The Influence of Blockchain Technology Adoption on the Future of Education

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Abstract

The emergence of blockchain technology, with its capacity to revolutionize traditional systems, has recently prompted the education sector to embark on exploring its adoption. This paper presents the characteristics of blockchain platforms within the educational sector, encompassing the secure storage, distribution, and validation of academic certificates, establishment of a secure and transparent repository for academic and professional accomplishments, and facilitation of streamlined processes for course registration, payments, and authentication. Leveraging blockchain technology holds the promise of substantially reshaping the future of education by increasing transparency, improving security measures, and enhancing operational efficiency in the management of educational data and the development of digital competencies. The main objective of this paper is to identify the determinants influencing performance improvement as a result of the adoption of blockchain technology in educational settings. A comprehensive review of extant literature concerning blockchain technology in education, its associated advantages, and prevailing applications is first presented. Subsequently, the proposed conceptual framework which identifies the factors underpinning prospective performance enhancement through blockchain adoption is presented. Also, the paper presents the methodology employed in this research, along with the conceptual model and subsequent analysis elucidating the impact of identified factors on performance augmentation facilitated by blockchain technology in education.

Keywords: *education, blockchain technology, adoption, future, performance*

1. Introduction

In today's dynamic environment, innovation plays a pivotal role in driving progress across diverse sectors, including education, which is undergoing a transition to meet the demands of a digitally interconnected society. Despite strides in digital integration, many educational institutions still grapple with outdated systems, hindering operational efficiency and transparency [1]. Recognizing the need for change, blockchain technology emerges as a transformative solution, offering secure and decentralized frameworks for managing educational data and credentials [2]. By leveraging blockchain, educational institutions can enhance efficiency, credibility, and accessibility while mitigating reliance on intermediaries. Moreover, blockchain's inherent features, such as automation, transparency, and non-repudiation, ensure robust and trustworthy data management, promising a paradigm shift in educational practices [3].

In light of the emerging discourse surrounding blockchain adoption in education, notable research gaps necessitate attention. Primarily, a comprehensive adoption model tailored for guiding educational leaders in expediting blockchain innovation remains notably absent. Moreover, empirical studies exploring the adoption determinants of blockchain educational platforms, with a particular focus on the resultant performance enhancements, are scarce in the extant literature. Hence, this paper endeavors to enrich the discourse on blockchain adoption by delineating the determinants underpinning the utilization of blockchain-based educational platforms and elucidating their impact on institutional performance enhancements.

2. Literature Review on Blockchain Technology in Education

As a cornerstone of the Education 4.0 movement, blockchain represents the latest innovation poised to revolutionize the educational landscape. With its foundation rooted in decentralization and distributed computing, blockchain technology holds promise for reshaping various facets of education. This emerging technology is anticipated to exert a profound influence on the sector's future, offering a robust and secure framework across a spectrum of applications. These include academic record management, digital credentials, decentralized learning environments, safeguarding intellectual property rights, academic publishing, and facilitating student exchanges [4].

Perceived as a highly impactful innovation driving the evolution of novel paradigms, blockchain technology presents a diverse array of possibilities for transferring value among participants with reliability and convenience. Blockchain technology is defined as a secure, distributed platform facilitating data movement in transactions, ensuring integrity and authenticity through cryptographic measures, as well as maintaining immutable historical records across multiple servers that are validated through consensus mechanisms [5].

Blockchain technology offers a multitude of benefits in education, including enhanced security, privacy, and identity verification. By integrating blockchain into educational systems, institutions can ensure the authenticity of credentials and mitigate fraud, instilling confidence among stakeholders [6]. Moreover, blockchain streamlines record management, providing a comprehensive solution for storing personal information, academic assessments, credentials, and performance evaluations securely. Additionally, blockchain fosters accountability and transparency by establishing an immutable and traceable record-keeping system for educational records [7]. Utilizing decentralized peer-to-peer networks and cryptographic mechanisms, blockchain technology eradicates fraudulent activities and cultivates confidence among participants, granting them the ability to proficiently oversee their identity and data interactions. The pivotal dimension of data security within blockchain technology underscores its role in safeguarding online certificate sharing and data exchanges. Essentially functioning as a decentralized ledger, blockchain meticulously records educational data across a distributed network of nodes, thereby guaranteeing the immutability and integrity of information, thus precluding unauthorized alterations of those data records [4].

Blockchain technology can also contribute to optimizing educational processes and resource management, thereby enhancing the overall efficiency and effectiveness of educational institutions [7]. Additionally, the implementation of smart contracts, which are self-executing digital contracts on blockchain, enhances administrative efficiency within the education ecosystem by automating tasks and facilitating smooth data exchange, thereby reducing bureaucratic burdens [8]. Furthermore, blockchain technology plays a pivotal role in facilitating the establishment of decentralized learning environments, where authentic educational records are securely maintained on the network, thereby contributing to the enhancement of accessibility and flexibility in accessing educational resources [9]. By leveraging blockchain, educational platforms can be developed to prioritize learner ownership and control, diminishing the reliance on traditional intermediaries. This shift towards learner-centric platforms empowers individuals to take charge of their educational journey and access resources tailored to their needs and preferences [6]. Furthermore, the transparent and decentralized nature of blockchain technology fosters collaboration within the educational ecosystem, facilitating the development of innovative pedagogical strategies and educational technologies, including the creation of novel curricula and teaching methods [10].

Blockchain technology can be leveraged across a variety of applications in education.

- Record Management: This innovative technology represents a paradigm shift in the management of educational records, offering a sophisticated solution tailored to diverse record-keeping requirements within educational contexts. Through its integration, blockchain guarantees the secure, transparent, immutable, and decentralized storage of students' personal information, academic assessments, credentials, and performance evaluations [7].
- Online Education: Blockchain technology shows potential for augmenting data storage and security, streamlining the management of educational certificates, and facilitating the collection, reporting, and analysis of data to inform decision-making within educational frameworks. By integrating blockchain into online learning platforms, opportunities arise for the development of personalized learning applications and transparent tracking of student progress, thus enhancing the learning experience and tailoring learning strategies to individual students [6].
- Digital credentials: Blockchain technology offers a robust solution for verifying and authenticating digital credentials, thereby enhancing the efficiency and reliability of certificate management through interoperable record-keeping systems. By leveraging the immutability and transparency of blockchain systems, digital credentials are bolstered against fraud, fostering trust among stakeholders in the educational system. This streamlined approach simplifies the acquisition and validation of academic qualifications by eliminating the necessity for intermediaries, providing an unalterable ledger of students' records [6].
- Intellectual Property: Within the educational landscape, blockchain technology emerges as a pivotal tool for safeguarding rights and preserving authenticity. Its decentralized and immutable nature serves to establish ownership and protect the originality of intellectual property assets. With traceability and provenance features, blockchain safeguards creators' rights, ensuring content integrity. This benefits learners with quality content access, enables educators to monetize their work, and helps providers enforce usage terms [11].
- Academic Publishing: Within the scholarly realm, blockchain technology revolutionizes the landscape by providing a transparent peer review process and immutable publication records. This ensures the

integrity and authenticity of scholarly works, while fostering open access and collaboration within the academic community [2].

The integration of blockchain technology within educational contexts holds considerable promise, yet its widespread implementation encounters multifaceted challenges. Despite the acknowledged potential benefits, blockchain technology remains in a nascent phase of development, thus lacking full maturity. A key challenge pertains to the management of extensive student data, a task which may not only prolong verification processes, but also exacerbate energy consumption. Furthermore, the limited interoperability across disparate blockchain networks, coupled with integration difficulties with existing systems, presents additional hurdles to adoption. Additionally, the scarcity of proficient blockchain engineers exacerbates the challenge, impeding the development of robust educational platforms. Overcoming these obstacles necessitates a comprehensive approach, encompassing technical competence, data privacy and accessibility, interoperability, regulatory adherence, and financial considerations [12].

While blockchain adoption is still in its nascent phases, certain education institutions are actively exploring the potential of this technology to promote innovation. Below is an overview of four blockchain-based platforms in education:

- EduCTX is a blockchain-powered platform which manages academic credits and grading by utilizing tokens to symbolize completed credits in students' records. Inspired by the European Credit Transfer and Accumulation System (ECTS), it provides a globally recognized, decentralized system, fostering coherence among students and education institutions [13].
- APPII authenticates academic credentials for students and professors, locking verified information into its blockchain. The platform, using Ethereum Blockchain, enables users to create profiles and CVs with verified courses from various e-learning platforms, earning tokens for course completion or verifying others' credentials. Smart contracts ensure data security and verification throughout the process [11].
- Blockcerts, a collaborative project between Learning Machine and MIT Media Lab, utilizes blockchain technology to issue and verify tamper-proof digital certificates, offering recipients increased control over their credentials and eliminating reliance on third-party verification. By recording academic transcripts and credentials on the blockchain, Blockcerts ensures document integrity and facilitates fraud detection [14].
- ODEM, the On-Demand Education Marketplace, is a blockchain platform connecting students, educators, and employers directly, bypassing intermediaries. ODEM aims to enhance global education quality affordably by connecting educators worldwide to create tailored curricula accessible via smart contracts [4].

The decision to integrate novel technology into an institution’s infrastructure remains a contentious issue among scholars and professionals, largely due to the accelerating pace of technological advancements. This increasing academic interest has led to the development of various theories and models to understand technology adoption and utilization. One notable model is the Technology, Organization and Environment (TOE) Framework, which predicts organizational adoption of new technologies by considering three primary contexts: technological, organizational, and environmental influences [15]. The technological context encompasses both existing and emerging technologies relevant to an institution, considering technical factors like infrastructure, quality, and integration, which influence the scope, objective, and pace of technology adoption. The organizational context includes internal features such as organizational structure, resource availability, technological readiness, decision-making capacity, and human capital expertise, all of which impact the adoption of new technologies. Lastly, the environmental context, encompassing industry structure, regulatory landscape, supplier support, competitive environment, and presence of technology service providers, is also critical for assessing disruptive innovations [16].

3. Research Methodology

3.1. Research Objectives

The primary goal of this study is to attain a comprehensive understanding of the determinants influencing the adoption of educational platforms utilizing blockchain technology, while also elucidating the effects of adoption on performance enhancement within educational institutions. In this regard, the research delineates the following objectives:

O_1 Establishment of the importance of adopting blockchain technology to enhance performance in education;

O_2 Identification of determining factors from their literature and analysis of the influence on the adoption of blockchain technology in education;

O_3 Modeling and assessing the impact of determinants on the adoption of blockchain technology to increase performance in education;

O_4 Formulation of conclusions and recommendations regarding the role of blockchain technology adoption in increasing performance in education.

3.2. Data Collection and Measurement Items

This study engaged 147 participants occupying managerial roles within educational institutions across Romania (26.53%), Poland (25.17%), Hungary (19.73%), Czech Republic (11.56%), Slovakia (9.52%), and Moldova (7.48%).

A survey instrument with 17 measurement items was developed to assess the constructs delineated within the conceptual framework: Technological Factors (TF), Organizational Factors (OF), and Environmental Factors (EF). Respondents were prompted to draw from their individual insights and professional acumen, with the understanding that responses would be solely utilized for academic research. The survey was administered via Qualtrics between March and April 2023.

The technological factors considered the following measurement items:

- Relative Advantage: In education, relative advantage denotes the superiority of an innovation compared to existing methods. Blockchain technology, offering unparalleled traceability and provenance, presents significant benefits over traditional educational systems [16].
- Information Security: In educational settings, information security is crucial for protecting students' data during transmission and storage. Efficient risk management is essential for successful adoption, given the potential vulnerability of processes built on blockchain to technological failures and cyberattacks, despite the resilience of distributed ledgers [16].
- Compatibility: In educational institutions, compatibility refers to the alignment of blockchain technology with regulatory standards and existing systems. Legacy systems pose challenges to adoption due to their deep integration, complicating the transition and raising concerns about data integrity [16].
- Complexity: In the realm of blockchain adoption, complexity denotes the challenge of comprehending and applying innovations, which can involve intricate technical processes. This complexity may deter educational institutions from adopting blockchain solutions [17].

The Organizational Factors included the following measurement items:

- Institutional Readiness: Within the realm of blockchain adoption in education, institutional readiness pertains to an institution's perception of its capacity to adopt blockchain. It focuses on factors such as technological infrastructure, financial resources, and proper governance. Effective allocation of resources and innovative capabilities are pivotal for successful blockchain adoption [16].
- Educational Leadership Support: In the context of blockchain adoption in education, educational leadership support refers to the commitment and involvement of top management in understanding the strategic importance of blockchain technology. It aims to foster an environment conducive to innovation and change within educational institutions. This support is crucial for overcoming barriers and ensuring successful adoption by allocating proper resources, fostering an innovative culture, and making informed decisions [18].
- Blockchain Knowledge: In the realm of blockchain adoption within educational settings, blockchain knowledge denotes an organization's access to technically skilled experts and consultants for guiding blockchain implementation and operations. Lack of awareness and technical expertise can impede adoption, whereas possessing technical know-how enhances perceived usefulness by simplifying complexities [16].

The Environmental Factors were measured through the following items:

- Partner Readiness: In education, partner readiness underscores the vital role of educational collaborators in facilitating blockchain adoption. Their readiness to integrate blockchain into operational processes significantly impacts its deployment efficiency [16].
- Competitive Pressure: In the educational landscape, competitive pressure propels institutions to embrace blockchain technology for innovation and market differentiation, recognizing its potential to redefine educational standards [17].
- Legislation and Regulation: The challenge of legislation and regulation in education stems from the evolving regulatory landscape in response to blockchain's disruptive influence. Varied regulatory approaches create uncertainty, but government support through policies and incentives can accelerate its widespread adoption [17].

3.3. Conceptual Model and Hypothesis Development

This study proposes a conceptual model based on the TOE framework to assess the determinants of blockchain technology adoption in educational settings and its resulting enhancement in performance. The conceptual framework incorporates constructs derived from extant literature on technology adoption, tailored to accommodate the unique context of the education field. Consequently, the following hypotheses have been formulated:

H_1: Technological Factors will positively influence blockchain technology adoption in education.
H_2: Organizational Factors will positively influence blockchain technology adoption in education.
H_3: Environmental Factors will have a positive influence on blockchain adoption in education.
H_4: The adoption blockchain technology will be positively associated with performance in education.

The proposed conceptual model is graphically depicted in Figure 1.

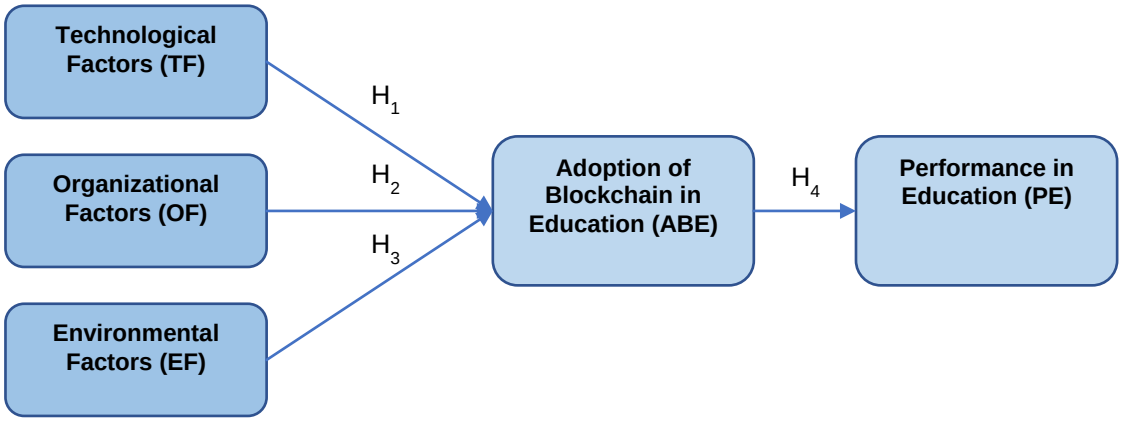

Fig.1. Proposed conceptual model

The proposed conceptual model underwent validation through Partial Least Squares Structural Equation Modeling (PLS-SEM), which is a robust analytical method. SmartPLS 4.0 software was utilized for survey data analysis, enabling assessment of the model and hypothesis testing.

Results

3.4. Assessment of the Measurement Model

For the evaluation of the measurement model, an analysis was conducted concerning the reliability and validity of the constructs. The findings revealed that both Cronbach's alpha and Dijkstra-Henseler's rho coefficients exceeded 0.7, affirming adequate internal consistency and reliability. Additionally, each construct exhibited a composite reliability (CR) value surpassing the 0.7 threshold, indicating consistent and dependable measurements.

Simultaneously, the assessment of the constructs' convergent validity through the employment of the average variance extracted (AVE) revealed significant scores spanning from 0.751 to 0.828 across all constructs. This result implies that at least 75.1% of the observed variability among the indicators can be attributed to the underlying construct. Such results underscore a commendable level of convergent validity, surpassing the stipulated 0.5 benchmark. A detailed presentation of the convergent validity and reliability assessments for the constructs can be found in Table 2.

Table 2. Convergent validity and reliability of constructs

Construct	CR	Cronbach's alpha	rho_a	Average variance extracted (AVE)
TF	0.945	0.945	0.946	0.81
OF	0.9	0.898	0.903	0.751
EF	0.935	0.935	0.935	0.828
ABE	0.889	0.888	0.892	0.727
PE	0.945	0.946	0.949	0.813

Furthermore, the investigation assessed the variance inflation factor (VIF) to discern any collinearity present among the constructs, with findings demonstrating that all VIF values remained below 5.00, thus implying the absence of collinearity among the variables. Moreover, the factor loadings for all indicators surpassed the established threshold of 0.60, ranging from 0.798 to 0.976, thereby affirming the validity and reliability of the measurement model under scrutiny.

The examination of discriminant validity was conducted employing the Fornell and Larcker criterion, aimed at discerning the extent to which each construct diverges from others within the structural model. The findings substantiated the discriminant validity of the constructs, as evidenced by the square root of the average variance extracted (AVE) surpassing the respective correlation coefficients between constructs. Table 3 presents the discriminant validity outcomes.

Table 3. Discriminant validity of the constructs

	ABE	EF	OF	PE	TF
ABE	**0.853**				
EF	0.739	**0.91**			
OF	0.84	0.674	**0.867**		
PE	0.591	0.406	0.656	**0.902**	
TF	0.819	0.646	0.712	0.551	**0.9**

3.5. Assessment of the Structural Model

For the assessment of the structural model, the statistical significance of the path coefficients underwent scrutiny through the utilization of a conventional bootstrapping approach employing a sample size of 5000. The findings revealed a substantively significant association between Technological Factors (TF) and Adoption of Blockchain in Education (ABE) at a 1% significance level (TF -> ABE, $\beta = 0.381$, t-value = 6.815, $p < 0.01$), thereby lending empirical support to hypothesis H1. Similarly, the hypothesized positive influence of Organizational Factors (OF) on Adoption of Blockchain in Education (ABE) in hypothesis H2 was statistically significant (OF -> ABE, $\beta = 0.433$, t-value = 6.349, $p < 0.01$), with Organizational Factors emerging as pivotal determinants in adoption decision-making processes. Likewise, Environmental Factors (EF) exhibited a notable positive impact on the Adoption of Blockchain in Education (ABE) (EF -> ABE, $\beta = 0.200$, t-value = 5.038, $p < 0.01$), thus corroborating the assertion made in hypothesis H3. Furthermore, evidence supported a positive relationship between Adoption of Blockchain in Education (ABE) and Performance in Education (PE) (ABE -> EF, $\beta = 0.591$, t-value = 11.453, $p < 0.01$), reinforcing the validity of hypothesis H4. A comprehensive presentation of the significance test outcomes, inclusive of the final decision regarding hypothesis acceptance or rejection, is provided in Table 4.

Table 4. Hypothesis Testing

Hypothesis	β Coeff.	Standard deviation	T statistics	P values	Decision
H_1: TF -> ABE	0.381	0.055	6.815	0	Supported
H_2: OF -> ABE	0.433	0.059	6.349	0	Supported
H_3: EF -> ABE	0.200	0.043	5.038	0	Supported
H_4: ABE -> PE	0.591	0.047	11.453	0	Supported

Figure 2 illustrates the causal relationships within the proposed structural equation model.

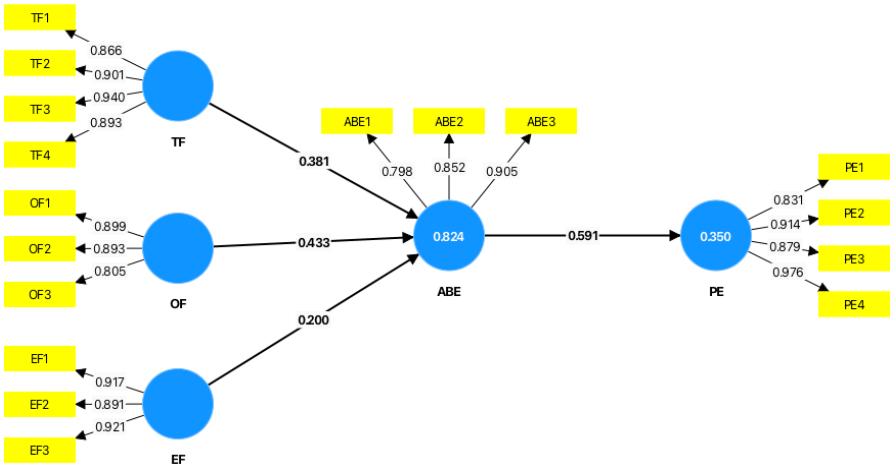

Fig.2. Causal relationships identified in the model

4. Conclusions

In today's rapidly evolving landscape, innovation serves as a cornerstone in propelling advancements across various sectors, including education, as it adapts to meet the demands of an increasingly interconnected digital society. Despite progress in digital integration, many educational institutions grapple with outdated systems, impeding operational efficiency and transparency. Recognizing the imperative for change, blockchain technology emerges as a transformative solution, offering secure and decentralized frameworks for managing educational data and credentials. By harnessing blockchain, educational institutions stand to enhance efficiency, credibility, and accessibility, while reducing reliance on intermediaries.

This research utilized a quantitative approach to develop and validate a theoretical framework rooted in the Technology-Organization-Environment paradigm. The novelty of this study lies in the expansion of the

conceptual framework by integrating the concept of performance in education as an outcome of technology adoption, offering valuable insights into how educational institutions can leverage blockchain technology to enhance performance. Data were collected via an online survey among 147 educational leaders across six countries and analyzed using Partial Least Squares Structural Equation Modeling. The results highlight the influence of Technological and Environmental factors on Blockchain Adoption in Education, while Organizational factors demonstrate the strongest association with decision-making. This underscores the importance for educational institutions to secure support from educational leadership, alongside technological infrastructure, financial resources, skilled personnel, and proper governance. Additionally, the study reveals a significant relationship between blockchain adoption and performance improvement, shedding light on how educational institutions can enhance their performance outcomes and establish themselves as leaders in technological innovation. These findings carry significant implications for various stakeholders, including the management of educational institutions, regulators, blockchain practitioners, educational staff, and researchers.

Although offering novel insights into the variables influencing the adoption of blockchain in the educational realm, the empirical testing of the newly developed UTAUT model was constrained by a sample size of 147 respondents whose perceptions were captured at a single time point. While advancing insights into the integration of variables driving blockchain adoption intentions in education, this study prompts further exploration and application of the model across multiple countries to enhance its generalizability. Researchers are also urged to consider incorporating supplementary factors beyond those outlined in the proposed TOE framework to bolster its explanatory capacity, recognizing the multifaceted nature of considerations confronting educational institutions when embracing blockchain technology.

The authors recommend the following blockchains in education: APPI, BLOCKCERTS, ODEM, OPENXCELL. With APPI, academic credentials can be verified using blockchain, smart contracts and machine learning. Bockchain Blockcerts can store academic results, transcripts and diplomas, for an immutable view of past academic achievements. With ODEM students and teachers can connect to specific courses that support education. Students and teachers are recognized in the ODEM register for the courses they have taken and for the courses they have taught.By adopting blockchain technology in education students and teachers will benefit from the speed and security of blockchain technology. OpenXcell simplifies record keeping, improves transparency and security, supports hiring processes, and transfers ownership of academic records to students.

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