A Blockchain-based Trustworthy and Secure Review System for Decentralized e-Portfolio Platforms

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***Abstract*—E-portfolios have emerged as powerful tools in the education and professional development fields, enabling learners to showcase their skills, achievements, and credentials in a digital format. However, ensuring the security, authenticity and reliability of e-portfolio artifacts and credentials remains a challenge. Existing review systems face challenges such as lack of transparency, vulnerability to manipulation, and reliance on centralized trust. Therefore, this paper proposes *B-TrustReview*, a trustworthy and secure review system for decentralized e-portfolio platforms that leverages blockchain and smart contracts. By leveraging blockchain's decentralized and tamper-resistant nature, the system enhances the security, transparency, and reliability of reviews. Every review is securely recorded on the blockchain, creating an auditable and transparent record of evaluations. Smart contracts govern the execution of the review process, automating the validation and verification of reviews based on predefined criteria. This automation reduces reliance on intermediaries and minimizes the risk of biased or manipulated reviews fostering transparency, accountability, and credibility in evaluating e-portfolios. Moreover, it enables secure and efficient transactions, ensuring the confidentiality of user data and protecting against unauthorized access.**

***Index Terms*—Blockchain, Decentralized review system, Electronic portfolio (e-portfolio), Reputation system, Smart contract**

I. Introduction

E-portfolios have emerged as powerful tools in the field of education and professional development, enabling learners to showcase their skills, achievements, and credentials in a digital format [1]–[6]. These platforms facilitate the creation, publication, and management of e-portfolios, providing a comprehensive view of an individual's capabilities [4]–[7]. Review systems play a vital role in assessing and validating the quality, credibility, and achievements of users' e-portfolios [6]–[9]. These systems allow stakeholders, such as educators, peers, and employers, to contribute comments, ratings, and recommendations. Review systems aim to improve e-portfolio content, support self-reflection, and assist decision-making processes, while allowing to build online reputation [7]–[13]. However, existing review and reputation management systems within e-portfolio platforms face significant limitations that hinder their effectiveness and impact [8]–[16]. These limitations include centralized trust, fake reviews, lack of verifiability, limited transparency, vulnerability to manipulation, privacy concerns, limited user incentives, and scalability challenges.

To address these limitations, there is a growing need for a trustworthy and secure review system that can enhance the credibility, transparency, and reliability of e-portfolio reviews [8]–[10]. Blockchain technology has opened up new possibilities for building decentralized systems that can provide robust trust and security mechanisms [17]–[23], [25]. With the emergence of blockchain-enabled decentralized e-portfolio platforms [26]–[39], learners have gained the ability to exercise complete ownership and control over their e-portfolios. Thus, potential employers seek to independently verify the credentials and artifacts presented in these e-portfolios without relying on trusted third parties. However, ensuring trustworthiness, transparency, security, and auditability within these platforms remains a challenge.

In this paper, we propose *"B-TrustReview"*, a blockchain-based trustworthy and secure review system for decentralized e-portfolio platforms. The system aims to address the aforesaid limitations of existing review systems by leveraging the capabilities of blockchain technology, smart contracts, and cryptographic techniques. By leveraging the decentralized and tamper-resistant nature of blockchain, the system enhances the security, transparency, and reliability of the review process, and ensures the integrity of review data. Every review is securely recorded on the blockchain, creating an auditable and transparent record of evaluations. Cryptography techniques including digital signatures and zero-knowledge proofs (ZKP), are used to preserve user privacy and ensure that reviews are tamper-proof and originated from genuine sources. Smart contracts govern the execution of the review process, automating the validation and verification of reviews based on predefined criteria. This automation reduces reliance on trusted intermediaries and minimizes the risk of biased or manipulated reviews fostering transparency, accountability, and credibility in evaluating e-portfolios. It also enables secure and efficient transactions, ensuring the confidentiality of user data and protecting against unauthorized access. The implementation and evaluation of the proposed system proved its effectiveness and scalability. This paper extends our previous work [26].

The rest of the paper is organized as follows. Section II elaborates on the research background and related works. Section III presents the proposed system design and architecture. Section IV covers the implementation and evaluation details.

Section V concludes the paper and suggests future research directions.

II. Background and Related Work

This section provides the research background and recent efforts towards secure and trustworthy review schemes for decentralized e-portfolio systems.

A. E-Portfolio and Review Systems

E-portfolios are digital repositories that enable learners to document and present their accomplishments, skills, and experiences [1]–[3]. They provide a comprehensive view of an individual's learning journey and serve as a reflective tool for self-assessment and goal setting. E-portfolios offer several benefits, such as fostering lifelong learning, promoting critical thinking and reflection, facilitating career development, and supporting assessment and evaluation processes [4]–[7]. Research in the e-portfolio domain has focused on various aspects [2]–[7], including design principles, pedagogical approaches, assessment strategies, and technical implementations. An overview of e-portfolios is given in [1]–[4], discussing their purpose, benefits, and designs [5], [6]. Studies in [4], [7] have explored the impact of e-portfolios on student engagement, learning outcomes, and professional development. Challenges of balancing the two faces of e-portfolios are studied [3], focusing on the tension between showcasing achievements and supporting critical reflection. These studies provide foundational knowledge on e-portfolios, setting the stage for developing online portfolio platforms.

Review systems play a crucial role in assessing and validating the quality, credibility, and achievements of individuals' e-portfolios [8], [9]. These systems facilitate the evaluation process for potential employers, educators, and peers, allowing them to make informed decisions based on the reviews associated with e-portfolios to their online reputation [6], [8]–[10]. E-portfolio review systems provide features for users to provide feedback, comments, and evaluations on various aspects of an e-portfolio, including the content, presentation, organization, and overall quality [1], [4], [6].

The literature on review systems emphasizes the importance of reliable and trustworthy feedback mechanisms [8]–[15]. In [8], they analyzed the credibility of online review platforms. The impact of online review features on user behavior is studied in [9]. The reputation competition and review fraud on online platforms are explored in [10]–[13]. Authors in [14]–[16] examined different review methods, including rubrics, peer assessment, and expert evaluation, to ensure fairness, validity, and consistency. In [21], [22], they have explored the role of review systems in fostering a supportive learning community, enhancing social interaction, and improving the quality of e-portfolio content. These studies shed light on the factors influencing the credibility, trustworthiness, and manipulation of online reviews. Reputation management schemes are required to establish the credibility and trustworthiness of e-portfolios and their owners [21]–[25]. These systems assign reputation scores based on the quality of e-portfolios, as determined by the reviews and evaluations received. Review and reputation scores provide potential employers and stakeholders with an assessment of an individual's competence and achievements, aiding in the evaluation process [23].

However, traditional e-portfolio review systems have several limitations that need to be addressed. These include centralized trust, lack of verifiability, limited transparency, vulnerability to manipulation, privacy concerns, and limited user incentives [8]–[22]. These limitations can undermine the reliability, credibility, and fairness of the review process. To overcome these challenges, there is a need for innovative approaches that leverage emerging technologies like blockchain, smart contracts, and cryptography to ensure trustworthy, transparent, and secure e-portfolio review systems [21]–[28].

B. Blokchain and Smart Contracts

Blockchain is a decentralized and immutable ledger technology that enables secure and transparent transactions [17], [18]. It operates on a peer-to-peer network, where each participant has a copy of the ledger, ensuring transparency and immutability of data. Blockchain achieves this by leveraging cryptography algorithms that secure the transactions and link them together in blocks, forming a chain of blocks [18]. Additionally, blockchain offers robust security through cryptography algorithms, making it resistant to tampering and fraud. Smart contracts, on the other hand, are self-executing agreements that are written into code and automatically execute predefined actions when certain conditions are met [17]–[20]. These contracts eliminate the need for intermediaries and provide automation, efficiency, and accuracy in executing transactions. Smart contracts are deployed on the blockchain and operate in a transparent and deterministic manner. They facilitate automated and secure transactions, eliminating the need for trust in traditional contractual relationships.

C. Blokchain-based e-Portfolio Review Systems

The integration of blockchain technology into e-portfolio and review systems has recently gained attention for addressing challenges related to trust, security, and data integrity [23]–[27]. Blockchain provides a decentralized and tamper-proof ledger that ensures the authenticity and immutability of e-portfolio artifacts and reviews. It removes the need for intermediaries, reduces risks of data manipulation, and enhances the transparency and credibility of the review process [19]–[24]. Decentralized e-portfolio platforms empower learners to have complete ownership, control, and management over their e-portfolios [25]–[30]. They also aim to enable potential employers to independently verify e-portfolio artifacts and credentials without having to rely on trusted third parties [26].

The literature on blockchain-based e-portfolios and review systems is still evolving, with limited empirical studies and practical implementations. In [23], they explored the use of blockchain for educational record reputation and reward systems, highlighting the advantages of distributed systems in enhancing trust and recognition. A blockchain-based architecture is presented in [24] for ensuring the integrity and trans-

parency of learning trace repositories. An hybrid access control approach for enhanced security and privacy blockchain-based e-portfolio platform is proposed in [28]. A decentralized peer-review model is introduced in [31], which leverages blockchain to enhance the credibility and transparency of the review process. A decentralized reputation system-based on blockchain is presented in [32] for e-commerce environments, aiming to mitigate issues related to trust and reliability in online reviews. In [33], they present a scientific publishing platform powered by blockchain enabling transparent and immutable peer review processes. Decentralized approaches for scientific publication and peer review are introduced in [34]–[37], utilizing blockchain and IPFS to enhance transparency and trust. In [34], they emphasize on shared governance and collaboration among researchers. Singh et al. [34] focused on ensuring the integrity and trustworthiness of the review process. In [37], they tackled the transparency and privacy issues in academic publication systems.

In [38], they discussed challenges and strategies for reputation management in the age of the World Wide Web. In [39], they focused on ranking reputation and quality in online rating systems, proposing methods to improve the accuracy and fairness of reputation rankings. The potential benefits and challenges associated with online reputation systems are discussed in [40]. Zhou et al. [41], [42] proposed a reputation ranking method based on rating patterns and rating deviation to enhance the accuracy and reliability of review reputation systems. In [43], they developed a product recommendation system using deep learning-based recurrent neural networks to improve the accuracy and effectiveness of recommendations.

These studies collectively contributed to the understanding of e-portfolio and reputation management, and blockchain technology in the context of review systems. They provide insights into the challenges and opportunities associated with developing trustworthy, transparent, and secure review systems for blockchain-based decentralized e-portfolio platforms.

III. System Design and Architecture

This section describes the system design and architecture.

A. System Architecture

Fig. 1 depicts the proposed *B-TrustReview* system architecture for blockchain-based decentralized e-portfolio platforms. The description of e-portfolio management process in black color can be found in [26]. The flow in brown color depicts the e-portfolio review management process. After an e-portfolio has been submitted for evaluation to an evaluator, who uses the system to find reviewers matching with the portfolio field, and send them review requests (1). Upon accepting the request, reviewers receive e-portfolio and artifact details for review (3) and will submit the review report (4) that needs to be approved by the evaluator (5) for the reviewers to receive their rewards (6). Considering given reviews, the evaluator completes the e-portfolio assessment and issues digitally signed evaluation proof verifiable credentials. Upon receiving the evaluation proof, (7) the holder can publish e-portfolio credentials for

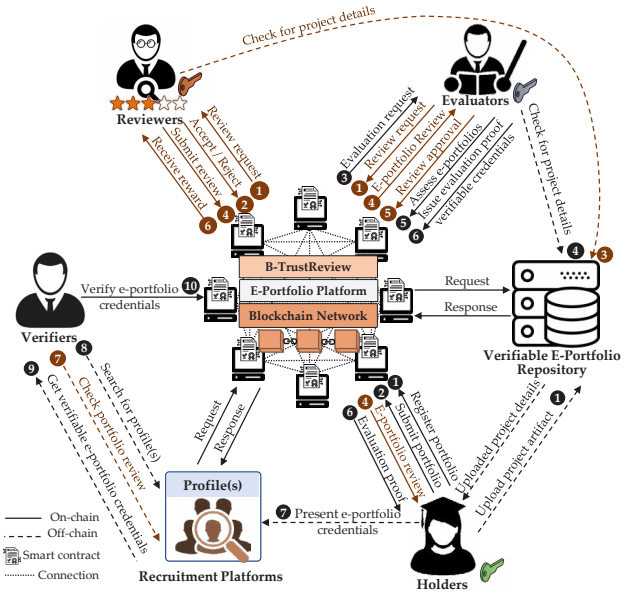

Fig. 1. Overview of the proposed *B-TrustReview*, a blockchain-based trustworthy and secure review system for decentralized e-portfolio platforms [2].

potential recruiters or independent versifiers (7)–(8) to be able to access and verify their integrity and authenticity.

Fig. 2 depicts the system architecture of the proposed trustworthy and secure review system for blockchain-based decentralized e-portfolio platforms, organized as follows.

1) Blockchain-based TrustReview System: It is a core module that ensures trustworthiness and security of the review system in a blockchain-based decentralized e-portfolio platform.

- *Reviwer Matcher* matches reviewers with relevant e-portfolios based on their expertise, skills, and interests. It ensures that reviewers are certified in the domain to enhance the credibility and quality of the reviews.
- *Review Registrator* is responsible for receiving and recording reviews submitted by reviewers. It securely stores reviews as transactions on the blockchain, ensuring immutability and transparency.
- *Review Validator* performs a validation process to ensure the accuracy and reliability of reviews. It verifies the identity of reviewers and validates the authenticity of reviews using cryptographic methods and identity management mechanisms. It checks for consistency, quality, and conformity to predefined criteria or guidelines.
- *Review Verifier* checks the authenticity and integrity of reviews. It employs cryptographic techniques, such as digital signatures or zero-knowledge proofs, to ensure that reviews are tamper-proof and originated from genuine sources. So, verifiers can independently verify and validate the review data, fostering trust among users.
- *Reputation Manager* tracks and maintains the reputation of reviewers based on their past reviews and interactions within the e-portfolio platform. Reputation scores or ratings can be calculated based on factors such as review quality, consistency, and feedback from other

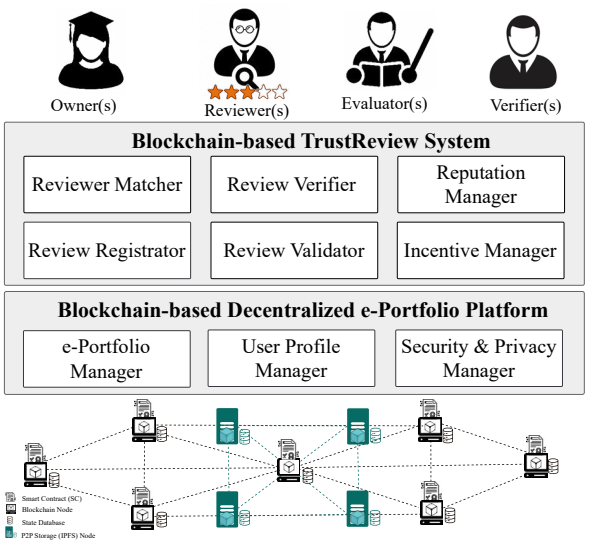

Fig. 2. System architecture of the proposed blockchain-based trustworthy and secure review system for decentralized e-portfolio platforms.

users. It helps users assess the reliability and credibility of reviewers, promoting trust in the review system.

- *Incentive Manager*: encourages active participation and quality contributions by providing incentives to reviewers. It can offer rewards, tokens, or other forms of recognition to incentivize users to submit honest and helpful reviews. It is critical for motivating users to engage in the review process and maintain the overall integrity of the system.

2) Blockchain-based Decentralized E-Portfolio Platform: It provides features for managing user profiles, e-portfolios, and ensuring security and privacy within the platform.

- *E-Portfolio manager* enables users to create, publish, and manage their e-portfolios. Encrypted artifacts of registered e-portfolios are securely stored in repositories powered by InterPlanetary File Systems (IPFS)[1]. Smart contracts are leveraged for ownership and access control management. E-Portfolio manager provides a user-friendly interface for users to showcase their achievements, skills, and experiences. It ensures the integrity and availability of e-portfolio data, facilitating seamless interactions between users and potential employers.
- *User profile manager* manages the membership enrollments, decentralized identifiers (DID) [44], user profiles, roles, and credentials. It allows users to create and manage their profiles within the e-portfolio platform. It securely stores user information and handles authentication and authorization processes. It also ensures that only authorized users can access and modify their profile data, safeguarding user privacy and security.
- *Security and privacy manager* provides robust security measures and privacy controls within the e-portfolio platform. It safeguards user data, enforces access control policies, and protects against unauthorized access or data breaches. It ensures that user information is handled in compliance with privacy regulations, like GDPR [19] and industry best practices, enhancing the security and privacy of the e-portfolio platform.

[1]https://ipfs.tech/

Algorithm 1 E-portfolio review registration

Setup: Smart contract parameters: $[C_a, A_a]$
Input: Pf_{id}, R_{id} = {*Review attributes*}, *msg.sender*, P_k, S_k
Output: Transaction execution state

Collect completed e-portfolio reviews from RM_TDB:
*SELECT*FROM* RM_TDB *WHERE* $Pf[_{id}]$.*rv_status* = "Completed"
while (R_{id}, Pf_{id}) **do**
  Check whether R_{id} exists in the blockchain:
  $R \leftarrow$ *sc.getReviewInfo*(R_{id})
  if (*msg.sender* $\in A) \wedge (R \neq NULL)$ **then**
    $R[_{id}] \leftarrow$ *sc.newReview*(*sign*(R_{id}, Pf_{id}), P_k, S_k)
    if $err \neq NULL$ **then**
      return *errorMessage(err.Text)*
    else
      Emit *sc.newReview*(*msg.sender*, R_{id}, R_{Rv}, t)
      Save T_h in RM_TDB (Review Management Transactional DB)
    end if
  else
    return "Not authorized or R_{id} already exists"
  end if
end while

Algorithm 2 E-portfolio review approval and proof generation

Setup: Smart contract parameters: $[C_a, A_a]$
Input: R_{id}, *msg.sender*, P_k, S_k
Output: Transaction execution state

Collect submitted review state: *sc.getReview*(*rv_status* = "Subimtted")
while (R_{id}) **do**
  if (*msg.sender* $\in A) \wedge (R[_{id}]$.*rv_status* $\neq$ "Approved") **then**
    if R_{id} satisfies review policy requirements **then**
      rv_status $\leftarrow$ "Approved"
      $R[_{id}] \leftarrow$ *sc.reviewUpdate*(*sign*$(R_{id}$, *rv_status*, $t), P_k, S_k$)
      sc.sendReward$(R_{id}, R_{Rv}, \Gamma, t)$
      sc.generateReviewProof$(R_{id}, \mathcal{P}_{id}, R_{Rv}, t)$
      if *err* $\neq$ *NULL* **then**
        return *errorMessage*(*err.Text*)
      else
        Emit *sc.reviewApproved*(*msg.sender*, $R_{id}, \mathcal{P}_{id}, R_{Rv}, t$)
        Save T_h in the RMS_TDB transactional database
      end if
    else
      return "R_{id} is rejected"
    end if
  else
    return "Not authorized or R_{id} already approved"
  end if
end while

IV. Implementation and Evaluation

Algorithm 1 depicts the e-portfolio review on-chain registration procedure, which receives portfolio identifier Pf_{id}, review identifier R_{id} and attributes, sender address, public P_k and private S_k keys as input. Upon a calling, the function starts by verifying if the review status is completed in the RM_TDB and checking if the sender is authorized and R_{id} does not exist in the blockchain, then it signs the transaction, saves the review record on blockchain and the transaction hash in RM_TDB. The e-portfolio review approval and proof generation procedure is described in Algorithm 2, which gets R_{id}, sender address, public P_k and private S_k keys as inputs.

Algorithm 3 E-portfolio review proof evaluation

Setup: Smart contract parameters: $[C_a, A_a]$
Input: $R_{id}, \mathcal{P}_{id}$, *msg.sender*
Output: True/False

while (R_{id}, P_{id}) **do**
  Check whether R_{id} and $\mathcal{P}_{id}$ exist in the blockchain:
  $R \leftarrow$ *sc.getReviewInfo*(R_{id})
  if (*msg.sender* $\in A$) $\wedge$ ($R \neq$ *NULL*) $\wedge$ $R.\mathcal{P}_{id} = \mathcal{P}_{id}$ **then**
    sc.verifyReviewProof$(R_{id}, \mathcal{P}_{id})$
    if $\mathcal{P}_{id}$ and R_{id} are genuine **then**
      return True
    else
      return False
    end if
  else
    return "Not authorized or R_{id} and $\mathcal{P}_{id}$ don't match."
  end if
end while

Upon a calling, the function checks if the sender address is allowed and the review status is not approved yet, then updates the status as "Approved", signs the transaction, updates the review state in blockchain. Next, it sends the reward token Γ to reviewer R_{Rv} and issues evaluation proof $\mathcal{P}_{id}$, and saves the transaction hash in RM_TDB. The review proof verification procedure is given in Algorithm 3. It gets R_{id} and $\mathcal{P}_{id}$ as inputs to verify whether the given proof is authentic and valid or not.

Goerli[2] testnet was used as the blockchain network. Goerli is an Ethereum [17] test network using Proof of Authority (PoA) consensus. The smart contracts were implemented in Solidity language. Incentive Manager utilizes ERC20 tokens [45] to provide incentives to reviewers. ERC20 tokens are cryptographic tokens that follow a set of standards that are established on the Ethereum blockchain network. The Incentive Manager rewards reviewers with ERC20 tokens for their contributions, encouraging active involvement and high-quality reviews. These tokens can be exchanged, redeemed, or traded within the platform, creating an incentivized ecosystem for reviewers. ZoKrates[3] was adopted as ZKP protocol for e-portfolio evaluation proof generation and verification. It is a toolbox for zkSNARKs [46] implementation on Ethereum. Nodejs, React, Hardhat, and Web3.js were used to built our decentralized application (Dapp) and Firebase[4] was used as transactional database. Metamask[5] was used for managing public-private key pairs and signing transactions.

TABLE I
B-TRUSTREVIEW SMART CONTRACTS DEPLOYMENT COST

No	Smart contract	Deployment Cost		
		Gas used (Gwei)	ETH	USD†
(1)	PortfolioProjectMgr.sol	4,566,672	0.004566	8.5
(2)	BTrustReviewMgr.sol	2,397,899	0.002397	4.4
(3)	BTR_TokenMgr.sol	1,344,365	0.001344	2.5
(4)	ProofVerifier.sol	1,182,965	0.001183	2.2

†ETH Price: 1 ETH = $ 1,875.79 (2023.06.29) – https://coinmarketcap.com/

[2]https://goerli.net/
[3]https://github.com/Zokrates/ZoKrates/tree/0.8.4
[4]https://firebase.google.com/
[5]https://metamask.io/

TABLE II
B-TRUSTREVIEW SMART CONTRACTS OPERATIONAL COST

No	Core contract set functions	Operational Cost		
		Gas used (Gwei)	ETH	USD†
(1)	uploadAndSumbitProject	188,329	0.000188	0.35
(2)	newEvaluator	68,776	0.000069	0.13
(4)	newReviewer	68,775	0.000069	0.13
(3)	newProjectReview	124,400	0.000124	0.23
(4)	approveReview	161,550	0.000162	0.30
(5)	sendReward	182,320	0.000182	0.34
(6)	issueProof	227,980	0.000228	0.43

†ETH Price: 1 ETH = $ 1,875.79 (2023.06.29) – https://coinmarketcap.com/

The evaluation of Solidity smart contract deployment and operational costs is important to understand the resource requirements and financial implications of deploying and executing contracts. Gas usage, representing computational effort for deploying and running smart contracts on the Ethereum blockchain, is used to measure costs. It is essential for ensuring network security and efficiency. Table I provides the deployment cost assessment of core smart contracts measured in Gwei, with corresponding Ether (ETH) and USD values. Smart contract (1) required 4,566,672 gas, which is equal to 0.004566 ETH or approximately 8.5 USD. Similarly, contract (2) had a deployment cost of 2,397,899 gas, equivalent to 0.002397 ETH or around 4.4 USD. Contracts (3) and (4) also incurred gas costs, with their respective ETH and USD values provided in Table I. In Table II, we assessed the operation costs of main setter functions of the proposed system that store the data on blockchain. Unlike storage, reading (getter) functions do not cost gas fees, as they do not change the ledger state. Based on the results of the experiment, the system requires on average 122,362 gas, corresponding to 0.000085 ETH, approximately 0.16 USD operational cost. Evaluating contract costs helps with budgeting, optimization, and financial planning, allowing estimation of expenses and optimization of contract design.

V. CONCLUSION AND FUTURE WORK

In this paper, we proposed a blockchain-enabled trustworthy, transparent, secure, and auditable review system (called *"B-TrustReview"*) for decentralized e-portfolio platforms. By leveraging blockchain technology, smart contracts, and cryptography techniques, the system addresses the limitations of existing review systems and establishes a reliable and transparent ecosystem. The findings highlight the potential of blockchain in revolutionizing e-portfolio platforms, providing enhanced control, accountability, and credibility. Future research can focus on privacy-preserving robust recommendation mechanisms, scalability enhancements, and real-world implementation to advance the practicality and effectiveness of the proposed review system.

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