore, we propose the following:

H8: Satisfaction is significantly related to Blockchain sustainability.

3.8 Perceived usefulness

Perceived usefulness is "the degree to which a person believes that using a particular system would enhance his/her job performance" (Davis, 1989). It encompasses three aspects: performance-based outcome expectations, personal-based outcome expectations, and intrinsic motivation (Saadé, 2007). According to many researchers, the most important predictor of the intention to adopt and use technology is "perceived usefulness" (Ambalov, 2021; Venkatesh et al., 2003; King & He, 2006; Venkatesh et al., 2012). The perception of usefulness plays a vital

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role in deciding whether a technology will be continued to be used, and research has shown that it has a substantial impact on one's intentions to use the technology in various technological situations (Guriting & Oly Ndubisi, 2006; Laforet & Li, 2005; Liao & Cheung, 2002; Polatoglu & Ekin, 2001). Previous research has also found that perceived usefulness has a significant relationship with satisfaction (Al-Emran et al., 2020; E. Park, 2020; Suzianti & Paramadini, 2021). In the context of this study, it is vital to understand how students perceive Blockchain technology because their perceptions can have an impact on their performance and Blockchain sustainability. Students with positive perceptions of Blockchain technology may be more likely to use it effectively and consistently. On the other hand, if students have negative perceptions of the technology, they may be less likely to use it or struggle to use it effectively. Understanding students' perceptions of Blockchain technology can therefore be helpful in promoting its sustainable use in higher education. Thus, the following hypotheses are put forward:

H9: Perceived usefulness is significantly related to Blockchain sustainability.

H10: Perceived usefulness is significantly related to satisfaction.

4. Methodology

A quantitative research approach through an online survey was utilized among university students in the UAE to validate the proposed model and to meet the study objectives. This approach was chosen because it allows for the collection of data from a large number of participants in a relatively short amount of time, and could provide insights into the attitudes and perceptions of students toward Blockchain technology and its use in higher education (Malhotra & Grover, 1998; Sekaran & Bougie, 2016)(Punch, 1998). The sampling frame for this study consisted of students enrolled at universities in the UAE who were using Blockchain technologies for educational purposes. These students were chosen as the subjects of the study because they represent a group of individuals who were actively using Blockchain technologies, and who were likely to have valuable insights into the factors that influence the adoption of this technology. To be eligible for the study, participants had to be students enrolled at a university in the UAE and have experience using Blockchain technologies. Participants were recruited through emails and social media platforms, and were asked to complete an online survey. Informed consent was obtained electronically from all participants before they began the survey. A purposive sampling method was used to recruit participants for the survey. This sampling method is chosen because it allows selecting a sample tailored explicitly to the research objectives and aimed to maximize the chances of obtaining valuable and relevant data (Tongco, 2007). Purposive sampling is often used when the research investigates a specific subgroup within a large population (Sekaran & Bougie, 2016).

To ensure the quality of the data collected, the survey was pilot tested with a small group of participants before being distributed to the full sample. The research instrument for this study consisted of two main sections. The first section included questions about socio-demographic characteristics, such as gender, age, nationality, education level, and educational institution. It also included questions about Blockchain technology usage patterns, such as the frequency and types of applications the participants had used. The second section consisted of the items measuring the factors in the proposed model. These items were measured using validated questions from previous research studies that had been adapted for use in this study. All the items were measured using a five-point Likert scale ranging from “1 = strongly disagree” to “5 = strongly agree”. The adopted items and their sources are demonstrated in the Appendix. The G*Power tool (Erdfelder et al., 2009) was used to find the minimum sample size needed with parameters of effect size 0.15, error type (α) 0.01, power 0.8, and 7 predictors. Based on these parameters, the G*Power tool recommended a minimum sample size of 142. Therefore, the collected sample size of 425 surveys is considered sufficient. After removing outliers, 374 responses were retained for further analysis. Table 1 shows the demographic characteristics of the respondents.

In order to analyze the data, both partial least squares-structural equation modeling (PLS-SEM) and artificial neural network (ANN) were used. PLS-SEM is a multivariate statistical technique that is particularly useful for analyzing survey data and examining relationships between constructs (Henseler et al., 2016). It is particularly well-suited for this study because it can handle complex models and does not assume a normal distribution of the data (Hair et al., 2014; Hair Jr et al., 2016). Despite the widespread use of PLS-SEM for evaluating linear models, there have been instances where the complexities involved in sustaining Blockchain technology in higher education may be oversimplified. An ANN approach was deemed necessary to address this issue, as it has the capability to recognize both linear and non-linear associations. ANN is a type of machine learning algorithm that is able to learn and adapt based on input data. It can be used to build predictive models and to make decisions based on patterns and trends in the data (Alkawsi et al., 2021; Y. A. M. Qasem et al., 2020). Additionally, the ANN approach was chosen as a predictive tool in conjunction with other methodologies due to the advancement of the multilayer notion. These methods have a strong potential for accurate predictions and are more rigorous than traditional regression methods (Al-Sharafi et al., 2022; Kalinić et al., 2021; Mohd Rahim et al., 2022; Ooi et al., 2018; Sharma et al., 2021).

Table 1. Demographic characteristics of the respondents.

Characteristics	Items	Frequency	Percentage (%)
Gender	Male	177	47.32
	Female	197	52.67
Age	18-22	189	50.53
	23-28	139	37.16
	29-35	40	10.69
	Above 35	6	1.6
Educational institute	The British University in Dubai	133	35.56
	UAE University	123	32.88
	University of Dubai	30	8
	Zayed University	88	23.52
Educational level	Postgraduate	162	43.31
	Undergraduate	212	56.68
Nationality	Non-locals	215	57.48
	Locals	159	42.51
Experience	0 to 1 year	198	52.94
	2 to 3 years	168	44.91
	4 to 5 years	6	1.6
	Above 5 years	2	0.53
Most frequent Blockchain service use	Record-keeping of certificates	122	32.62
	Seamless payments	88	23.52
	Teaching and storage space	91	24.33
	Records of education achievements	62	16.58
	others	11	2.94

5. Results

5.1 Common method bias (CMB)

To evaluate the potential for common method bias (CMB) in the collected sample, the Harman's single-factor method was used. The single factor had a cut-off value of less than 50% (Harman, 1976). The full collinearity evaluation method was also employed, resulting in variance inflation factor (VIF) values that were less than 3.3 (Kock, 2015). The observation of the two methods suggests that CMB is unlikely to be a significant concern in this study.

5.2 Measurement model assessment

Evaluating the measurement model involves analyzing its internal consistency reliability, convergent validity, and discriminant validity (Hair et al., 2019; Hair Jr et al., 2016). To assess the internal consistency reliability, we tested the composite reliability (CR) and Cronbach's Alpha (Hair Jr et al., 2016). As shown in Table 2, the values for Cronbach's Alpha and CR are above the recommended threshold value of 0.70, indicating good internal consistency reliability (Hair et al., 2019; Hair Jr et al., 2016).

The convergent validity is evaluated by testing the average variance extracted (AVE) and factors loadings (Hair Jr et al., 2016). The values of factor loadings, as shown in Table 2, are all greater than 0.7. Additionally, the AVE values for all constructs exceed the recommended threshold value of 0.5. These results indicate that the convergent validity is confirmed. To evaluate the discriminant validity, it is suggested to test the Heterotrait-Monotrait ratio of correlations (HTMT) (Henseler et al., 2015). According to Table 3, it is evident that all HTMT values are less than the proposed threshold value of 0.85. This indicates that there are no issues with discriminant validity.

Table 2. Internal consistency reliability and convergent validity results.

Constructs	**Items**	**Loadings**	**Cronbach's Alpha**	**Composite Reliability**	**AVE**
Sustainability	SUS1	0.938	0.938	0.960	0.890
	SUS2	0.939			
	SUS3	0.953			
Expectation confirmation	EC1	0.922	0.938	0.960	0.890
	EC2	0.953			
	EC3	0.954			
Perceived severity	PS1	0.893	0.948	0.960	0.827
	PS2	0.923			
	PS3	0.935			
	PS4	0.910			
	PS5	0.884			
Perceived usefulness	PU1	0.917	0.971	0.977	0.896
	PU2	0.962			
	PU3	0.962			
	PU4	0.952			
	PU5	0.940			
Perceived vulnerability	PV1	0.955	0.938	0.961	0.891
	PV2	0.965			
	PV3	0.910			
Response costs	RC1	0.930	0.96	0.971	0.893
	RC2	0.964			
	RC3	0.929			
	RC4	0.954			
Response efficacy	RE1	0.959	0.976	0.982	0.933
	RE2	0.974			
	RE3	0.965			
	RE4	0.966			
Satisfaction	SA1	0.970	0.965	0.977	0.935
	SA2	0.969			
	SA3	0.962			
Self-efficacy	SE1	0.945	0.937	0.960	0.889
	SE2	0.953			
	SE3	0.929			

Table 3. HTMT results.

	SUS	EC	PS	PU	PV	RC	RE	SA	SE
SUS									
EC	0.770								
PS	0.463	0.491							
PU	0.843	0.830	0.401						
PV	0.443	0.434	0.744	0.420					
RC	0.235	0.201	0.379	0.159	0.400				
RE	0.577	0.590	0.309	0.585	0.262	0.089			
SA	0.911	0.778	0.410	0.843	0.412	0.191	0.579		
SE	0.481	0.520	0.249	0.481	0.184	0.086	0.668	0.479	

5.3 Structural model assessment

After ensuring that the proposed model is reliable and valid, the next step is to assess the structural model by testing the relationships among the constructs and the coefficient of determination (R^2). In assessing the structural model, all hypotheses are evaluated simultaneously using the SEM technique. A nonparametric significance test is conducted using PLS-SEM with 5,000 re-samples to determine the significance levels among the path coefficients (Hair Jr et al., 2016). The results showed that the model could explain 79.1% of the total variance in Blockchain sustainability, 69% in satisfaction, and 62.7% in perceived usefulness. The results of the hypotheses testing are described in Table 4. The results indicate that the empirical data supported seven out of ten hypotheses, while H2, H3, and H4 were rejected.

Table 4. Hypotheses testing results.

Hypothesis	**Structural path**	**Path coefficient**	***t*-value**	***p*-value**	**Remarks**
H1	Perceived severity → Sustainability	-0.076	2.004	0.045	Supported
H2	Perceived vulnerability → Sustainability	0.000	0.014	0.989	Not Supported
H3	Self-efficacy → Sustainability	0.019	0.574	0.566	Not Supported
H4	Response efficacy → Sustainability	0.035	1.045	0.296	Not Supported
H5	Response costs → Sustainability	-0.044	2.207	0.027	Supported
H6	Expectation confirmation → Satisfaction	0.251	3.423	0.001	Supported
H7	Expectation confirmation → Perceived usefulness	0.792	21.907	0.000	Supported
H8	Satisfaction → Sustainability	0.590	9.508	0.000	Supported
H9	Perceived usefulness → Sustainability	0.258	4.037	0.000	Supported
H10	Perceived usefulness → Satisfaction	0.617	9.090	0.000	Supported

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5.4 ANN results

To better understand the relationships among the variables in the research model, the model is divided into two ANN models, as shown in Figures 2 and 3. ANNs allow us to determine the important determinants impacting Blockchain sustainability in higher education. In this research, the ANN models have two hidden layers to enable deep learning. The number of neurons in each hidden layer was generated based on the model's requirements (Alkawsi et al., 2021). A 10-fold cross-validation strategy was implemented to prevent overfitting, which involves dividing the data into 90% for training and 10% for testing (Al-Sharafi et al., 2022; Mohd Rahim et al., 2022; Ooi et al., 2018). The activation function employed in the hidden and output layers of the ANN model was the sigmoid function (Kalinić et al., 2021). In the first ANN model depicted in Figure 2, four external factors (perceived severity, response costs, satisfaction, and perceived usefulness) served as the input layers, while the target variable (sustainability) acted as the output layer. As depicted in Figure 3, the second ANN model operates with exogenous variables, specifically expectation confirmation and perceived usefulness, as the input layers, and the endogenous variable, satisfaction, as the output layer.

The prediction accuracy of the two ANN models was evaluated by calculating the root mean square error (RMSE) from the ten networks (Kalinić et al., 2021; Morris et al., 2004). As shown in Table 5, the RMSE values for model 1 range from 0.072 to 0.084 during training and from 0.047 to 0.108 during testing. For model 2, the RMSE values for training fall between 0.088 and 0.098, and for testing, they range from 0.058 to 0.100. The higher precision of the models was demonstrated by the slight differences in the RMSE values and standard deviation calculations, indicating that the implementation of ANN improved their accuracy. This shows that ANN models can accurately capture the relationships between predictors and outputs, resulting in enhanced prediction performance through effective data utilization.

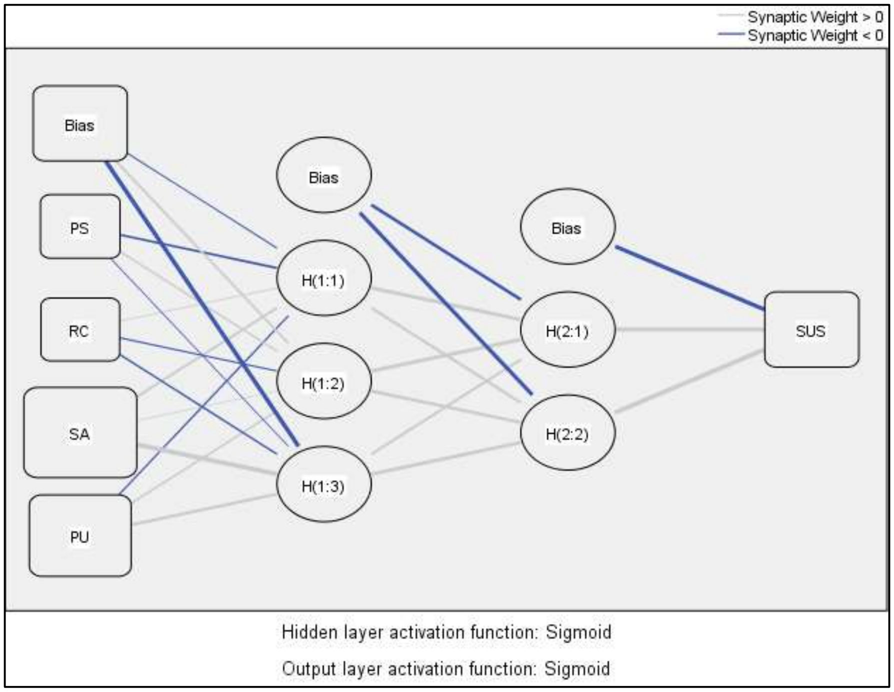

Figure 2. ANN model 1.

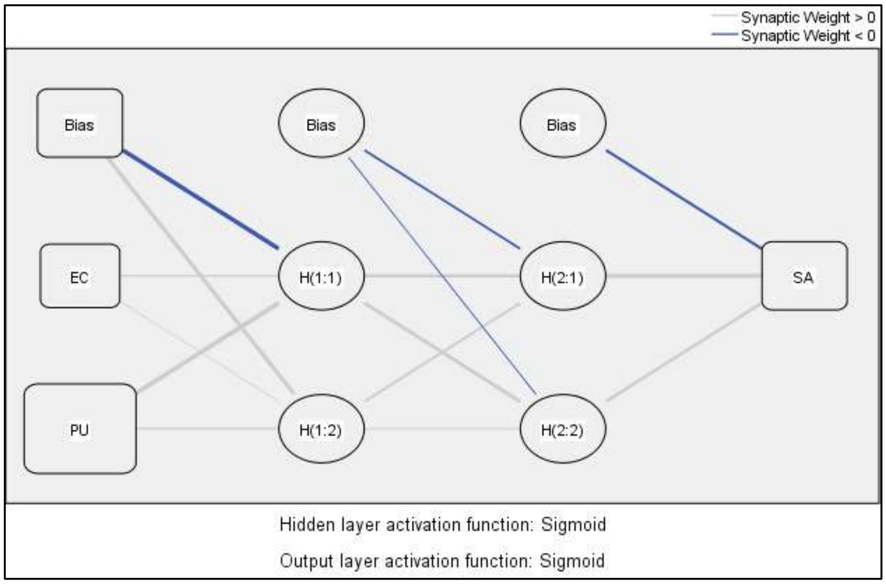

Figure 3. ANN model 2.

Table 5. RMSE values of ANN models.

Network	**Model 1**		**Model 2**	
	RMSE (Training)	**RMSE (Testing)**	**RMSE (Training)**	**RMSE (Testing)**
1	0.075	0.108	0.093	0.088
2	0.078	0.068	0.094	0.098
3	0.076	0.049	0.091	0.069
4	0.076	0.082	0.093	0.082
5	0.076	0.085	0.090	0.088
6	0.084	0.067	0.092	0.071

7	0.072	0.073	0.098	0.062
8	0.077	0.053	0.094	0.058
9	0.074	0.087	0.093	0.075
10	0.077	0.047	0.088	0.100
Mean	0.077	0.072	0.093	0.079
Standard deviation	0.003107942	0.019298351	0.002706407	0.014498682

5.5 Sensitivity analysis

This study employs sensitivity analysis to determine the impact of each predictor on the output variable. This is carried out by calculating the established significance as a percentage and determining the relative importance of each input by the optimal relative importance (Al-Shihi et al., 2018; Chong, 2013; Kalinić et al., 2021; Y. A. M. Qasem et al., 2020). Based on the results from the empirical data in Table 6, the satisfaction construct, with normalized importance of 100%, is considered the most important factor affecting Blockchain sustainability in higher education. This is followed by perceived usefulness (58.8%), perceived severity (12.1%), and response costs (9.2%). In addition, Table 7 shows the sensitivity analysis results for model 2. It can be seen that perceived usefulness, with a normalized importance of 100%, is the most important factor affecting satisfaction.

Table 6. Sensitivity analysis for model 1.

Neural networks	**Perceived severity**	**Response costs**	**Satisfaction**	**Perceived usefulness**
1	0.039	0.061	0.559	0.342
2	0.076	0.053	0.482	0.389
3	0.077	0.052	0.522	0.349
4	0.053	0.057	0.527	0.362
5	0.051	0.083	0.566	0.299
6	0.067	0.075	0.728	0.130
7	0.600	0.200	0.570	0.349
8	0.103	0.032	0.563	0.302
9	0.086	0.034	0.570	0.310
10	0.060	0.048	0.523	0.369
Mean importance	0.121	0.070	0.561	0.320
Normalized importance (%)	12.1%	9.2%	100.0%	58.8%
Ranking	3	4	1	2

Table 7. Sensitivity analysis for model 2.

Neural networks	**Expectation confirmation**	**Perceived usefulness**
1	0.129	0.871
2	0.114	0.886
3	0.328	0.672
4	0.226	0.774
5	0.369	0.631
6	0.222	0.778
7	0.142	0.858
8	0.180	0.820

9	0.179	0.821
10	0.280	0.720
Mean importance	0.217	0.783
Normalized importance (%)	29.2%	100.0%
Ranking	2	1

6. Discussion

The main aim of this study was to investigate the factors influencing the sustainability of Blockchain in higher education. This is carried out by proposing a theoretical model based on the combination of PMT and ECM. The model was validated using a hybrid approach using PLS-SEM and ANN. The model explained 79.1% of the total variance in Blockchain sustainability. The study also tested the proposed hypotheses about the relationships between observed and latent variables, and found that the empirical data supported seven out of the ten. The ANN models achieved high levels of accuracy, as indicated by the RMSE values.

The results demonstrated that perceived severity significantly influences the sustainability of using Blockchain in higher education. Students who comply with the perceived severity of using Blockchain are more likely to sustain their use of the technology. This aligns with previous research that supported the role of perceived severity in affecting the adoption of protective behaviors (Al-Emran et al., 2021; Shahbaznezhad et al., 2020; Wu, 2020). However, it is worth noting that the results of previous studies on the impact of perceived severity on technology adoption have been varied, possibly due to differences in the context or methodological limitations.

The correlation between perceived vulnerability and Blockchain sustainability was insignificant, according to the findings of this study. However, this result contradicts previous studies that supported this correlation (Al-Emran et al., 2021; Shahbaznezhad et al., 2020; Wu, 2020). One potential explanation for the discrepancy between the results of this study and previous research could be the specific context in which the study was conducted. It is possible that the students in this study did not perceive certain types of threats as being likely to occur, despite their potential existence. This could be because the potential losses resulting from the use of technology in this study are likely to be borne by the institutions rather than the students. As such, the students may not feel motivated to take security measures to reduce the likelihood of security breaches. Given the severe nature of the dangers that can be countered by Blockchain technology and the common occurrence of cyber-attacks, it is plausible to think that the perception of vulnerability would have a crucial impact on the longevity of utilizing Blockchain technology in higher education.

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In addition, the results also revealed that self-efficacy did not have any significant effects on Blockchain sustainability. This result is against what was claimed in earlier studies (Jeong & Yoon, 2013; Marakarkandy et al., 2017). One possible explanation for the lack of a significant relationship between self-efficacy and sustainability in this study could be the context in which the study was conducted. It is possible that the students participating in the study already had a high level of self-efficacy regarding their use of Blockchain, leading to a lack of difference in sustainability among those with different levels of self-efficacy. Alternatively, other factors, such as perceived usefulness or satisfaction with the technology, maybe more influential in determining sustainability in this context. Further research may be needed to fully understand the relationship between self-efficacy and Blockchain sustainability in the context of higher education.

Unlike what we hypothesized, the response efficacy did not have a notable effect on the sustainability of Blockchain. This indicates that the students do not trust the recommended actions to mitigate security hazards when utilizing Blockchain technology in education. This is not in line with the findings of previous studies (Al-Emran et al., 2021; Shahbaznezhad et al., 2020; Wu, 2020). While the findings of this research indicate that response efficacy does not significantly impact Blockchain sustainability, this may not be the case in other contexts or with other technologies. It is possible that the specific nature of Blockchain and its characteristics in higher education, as well as the sample and context of this study, may have contributed to these findings. Additionally, it was discovered that response costs have a substantial negative impact on the sustainability of Blockchain. This highlights that students' compliance with recommended safe practices for utilizing Blockchain technology significantly affects their ability to maintain its use in education. This suggests that students consider the time and effort required to learn and use Blockchain technology as a barrier to its sustainable adoption in education. This result confirms the findings reported earlier (Al-Emran et al., 2021; Shahbaznezhad et al., 2020; Wu, 2020).

The study also found that the expectation confirmation of Blockchain technology can significantly affect students' satisfaction. When students' expectations of the benefits of Blockchain technology are met, the sustainable use of Blockchain can improve their performance and satisfaction. This finding aligns with the results of previous studies (Gupta et al., 2020; Wu, 2020). Developers and designers of Blockchain technology need to consider how to meet or exceed the expectations of their users in order to increase satisfaction and the likelihood of sustained adoption. This may include providing clear information about the capabilities and limitations of the technology, as well as offering personalized support and training to ensure that users can make the most of the technology's features.

The results supported the role of expectation confirmation in affecting perceived usefulness. This result confirms the conclusions of previous studies (Al-Emran et al., 2021; Bhattacherjee, 2001). When the students have expectations about the Blockchain capabilities, and the technology meets those expectations, the students would perceive the technology as more practical. On the other hand, if the expectations are not met, the technology is perceived as less valuable. For example, when students expect Blockchain technology to improve record-keeping and the technology does so, they would perceive the technology as applicable and confirm their expectations. The findings also demonstrated a substantial positive relationship between satisfaction and Blockchain sustainability. Although Blockchain can improve the performance and satisfaction of students in the UAE, their expectations for the benefits of using Blockchain may be higher than what they actually experience, leading to sustainable use of the technology. This aligns with the findings of previous research (Dai et al., 2020; E. Park, 2020).

Furthermore, the findings suggested that the sustainability of Blockchain is considerably affected by perceived usefulness. This can be attributed to the fact that when students perceive that using Blockchain technology will improve their performance, they are more likely to sustain their use of the technology. This result agrees with the findings of previous studies (Guriting & Oly Ndubisi, 2006; Laforet & Li, 2005). Additionally, the study found that perceived usefulness is a major factor in predicting satisfaction. It is believed that the overall usefulness of Blockchain technology plays a role in its acceptance and diffusion. When Blockchain technology enhances students' performance, students tend to be more satisfied. This result aligns with the findings of previous studies (E. Park, 2020; Suzianti & Paramadini, 2021).

It is essential to recognize that the successful implementation of Blockchain technology in higher education hinges not only on student acceptance but also on the decisions and actions of university administrations. University leaders play a pivotal role in deciding the adoption of Blockchain-based systems for various educational processes, such as transcripts and credentials. Collaborative efforts between students and administrations are instrumental in ensuring the sustainable and effective use of Blockchain technology within educational institutions.

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7. Conclusion

7.1 Theoretical contributions

The results of this study offer several theoretical contributions. First, research on Blockchain sustainability in higher education is limited (AlShamsi et al., 2022), making this particular study potentially valuable and unique. The study addressed this limitation by examining the factors that drive or inhibit university students' sustained use of Blockchain. This is significant because higher education is a critical sector where Blockchain technology has the potential to make a significant impact, and understanding how to promote its sustainable use in this context is essential. Second, understanding the determinants of Blockchain sustainability has been accomplished by integrating two well-known theories: PMT and ECM, thus validating the applicability of the two theories in a new domain (higher education) with a new technology (Blockchain). Third, a recent systematic review revealed that most Blockchain adoption studies were conducted in individualistic societies (AlShamsi et al., 2022). This research bridges the gap by examining the determinants of Blockchain sustainability in a new research context (UAE), which offers more insights into how the technology is used in collectivistic contexts.

7.2 Practical implications

The focus on the higher education sector is valuable for understanding the specific challenges and opportunities related to the sustainable use of Blockchain in this sector. The findings can inform the development of a comprehensive sustainability plan for Blockchain technology in higher education, including guidelines, policies, and processes to ensure its long-term viability. The findings can assist policymakers in reviewing current data privacy policies and regulations and educating users about their roles and responsibilities. System analysts and developers can use the findings to improve the implementation of Blockchain technology and anticipate future enhancements that are more user-friendly. The results can inform the development of training programs for institutions implementing Blockchain technology by highlighting which factors they should focus on to ensure sustainability.

Perceived usefulness is an important factor in the sustainability of Blockchain technology for educational purposes. Therefore, service providers should prioritize features that provide users with reliable information and personalized notifications, particularly in "anytime, anywhere" setting. This can help students, specifically those with low experience, to effectively utilize Blockchain technology. Conversely, the results did not support the role of perceived vulnerability, self-efficacy, and response efficacy in affecting Blockchain sustainability in higher education. Decision-makers can consider these factors to inform their strategies for implementing Blockchain in higher education. The study may serve as a reference for developers and designers to identify best practices and avoid common pitfalls when developing Blockchain solutions for higher education. By considering the findings in their design and development processes, developers and designers can improve the sustainability of Blockchain, which can ultimately lead to its wider adoption and success.

7.3 Limitations and future work

While the current research offers valuable insights into the factors that impact the sustainable use of Blockchain in higher education, several limitations should also be considered. One limitation of this study is that the data were collected through questionnaires from a single country, which may limit the generalizability of the findings. To address this limitation, future research should test the hypotheses of this study in other cultural and contextual settings, including both developed and developing countries. Another limitation of this study is that it did not explore the role of moderating factors, such as gender, age, level of experience, and education level, on the relationship between independent and dependent variables. It is possible that these factors could influence the impact of the independent variables on the dependent variables. Further research on the moderating effect of these factors could provide additional insights into how they influence the sustainability of Blockchain technology in higher education. Additionally, the use of purposive sampling limits the generalization of the results to the entire population of Blockchain users or other contexts. Therefore, it is essential to approach these results with caution when considering the implementation of Blockchain in other contexts and settings. Moreover, we focused on student perspectives in evaluating Blockchain's sustainability in higher education. While this provides invaluable insights, it may not paint a comprehensive picture. A broader evaluation might benefit from incorporating feedback from faculty members, administrative staff, and IT departments. Future trials should actively solicit these diverse stakeholder viewpoints to ensure a well-rounded assessment of Blockchain's potential and challenges in the educational landscape.

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Appendix: Constructs, items, and their sources.

Constructs	Code	Items	Source
Perceived Severity	PS1	"I believe student records stored on blockchain are vulnerable to security incidents."	(R. W. Rogers & Prentice-Dunn, 1997)
	PS2	"I believe that security incidents threaten the productivity of blockchain."	
	PS3	"I believe that data protection incidents threaten the profitability of blockchain."	
	PS4	"I believe that blockchain can allow remote access to student records."	
	PS5	"I believe that blockchain can be used to download student records."	
Perceived Vulnerability	PV1	"Blockchain could be vulnerable to security incidents."	(R. W. Rogers & Prentice-Dunn, 1997)
	PV2	"Blockchain could be susceptible to security incidents."	
	PV3	"A security problem to my personal data could occur if I do not comply with the institution's blockchain security policy."	
Self-Efficacy	SE1	"It would be easy for me to use blockchain by myself."	(Sergueeva & Shaw, 2017)
	SE2	"I could adopt blockchain even if there is no one around to tell me what to do."	
	SE3	"I could adopt blockchain if I could contact someone when I got stuck."	
Response Efficacy	RE1	"Blockchain can successfully prevent security incidents."	(Johnston & Warkentin, 2010)
	RE2	"Blockchain is the best solution for counteracting security problems."	
	RE3	"If we use the blockchain for educational purposes, we can minimize the threat of security incidents."	
	RE4	"Compliance with blockchain security policy reduces the security threat to my personal data."	
Response Costs	RC1	"Blockchain is expensive to purchase and operate."	(R. W. Rogers & Prentice-Dunn, 1997)
	RC2	"We have to frequently upgrade our blockchain to download students' records."	
	RC3	"Security incidents can slow down the blockchain performance."	
	RC4	"Compliance with blockchain security policy would require considerable effort other than time."	
Expectation Confirmation	EC1	"My experience with using blockchain was better than what I expected."	(Bhattacherjee, 2001)
	EC2	"The service provided by my university concerning blockchain was better than what I expected."	
	EC3	"Overall, most of my expectations from using blockchain in my institute were confirmed."	
Perceived Usefulness	PU1	"Blockchain enhances my efficiency."	(Davis, 1989)
	PU2	"Blockchain enables me to accomplish tasks more quickly."	
	PU3	"Blockchain improves my performance."	

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	PU4	"Using blockchain increases my learning achievements."	
	PU5	"Overall, blockchain is useful to me."	
Sustainability	SUS1	"I intend to continue using blockchain rather than discontinue its use."	(Al-Sharafi, Al-Emran, et al., 2022; Al-Sharafi, Al-Qaysi, et al., 2022)
	SUS2	"I intend to continue using blockchain than other alternative means."	
	SUS3	"If I could, I would like to continue my use of blockchain."	
Satisfaction	SA1	"I am satisfied with using blockchain as an assisted tool in my institution."	(Doll et al., 1998)
	SA2	"I am satisfied with using blockchain technology services."	
	SA3	"My experience of using blockchain was very delightful."	

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