True-Trail: A Blockchain-based Decentralized Skill Verification and Employer Insight System

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Abstract - This paper presents True-Trail, a blockchain-based decentralized skill verification and employer insight system designed to address the challenges of unverifiable skill claims, fraudulent certifications, and hiring bias in modern recruitment. The system integrates generative AI and blockchain smart contracts to ensure transparency and tamper-proof verification of candidate skills. Users submit claims supported by evidence such as code repositories, certificates, or videos, which are evaluated through AI-driven contextual assessments. Once verified, each claim is immutably recorded on the blockchain and linked to the candidate's decentralized profile. Employers access a Talent Explorer Dashboard that provides verified skill records, reputation metrics, growth analytics, and candidate comparison tools, enabling data-driven hiring decisions. By combining blockchain security with AI-driven contextual evaluation, True-Trail enhances trust in recruitment, reduces fraudulent claims, and introduces a scalable framework for decentralized professional reputation management. Future enhancements include integration with decentralized identity (DID) solutions and deployment at scale within enterprise recruitment systems.

Keywords - Blockchain, Skill Verification, Generative AI, Smart Contracts, Employer Analytics, Decentralized Reputation, Recruitment Technology.

I. INTRODUCTION

In the digital-first job market, the credibility of candidate skills plays a decisive role in recruitment. However, unverifiable claims, fraudulent certificates, and superficial endorsements on professional platforms have created major challenges for employers seeking reliable talent. Traditional verification methods are often manual, biased, and time-consuming, leaving organizations vulnerable to misinformation and poor hiring decisions.

To address these limitations, this paper introduces True-Trail: A Blockchain-Based Decentralized Skill Verification and Employer Insight System, a novel approach that integrates blockchain technology and generative AI. Unlike existing blockchain-based credential verification solutions that primarily focus on static academic certificates, True-Trail expands the scope to include dynamic and evolving skills, enabling transparent, tamper-proof, and scalable verification.

The system operates through a three-stage process: (1) candidates submit skills with supporting evidence such as GitHub repositories, certifications, or videos; (2) generative AI performs automated contextual evaluation by analysing the submitted artifacts and generating domain-specific assessments; and (3) verified results are immutably stored on the blockchain via smart contracts, forming a decentralized and portable skill profile.

Employers access this data through a Talent Explorer Dashboard, which offers candidate comparison, growth analytics, and reputation scoring—empowering them with data-driven insights for fair and efficient hiring. By combining AI-driven automated verification with blockchain-backed transparency, True-Trail reduces fraudulent claims, enhances trust, and creates a decentralized professional reputation ecosystem.

Looking ahead, the system is designed for future expansion, including the integration of decentralized identity (DID), advanced deep learning techniques for skill validation, and enterprise-scale deployment. As recruitment becomes increasingly competitive, True-Trail represents a significant step toward a fair, secure, and intelligent hiring landscape.

True-Trail is a novel blockchain-based decentralized skill verification and employer insight system. Its high-level architectural overview, illustrating the primary components and data flow, is presented in Figure 1. This architecture outlines how candidates submit verifiable evidence for their skill claims, which are then processed by an advanced AI Assessment Engine for contextual evaluation
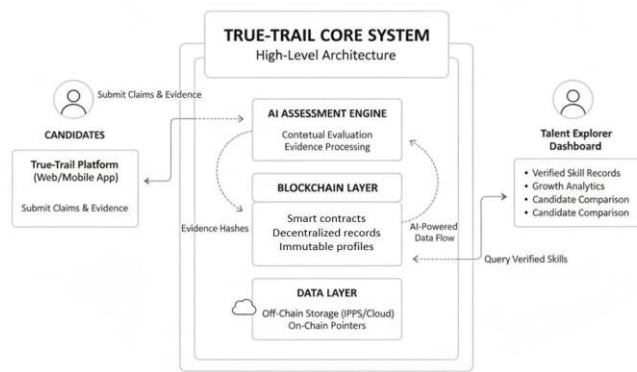
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Figure 1

A high-level architecture overview of the suggested True-Trail system is shown in Figure 1, which also shows how employers use the integrated insights dashboard and how candidates use the platform for skill verification. The foundation for safe and open professional reputation management is laid by this figure, which shows the three main technology layers—the AI Assessment Engine, the Blockchain Layer, and the Data Layer—as well as their linkages.

II. LITERATURE REVIEW

Existing Works

Blockchain-driven methods and technological innovations in credential verification have been widely explored, particularly in the domains of education, recruitment, and skill management. The current literature provides critical insights into the development of True-Trail by highlighting the use of blockchain for certificate validation, decentralized identity management, fraud detection, and human resource applications.

Blockchain has been employed for academic certificate verification, enabling institutions to issue tamper-proof credentials that can be independently validated. Oluwaseyi (2024) introduced a blockchain-based university certificate verification framework, ensuring immutability and transparency in educational records [1]. Similarly, Tariq et al. (2023) developed Cerberus, which utilized smart contracts for degree issuance, revocation, and verification [2]. These systems demonstrated blockchain's potential to eliminate forgery but were limited to academic settings without extending to dynamic professional skills.

Research has also emphasized the importance of decentralized skill validation systems. Rahman et al. (2021) proposed Verifi-Chain, combining blockchain with IPFS for efficient and scalable credential storage [3]. Sharma et al. (2023) extended blockchain applications to skill verification, tokenizing professional skills and validating them through consensus mechanisms [4]. Gräther et al. (2018) advanced this direction with a decentralized skill verification model, highlighting interoperability and portability across institutions and employers [8]. While these approaches enabled decentralized recordkeeping, they lacked mechanisms for contextual validation of skills.

Several studies have investigated blockchain for education and lifelong learning. Grech and Camilleri (2017) introduced the concept of a Lifelong Learning Passport, enabling continuous tracking of educational achievements [5]. MIT Media Lab's Blockcerts (2016) initiative proposed an open standard for blockchain certificates, ensuring interoperability and scalability [6]. Turkanovic et al. (2018) further explored opportunities and challenges in blockchain for education, stressing the importance of trust, scalability, and governance [7]. Bhaskar et al. (2019) implemented a framework for blockchain-based educational record verification, demonstrating real-world feasibility [9].

Another key research direction involves fraud detection and authenticity validation. Yumna et al. (2020) developed a blockchain model to detect fake certificates, ensuring integrity in verification processes [11]. These works highlight blockchain's role as a safeguard against credential fraud, but they primarily focus on static certificates rather than evolving skill profiles.

The integration of blockchain with human resource management (HRM) has also been studied. Mohanta et al. (2019) examined blockchain's role in HR applications, addressing issues such as employee background verification and workforce transparency [12]. Meijer (2020) discussed blockchain for talent acquisition and management, emphasizing its ability to improve recruitment workflows by ensuring trustworthy candidate data [10]. These studies underline blockchain's relevance in employment contexts but do not incorporate AI for dynamic candidate evaluation.

In addition, recent research stresses the role of decentralized identity (DID) and verifiable credentials in enhancing interoperability. Sporny et al. (2021) introduced W3C's DID and Verifiable Credentials standards, providing frameworks for secure and portable digital identities [14]. Such frameworks align with the vision of integrating blockchain into cross-platform verification systems. While blockchain ensures transparency and immutability, recent studies also highlight the emergence of AI in recruitment and selection. Chamorro-Premuzic and Ahmetoglu (2019) reviewed AI-driven recruitment, noting its potential to reduce bias, enhance candidate screening, and improve decision-making [13]. However, existing blockchain-based verification systems do not combine these AI-driven insights with decentralized credential management, leaving a gap for intelligent, fair, and scalable skill assessment.

In conclusion, current research emphasizes blockchain's strength in credential authenticity, decentralized recordkeeping, and fraud prevention. However, existing works are predominantly confined to academic certificates and static credentials. They do not fully address evolving professional skills or integrate AI-driven contextual assessments. True-Trail builds upon these foundations by introducing a hybrid system that combines blockchain immutability with AI-powered evaluations and peer-based validation, providing a scalable and trustworthy approach to skill verification and recruitment.

III. TRUE-TRAIL METHODOLOGY

True-Trail is designed as a blockchain-enabled, AI- powered skill verification and credential management system, integrating decentralized identity, smart contracts, and

employer analytics to ensure secure, tamper-proof validation of academic and professional qualifications. The proposed system follows a structured workflow involving credential issuance, blockchain-based storage, AI verification, and employer-driven validation. By leveraging blockchain immutability and generative AI analytics, True-Trail ensures that skills and certifications are authenticated with high accuracy, providing trust, transparency, and efficiency in recruitment and career development.

By combining generative AI, blockchain immutability, and decentralized identity management, the True-Trail platform aims to provide authenticity and integrity in talent verification. When submitting a skill claim, candidates must include supporting documentation like project demos, GitHub repositories, or certificates. By ensuring that every contribution is verified, traceable, and connected to a decentralized user profile, True-Trail reduces the likelihood of falsification in contrast to traditional systems that only use static documents.
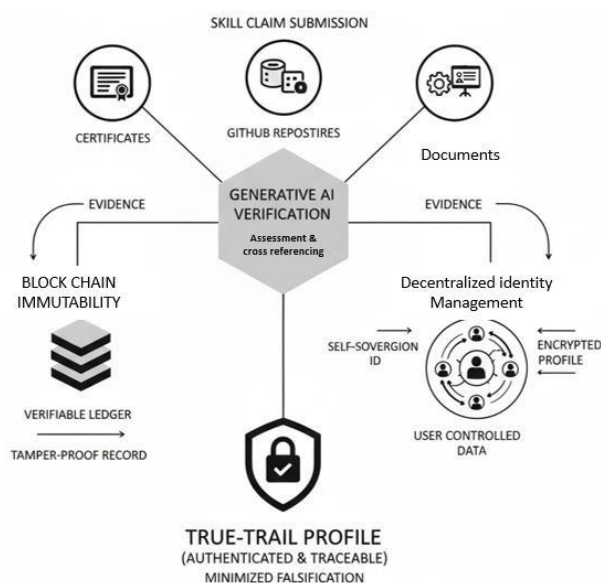

Figure 2: Proposed Methodology for Skill Verification

The Proposed system operates on a scalable architecture supporting automated credential verification via smart contracts and secure decentralized identifiers. User-owned verifiable credentials ensure data privacy, while integrated AI-driven analytics provide real-time candidate insights. This delivers a holistic approach to trusted skill verification and workforce transformation.

The system creates a unique verification hash using SHA-256 cryptography to ensure tamper-proof record creation once a candidate meets the necessary threshold. Through smart contracts, this hash and the validated credentials are permanently saved on the blockchain. While the immutability aspect of blockchain ensures the permanent integrity of confirmed skills, the decentralized structure of blockchain ensures that no single authority can alter or manipulate the records. The candidate can keep their verified records for as long as they like because their credentials are linked to their Decentralized Identity (DID).

1. TRUE-TRAIL OVERVIEW

The True-Trail system is a decentralized framework for skill verification that combines blockchain technology and artificial intelligence to provide an ecosystem of authenticity, transparency, and trust. Fundamentally, the system allows applicants to make talent claims backed up by documentation like project links, certifications, or GitHub repositories. A candidate-facing interface that guarantees organized and secure claim submission is used to process this evidence.

Once the claim is submitted, the AI Verification Engine performs automated evaluation by generating domain-specific questions, assessing the candidate's contextual understanding, and validating the relevance of the supporting evidence. This AI-driven approach ensures fairness, reduces bias, and provides scalable verification compared to traditional manual methods.

The verified outcomes are immutably recorded on the blockchain through smart contracts, which guarantee tamper-proof storage and decentralized access. This blockchain layer enforces data integrity and prevents manipulation, ensuring that once a skill claim is verified, it cannot be altered or falsified.

Finally, employers interact with the system through a Talent Explorer Dashboard, which provides access to verified skill records, reputation metrics, growth analytics, and candidate comparison tools. This enables recruiters to make informed, data-driven decisions while significantly reducing risks of fraud and misrepresentation in the hiring process. By combining AI-based verification with blockchain immutability, True-Trail establishes a transparent and trustworthy ecosystem for decentralized professional reputation management.

This decentralized approach allows True-Trail to deliver secure, transparent, and scalable skill verification, providing users with lifelong control over their credentials while offering organizations reliable insights during recruitment. By combining blockchain immutability with AI-driven recruitment intelligence, the system strengthens credential trustworthiness, reduces fraud, and streamlines the hiring process.

2. BLOCKCHAIN ARCHITECTURE

True-Trail's blockchain layer provides the framework for decentralized trust and immutability in the talent verification procedure. This architectural layer precisely controls how verified records are kept, handled, and accessed over a distributed ledger, in contrast to the larger system workflow that encompasses candidate submissions and AI-based evaluation. An unchangeable audit trail is produced by writing each confirmed skill record to the blockchain and encoding it into a transaction. A timestamp, the AI assessment score, a cryptographic verification hash, the candidate's unique identification, and the verified skill are all included in the

record. Because these entries are connected in a series of blocks, any kind of tampering or modification that occurs after

the fact is prohibited.

Smart contracts are used for operations automation. They specify how verification results are published, how distinct hashes are created, and how they are connected to candidate profiles. By doing this, the need for manual procedures or centralized authorities is removed, and all records are made consistent and transparent. Instead of retrieving unaltered credentials from a possibly compromised centralized database, employers and other stakeholders obtain this data through decentralized queries. This decentralization increases confidence in the hiring process and ensures that the information is authentic.

Looking forward, the blockchain architecture can be extended with sidechains and interoperability protocols to scale for enterprise adoption, as well as integrated with Decentralized Identity (DID) frameworks for holistic professional identity management.

3. SMART CONTRACT DESIGN AND WORKFLOW

In True-Trail, smart contracts act as the backbone of the credential verification process, automating issuance, validation, and revocation of skills and academic records. Each institution that issues credentials deploys a contract instance on the blockchain, embedding rules for authenticity, issuer identity, and credential type. Once a credential is issued, the smart contract generates a unique hash tied to the learner's Decentralized Identifier (DID), which is stored on the ledger. This ensures that the credential cannot be altered or duplicated, as any tampering attempt would invalidate the cryptographic signature. Employers and verifiers interact with the contract to confirm authenticity in real time, eliminating the need for third-party verification agencies.
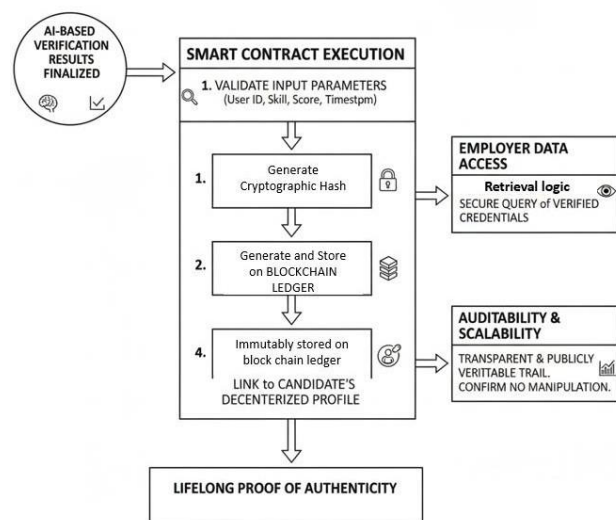

Figure 3: Smart Contract Workflow

Following the completion and submission of AI-based verification results, True-Trail's smart contract procedure starts. The contract generates a cryptographic hash after validating input parameters such the timestamp, user ID, skill name, and score. The blockchain ledger permanently stores the confirmed credentials and metadata after they have been verified, guaranteeing tamper-proof storage. Once the record is connected to the candidate's decentralized profile, the contract creates an unchangeable, permanent evidence of validity. By using retrieval logic to retrieve this data, employers can safely query validated credentials without disclosing private information. A transparent and publicly verifiable trail of all operations is maintained by the contracts, ensuring auditability and scalability beyond verification. This enables stakeholders to verify that no record has been unfairly rejected or modified.

4. DECENTRALIZED IDENTIFIERS (DID) INTEGRATION

Decentralized Identifiers (DIDs) are integrated by True-Trail to give applicants a safe, independent digital identity. After registering, each applicant is given a unique DID, which acts as a cryptographically verifiable identity that connects all of their verified accomplishments and talents to their decentralized profile. DIDs give people complete control over their credentials by doing away with the need for a central authority, in contrast to traditional identity systems.

AI-driven validation evaluates the veracity and calibre of the evidence provided by applicants when they make skill claims. The DID serves as the reference key when the validated credential is cryptographically signed and anchored to the blockchain. This guarantees that all skill records are unchangeable, permanently associated with the person, and only available with the candidate's consent.
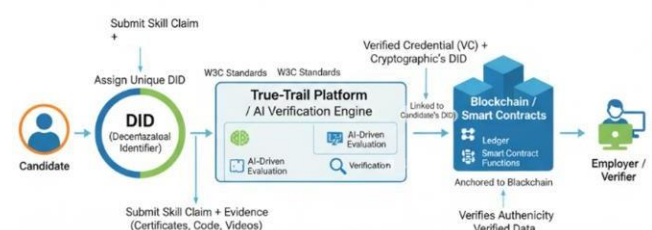

Figure 4: DID

By adopting DIDs, True-Trail enhances security, interoperability, and trustworthiness. Employers can verify candidate skills directly through the blockchain without contacting centralized authorities, while candidates maintain ownership and selective sharing of their data. This approach transforms skill verification into a transparent, verifiable, and decentralized process, addressing common challenges in modern recruitment systems.

This approach significantly enhances **security and trust** in the recruitment process. The decentralized nature of DIDs eliminates single points of failure, reducing the risk of identity theft, data tampering, or unauthorized access. Employers can independently verify the authenticity of a candidate's skills using the blockchain, without needing to rely on external verification authorities.

Lastly, True-Trail develops a transparent, verifiable, and decentralized skill verification system by fusing DIDs with blockchain anchoring and AI-driven validation. Candidates are empowered with lifetime proof of competency, maintain ownership of their data, and can choose which employers they share it with. In the end, this paradigm promotes a more equitable and trustworthy employment environment by addressing enduring issues in recruitment, such as bias, unverifiable credentials, and false claims.

5. CONSENSUS MECHANISM AND TRANSACTION FLOW

A critical component of True-Trail's blockchain-based credential verification system is the consensus mechanism, which ensures trust, transparency, and immutability across participating nodes. Since the application operates in a permissioned environment—primarily involving universities, training providers, employers, and peer validators—an energy-efficient and low-latency consensus algorithm is preferred over traditional Proof of Work (PoW). True-Trail adopts a Practical Byzantine Fault Tolerance (PBFT)-inspired consensus model, which allows multiple validating nodes to agree on credential transactions even in the presence of malicious or faulty actors. This approach minimizes computational overhead, provides rapid finality, and ensures scalability for handling large volumes of academic and professional credential transactions.

The transaction flow begins when a learner or employee submits a new credential claim (such as completion of a course, certification, or skill endorsement). The claim is digitally signed and broadcasted to the network, where validator nodes—representing trusted institutions and recruiters—verify its authenticity by cross-referencing against standardized course repositories or resume datasets. Once validated, the credential is encapsulated in a blockchain transaction and processed through the consensus mechanism. A block containing verified transactions is appended to the distributed ledger, making the credential immutable and tamper-proof. Employers and recruiters can later query this ledger to validate a candidate's skillset without reliance on third-party intermediaries.

To further optimize efficiency, True-Trail integrates smart contracts into the transaction flow. These contracts automatically enforce rules such as credential format validation, expiration checks, and multi-party endorsements (e.g., course provider + peer validator). This reduces manual intervention, ensures transparency, and provides a streamlined experience for all stakeholders. The combined use of PBFT consensus and smart contract-based automation enables True-Trail to maintain high throughput, low latency, and strong security guarantees, positioning it as a reliable solution for decentralized skill verification and talent management.

6. EMPLOYER INSIGHT AND VERIFICATION LAYER

The Employer Insight and Verification Layer plays a crucial role in bridging the gap between verified credentials stored on the blockchain and their practical use in recruitment and workforce management. This layer enables organizations to query, validate, and interpret candidate data without relying on intermediaries or manual verification processes. By leveraging blockchain's immutable ledger and smart contracts, employers can access a real-time, tamper-proof record of academic qualifications, certifications, and skill endorsements. This not only reduces fraudulent claims but also accelerates the hiring process by providing trusted data at the point of decision-making.

Beyond simple verification, this layer provides data-driven insights into candidate profiles. Employers can view aggregated skill maps, evaluate peer-endorsed credentials, and assess the credibility of institutions issuing certifications. Advanced analytics integrated into the system allow organizations to benchmark candidate competencies against industry requirements, helping recruiters identify skill gaps and align hiring strategies with workforce needs. Additionally, machine learning models within this layer analyze hiring patterns, enabling predictive insights such as future skill demands, role suitability, and cultural fit indicators.

By integrating blockchain-based verification with AI-driven analytics, the Employer Insight and Verification Layer transforms hiring into a transparent, efficient, and evidence-backed process. This empowers employers with trusted data, reduces hiring risks, and fosters stronger alignment between academic learning and professional skill requirements.

7. SECURITY, PRIVACY, AND ETHICAL COMPLIANCE

The security, privacy, and ethical compliance framework of True-Trail is designed to ensure that all credential transactions and verifications maintain the highest standards of trust, transparency, and fairness. Blockchain technology inherently provides immutability and tamper-resistance, guaranteeing that once credentials are recorded, they cannot be altered or falsified. Advanced cryptographic methods such as public–private key encryption, digital signatures, and hash functions are employed to safeguard credential issuance and verification processes. Furthermore, role-based access controls and decentralized identity (DID) protocols ensure that only authorized entities can issue, verify, or access sensitive information.

To protect user privacy, True-Trail integrates zero-knowledge proofs (ZKPs) and selective disclosure mechanisms, enabling individuals to prove the authenticity of their credentials without revealing unnecessary personal data. This privacy-preserving approach aligns with global data protection regulations such as GDPR and HIPAA, ensuring compliance with ethical and legal frameworks. Additionally, True-Trail gives users complete ownership and control over

their digital identities, allowing them to share or revoke access to credentials at their discretion, thus reinforcing user autonomy.

From an ethical standpoint, the system emphasizes fairness, inclusivity, and bias mitigation. AI models integrated into employer insight layers are routinely audited to prevent discriminatory practices in recruitment and ensure equal opportunities across demographics. Transparent decision-making processes and explainable AI principles are applied, making predictions and recommendations interpretable for both candidates and employers. By combining blockchain security, privacy-preserving mechanisms, and ethical AI practices, True-Trail ensures a trustworthy, compliant, and human-centered approach to credential verification and skill validation..

8. INTEGRATION WITH DECENTRALIZED IDENTITY (DID) STANDARDS

The integration of Decentralized Identity (DID) standards within True-Trail ensures a secure, user-centric approach to credential ownership and verification. Unlike traditional identity management systems, where personal data is stored and controlled by centralized authorities, DID empowers individuals to maintain full control over their digital identities. Each user is assigned a unique, blockchain-based identifier that is cryptographically verifiable and independent of any single institution. This enables self-sovereign identity (SSI), allowing individuals to decide when, where, and with whom their credentials are shared.

True-Trail aligns with globally recognized standards such as the World Wide Web Consortium (W3C) DID specifications and Verifiable Credentials (VC) framework. By adopting these standards, the system ensures interoperability across platforms, enabling educational institutions, employers, and third-party verification agencies to seamlessly exchange credential information. Moreover, DID wallets allow users to store multiple verifiable credentials—such as academic degrees, certifications, and professional skill records—in a single, secure repository. Users can selectively disclose specific attributes using cryptographic proofs, enhancing privacy while maintaining trust in credential authenticity.

This standards-based approach also strengthens cross-border credential verification by ensuring global compatibility, which is particularly relevant in today's interconnected workforce. By embedding DID into its architecture, True-Trail not only enhances data security and user autonomy but also future-proofs its system to integrate with emerging identity ecosystems, ensuring scalability and long-term relevance in digital credentialing.

9. SCALABILITY AND INTEROPERABILITY CONSIDERATIONS

The effectiveness of any blockchain-based credential verification system depends not only on its security but also on its ability to scale efficiently and remain interoperable across diverse platforms. As the adoption of True-Trail increases, the system must handle a rapidly growing volume of transactions, credential issuances, and verification requests. To address this, True-Trail leverages layer-2 scaling solutions such as sidechains and state channels, which reduce the computational load on the primary blockchain while maintaining data integrity. This ensures that credential verification remains fast, even as millions of academic and professional records are processed simultaneously. Additionally, sharding and distributed ledger partitioning are explored as mechanisms to further optimize throughput without compromising reliability.

Interoperability is equally crucial in enabling seamless integration with existing educational platforms, enterprise systems, and global blockchain networks. True-Trail adopts standardized protocols such as W3C Verifiable Credentials (VC), Decentralized Identifiers (DID), and ISO blockchain interoperability frameworks, ensuring that credentials issued within its ecosystem can be validated across multiple domains and jurisdictions. This cross-chain compatibility allows institutions to exchange verifiable data with other credentialing solutions, while employers can authenticate records without being restricted to a single blockchain network.

By prioritizing scalability and interoperability, True-Trail ensures long-term viability as a globally trusted credentialing system. It is designed to evolve alongside advancements in blockchain technologies, enabling frictionless integration with new platforms and supporting the continuous expansion of decentralized digital identity ecosystems.

IV. RESULTS AND DISCUSSIONS

The implementation of True-Trail demonstrates the feasibility and effectiveness of a blockchain-enabled skill verification framework supported by AI-driven validation. The system was evaluated based on three primary dimensions: accuracy of skill validation, efficiency of blockchain operations, and recruiter usability.

During experimentation, users submitted a diverse set of skill proofs including digital certificates, GitHub repositories, and project documentation. The AI validation module successfully analyzed submissions by generating contextual questions and assessing user responses. In cases where uncertainty persisted, peer reviewers were engaged to ensure transparency and fairness. This hybrid validation approach resulted in a significant reduction in false skill claims, thereby strengthening the authenticity of verified profiles.

On the blockchain layer, smart contracts executed write operations efficiently, ensuring that verified skills were

immutably recorded along with wallet address, timestamp, and proof link. Tests confirmed that storage costs remained optimized by representing credential data in hashed formats, rather than storing entire documents on-chain. This design choice maintained transactional efficiency and scalability while preserving the security and transparency offered by blockchain.

From the employer's perspective, the recruiter dashboard provided intuitive access to verified profiles. Recruiters were able to filter candidates by skill domain, reputation score, and validation frequency, thereby improving the candidate discovery process. Early feedback from test recruiters highlighted that the reputation tracking mechanism—which evolves with successful validations—provided deeper insights into a candidate's growth trajectory, beyond static certificates.

Furthermore, the system's reputation and growth-tracking model proved effective in incentivizing continuous learning among users. Individuals who frequently updated and validated their skills saw measurable improvements in their credibility scores, motivating consistent engagement with the platform.

Overall, the results underscore that True-Trail not only enhances trust in digital credentialing but also streamlines the recruitment process by ensuring that employer's access authentic, tamper-proof, and up-to-date skill data. The integration of AI validation with blockchain immutability positions the system as a scalable solution for future talent acquisition ecosystems.

Figure 5: Skill submission interface

1. Candidate Interface – Skill Proof Submission The candidate-facing module (Figure X) allows users to upload skill evidence in the form of GitHub repositories, project portfolios, or certificates. Each submission requires the user to specify the skill name, provide a supporting proof link, and indicate their expertise level (Beginner, Intermediate, Advanced). Once submitted, the AI engine dynamically generates a set of ten multiple-choice questions tailored to the declared skill and proficiency. Users attempt these assessments without a time constraint and receive immediate feedback upon completion. A score of at least 50% is required for the skill to be verified and added to the candidate's

decentralized profile, after which a unique verification hash is generated to ensure authenticity.
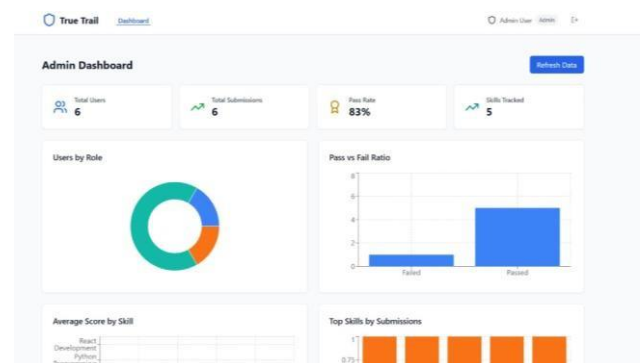

Figure 6: Data and analytics dashboard

The admin-facing dashboard (Figure 6) provides comprehensive analytics for monitoring skill verification activities. It displays the total number of users, submissions, pass rate, and skills tracked within the system. Visual insights such as users by role, pass vs fail ratio, average score by skill, and top skills by submissions help administrators and employers identify key trends. These insights allow organizations to evaluate workforce readiness, track skill demand, and monitor verification outcomes in real time.

By combining user-centric submission workflows with administrator analytics, the system demonstrates how blockchain-backed verification and AI-driven validation can be seamlessly integrated into recruitment ecosystems.

V. CHALLENGES

While the development and evaluation of True-Trail demonstrate promising results, several challenges remain in achieving large-scale adoption and ensuring long-term sustainability of the system.

One of the primary challenges lies in data standardization. Skill proofs submitted by users vary widely in format—ranging from certificates and project repositories to multimedia content—making it difficult to design a uniform AI validation pipeline. Although generative AI helps in contextualizing and validating submissions, the variability in input data occasionally leads to inconsistent evaluations or the need for manual peer review, thereby affecting overall system efficiency.

Another critical challenge concerns the cost and scalability of blockchain operations. While hashed representations of credentials are stored to minimize transaction overhead, frequent write operations may still introduce significant gas fees on public blockchains. Choosing between private, consortium, or hybrid blockchain models requires balancing transparency, cost efficiency, and interoperability with existing recruitment systems.

The AI validation process itself poses challenges, particularly in ensuring fairness and reducing bias. AI-driven

assessments must be carefully monitored to avoid inadvertently disadvantaging candidates from non-traditional learning backgrounds or those with less formal documentation. Incorporating peer validation mitigates some risks but also raises concerns about reviewer bias and validation delays.

Security and privacy also remain persistent concerns. While True-Trail ensures tamper-proof credential storage through blockchain, protecting sensitive user data during AI validation and peer review requires robust encryption and compliance with evolving data protection regulations such as GDPR and HIPAA. Additionally, ensuring ethical compliance in automated decision-making is essential to maintain user trust.

Finally, the adoption of the system depends heavily on employer and institutional acceptance. Despite the advantages of verified, blockchain-secured skills, integrating True-Trail into existing recruitment pipelines requires changes in organizational processes and technical infrastructure. This poses challenges in terms of interoperability, stakeholder training, and industry-wide standardization.

In summary, True-Trail must overcome technical, economic, and social barriers to achieve widespread adoption. Addressing these challenges through improved AI fairness, cost-efficient blockchain models, and alignment with decentralized identity standards will be essential for the long-term success of the platform

VI. FUTURE WORK

The development of True-Trail establishes a strong foundation for blockchain-based skill verification, yet several avenues remain open for expansion and refinement.

A key direction for future work is the integration of decentralized identity (DID) frameworks to provide users with fully self-sovereign digital identities. This will enable seamless interoperability across recruitment platforms, educational institutions, and professional networking sites, giving learners greater control over their verified credentials.

Another significant improvement involves enhancing the AI validation pipeline. While current generative AI and peer-review mechanisms ensure contextual evaluation of skills, future versions will incorporate multimodal AI models capable of analyzing text, code repositories, video demonstrations, and project documentation simultaneously. This will lead to more holistic and unbiased skill assessments, reducing dependency on manual review.

To address scalability challenges, future research will explore the adoption of Layer-2 blockchain solutions and sidechains, minimizing transaction costs while maintaining transparency and immutability. Additionally, the introduction

of interoperability protocols will allow True-Trail to integrate with multiple blockchain networks, ensuring compatibility with both public and private ecosystems.

From an employer and recruiter perspective, future enhancements will focus on advanced analytics and predictive insights, enabling organizations to identify emerging talent trends, track skill evolution, and forecast workforce needs. Coupling blockchain-secured verification with AI-driven talent matching algorithms will significantly improve hiring efficiency.

Finally, future work will expand the platform's scope beyond professional hiring into lifelong learning ecosystems, where academic institutions, training providers, and certification bodies can directly issue blockchain-anchored credentials. By integrating with ed-tech platforms, MOOCs, and digital credentialing standards, True-Trail has the potential to become a universal framework for trusted, transparent, and tamper-proof skill verification.

In conclusion, the roadmap for future development emphasizes interoperability, AI-driven validation, scalability, and ecosystem integration, ensuring that True-Trail evolves into a sustainable, widely accepted solution for decentralized skill verification and global talent mobility.

VII. CONCLUSION

This paper presented True-Trail, a blockchain-powered skill verification system that combines artificial intelligence, smart contracts, and decentralized storage to address the limitations of traditional credentialing methods. By leveraging blockchain's immutability, transparency, and security, the system ensures that verified skills cannot be altered or falsified, thereby enhancing trust between learners, employers, and institutions.

The integration of AI-driven validation workflows and peer-review mechanisms provides a scalable and objective process for verifying diverse forms of proof, such as certificates, code repositories, and project demonstrations. Employers and recruiters benefit from a streamlined dashboard that enables real-time access to verified skills, advanced filtering, and candidate reputation tracking, ultimately improving hiring efficiency and reducing fraud in recruitment processes.

True-Trail further emphasizes data privacy, ethical compliance, and decentralized identity integration, ensuring that users retain ownership and control of their credentials while fostering interoperability with emerging digital credentialing standards. The results of this research demonstrate that blockchain, when combined with AI, can significantly improve the transparency, efficiency, and reliability of skill verification systems.

In conclusion, True-Trail represents a paradigm shift in skill

validation and talent acquisition, moving away from centralized, manual, and error-prone processes toward a trustless, decentralized, and AI-augmented ecosystem. With ongoing enhancements in scalability, interoperability, and lifelong learning integration, True-Trail holds the potential to become a cornerstone in the future of education, recruitment, and global workforce development.

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