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UYAKUY - BLOCKCHAIN-BASED SOFTWARE APPLICATION FOR CERTIFICATE ISSUANCE: A Case Study in the IEEE Peru Section

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ABSTRACT

Currently, companies in the financial sector are widely adopting blockchain technology to address critical issues such as the verifiability of authentic documents and money laundering, among others. However, there remains a prevalence of illicit activities related to document forgery, which is a punishable offense carrying prison sentences. Document verification is a complex process, involving a myriad of challenges and burdens concerning authentication. In this paper, we present an optimized approach for certificate issuance through a blockchain-based web system, with the aim of enhancing certificate authenticity, reducing execution time, and augmenting customer satisfaction. Recently, blockchain has emerged as a promising tool for authenticating the document verification process and is viewed as a significant instrument in combating fraud and document misuse. This research zeroes in on leveraging decentralized technology to create verifiable documents, employing a specific architecture, and following the Rational Unified Process methodology. The results garnered illustrate an efficient process for issuing highly reliable certificates, thereby contributing to the deterrence of malicious use of certificates by third parties.
Keywords: *Web-based system, Blockchain, Issuance, Certificates, Documents, Technology, Dapps*

1. INTRODUCTION

Currently, issuing certificates presents a notable challenge for organizations, necessitating the assurance of their integrity to prevent potential criminal activities and misuse. Blockchain technology has emerged as a solution, facilitating the secure exchange of digital data without intermediaries, rendering it apt for transactions involving contracts, certificates, sale of goods and services, property titles, insurance policies, and more—all convertible into a digital format. The potential of blockchain to instigate significant transformations in the economy, industry, and society has propelled its exploration across various sectors and organizations. In a study conducted by [16], an architecture predicated on the creation of a cryptocurrency dubbed UniCert was proposed, through which decentralized contracts were developed utilizing API services. Additionally, [5] underscores that document verification is a complex domain entailing various challenging and tedious processes to ascertain authenticity. On the flip side, [15] proposes a structure called EDUBlock, facilitating the registration and traceability of student certificates, alongside resource management using blockchain technology. In [18], it's accentuated that the term "Blockchain" has transcended beyond the realm of cryptocurrencies and is increasingly employed in other fields of development where security mechanisms are proposed. An exemplification of this is the development of VECefblock, presented in [14], which is predicated on the creation of a dedicated server for decentralized transactions, optimizing computational resources. In [6], the Certchain scheme is delineated, supporting certificate traceability and enabling efficient revocation verification. Furthermore, [19] underscores the ability of pre-contract protocols in blockchain to ensure fairness and traceability through the utilization of centralized credible nodes. Meanwhile, [20] proposes a viable solution for tracing food in social programs, thereby ensuring the quality of supplied products to the populace. According to [27], documents can be lost or destroyed due to unforeseen circumstances, rendering the reissuance of certificates challenging, expensive, and at times, unfeasible. Herein, the solution transcends merely digitizing documents to embracing reliable centralized infrastructures. Blockchain technology has been adeptly applied across a myriad of technological sectors through hybrid frameworks, thereby enhancing transaction security and ensuring digital asset reliability. The authors [29] delve into the application of blockchain technology across three energy efficiency use cases, showcasing its potential to overcome inherent barriers. The examined approaches encompass P2P energy trading, WCS, and ESCOs, utilizing a decision framework to assess the viability of blockchain technology. The discussion broaches the barriers to blockchain adoption, emphasizing the imperative for policies that encourage the development of pilot studies. In their paper [30], the authors explore the utilization of blockchain technologies within the educational sphere to augment traceability, accountability, and information integrity, while concurrently ensuring privacy, transparency, and authenticity. The work delineates an innovative resolution to prevailing challenges, facilitating the issuance, storage, and verification of both formal and informal academic information. The study by the authors [31] posits that blockchain technology can significantly enhance efficiency in government services, notably in the issuance of notarial certificates. The envisioned system employs AES encryption and MongoDB for maintaining the status and details of requests. Certificates are dispatched to users via a grid API method through email, which in turn provides a password for certificate retrieval. The crux of this research is to scrutinize the application of blockchain for certificate issuance through a web-based system within a technological organization, with the Peru Section of the IEEE epitomizing a case study. This will elucidate how blockchain can harbor data rendering it virtually indelible, thereby facilitating open data interchange among users and establishing an unalterable transaction record. The advocated approach encapsulates the development of a certificate issuance system utilizing decentralized technology.

In contemporary times, document falsification persists as a recurrent illicit activity, originated by the alteration of documents with the aim of forging them. This action translates into a serious offense from the moment of the modification or creation of the apocryphal document, leading to criminal penalties. The realm of document verification is intricate, encompassing a blend of challenging and laborious processes on the journey towards authentication. Therefore, the following research question was posed: To what extent does the use of the Uyakuy Application based on Blockchain optimize the Issuance of Certificates in the Peru Section of the IEEE?. This article is structured as follows: Section 2 reviews related work on the application of blockchain technology in virtual records, highlighting existing contributions in the field of certificate issuance. The research purpose is detailed in Section 3, and Section 4 focuses on the experimental development of the certificate issuance system. Subsequently, Section 5 presents the results obtained during the system implementation. Finally, Section 6 discusses the study's conclusions and provides recommendations for future research.

2. THEORETICAL BACKGROUND

Currently, Blockchain technology finds applications across various sectors, both public and private, owing to its capability to store immutable, tamper-proof records of information, a characteristic derived from its secure architecture and design. Many organizations issuing certificates are eyeing Blockchain adoption to enhance the reliability and security of their record-keeping processes, with a primary aim of automating contracting processes entirely [1]. The recent years witnessed several attacks on the Public Key Infrastructure (PKI), underscoring the risks tied to verifying revoked certificates due to their centralized nature. Herein lies Blockchain's potential [6]. Emerging as a viable alternative to address this concern, Blockchain technology, as per [7], facilitates certificate issuance by housing certificate information on the Ethereum blockchain via smart contracts, thereby enabling efficient verification as required. Additionally, Blockchain is used to create distributed systems that record transaction information without the need for a third party for verification, saving costs and ensuring data security [8]. There is a growing concern about the prevalence of fraudulent academic certificates, with studies revealing high percentages of counterfeit diplomas at different educational levels. According to a study by the Human Competence entity, out of 15,000 reviewed diplomas, 14.4% were found to be fake, with 65% corresponding to bachelor's degrees, 21% to technical diplomas, and 14% to professional and specialization degrees [9]. In the context of PKI models, digital certificates play a fundamental role in the security of online communications, and the use of Blockchain can protect this data, significantly reducing fraud and enabling customers to directly

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validate their certificates on the blockchain without having to communicate with the original issuing organization. An additional benefit is the reduction of data administration costs [10] [11]. Software development with Blockchain technology has become a fundamental skill for modern developers, although a mature and disciplined development methodology is still lacking [12]. Digitizing certificates is a common trend in the digital realm, and in many cases, these certificates become digital versions of paper certificates. However, the next natural step is to store these certificates on the Blockchain [13]. Blockchain offers functionalities that are especially useful for information security, transaction verification, and smart contracts, which can transform traditional business processes into IT applications [14]. Furthermore, there is a need for appropriate anti-counterfeiting systems to ensure the authenticity of certificates [21]. In the medical field, Blockchain has been used to secure patient data and track their medical history [22]. There is a mutual influence between databases and Blockchain, as databases contribute to Blockchain technology by providing a solid foundation for distributed data storage [23]. In general, Blockchain technology is considered a unique source of shared truth that guarantees the integrity and immutability of stored information [26]. This technology can be used to store any type of digital data [12]. The decentralized and robust nature of blockchains helps reduce security breach risks [3]. However, it's noteworthy that Blockchain's transparency can engender privacy concerns [4]. Document verification, a complex endeavor fraught with challenges and tedious tasks to ascertain authenticity, has found a promising solution in Blockchain-based frameworks for enhancing authentication, authorization, confidentiality, privacy, and ownership of certificates, as exemplified by the Hyperledger Fabric Framework [5]. The introduction of a system for storing digital documents on Blockchain addresses common issues faced by electronic repositories, ensuring access and reliability [24]. Additionally, a tool has been crafted to scrutinize smart contracts, ensuring their secure deployment on the blockchain [25]. Blockchain's cornerstone is its data structure, wherein new entries are appended, and existing ones remain unalterable, guaranteeing record integrity and immutability [28].

3. RESEARCH METHODOLOGY

3.1 Methodology for Web System Development with Blockchain

This study employs the Rational Unified Process (RUP) methodology for the development of the Web System, leveraging Blockchain technology.

Rational Unified Process Methodology (RUP)

The Rational Unified Process (RUP) methodology, aligned with the Unified Modeling Language (UML), is a software development process selected for this research due to its configurable process environment adhering to standards. RUP, extensively utilized for analyzing, implementing, and documenting object-oriented systems, is depicted graphically in Figure 1.

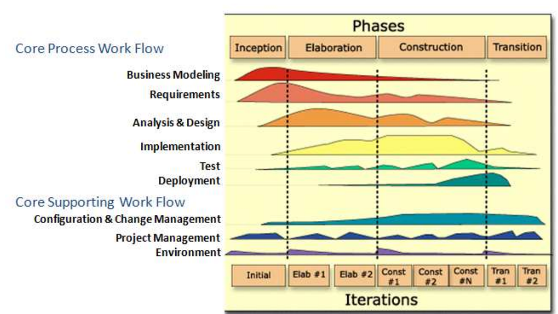

Table 1: RUP Methodology Process

Initiation Phase: In this initial stage of the project, collaboration with clients is key to defining the project scope and understanding their needs. Potential risks are identified, and a plan is developed that outlines the different phases and the initial iteration. An overview of the product architecture is also provided.

Elaboration Phase: In this phase, the initial design of the solution is carried out by selecting key use cases that help define the system's core architecture. A detailed analysis of the problem domain is also conducted.

Construction Phase: During this phase, the focus is on completing the system's functionality by addressing pending requirements and managing changes that arise from user evaluations. Project enhancements are made, and software quality is ensured.

Transition Phase: In this final stage of the process, the software is made available and ready for use by end users. Errors and defects identified during acceptance testing are corrected, and users receive training to effectively use the system. Continuous support is provided to ensure proper functioning.

3.2 Applied Research Methodology

Table 1 showcases the operationalization of the indicators pertaining to the dependent variable, Certificate Issuance.

Table 1: Operationalization of the Dependent Variable.

Indicator	Index	Unit of Measure ment
Average certificate issuance time	[15-20]	Minutes
Average certificate search and retrieval time	[10-20]	Minutes
Certificate issuance cost	[0-60]	Nuevo Sol S/.
Certificate authenticity level	Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree	Likert Scale
Customer satisfaction level	Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly Agree	Likert Scale

Research Design

The research had a quantitative applied approach with a Pure or True experimental design.

RGe X O_1

RGc -- O_2

An Experimental Group (Ge) encompassing all transactions in the Certificate Issuance Process is formed. Initial measurements of indicators (O_1) are taken in this group. Following this, an experimental stimulus, the Web System with Blockchain (X), is applied to tackle the process-related issues. Concurrently, detailed measurements of indicators for the Control Group (Gc), without any stimulus (--), are carried out (O_2), anticipating improved values compared to (O_1).

Universe and Sample

This research encompasses all Certificate Issuance processes in organizations globally as the universe. The sample specifically zeroes in on the Certificate Issuance processes within the Peru Section of the IEEE. Consequently, the sample size stands at n = 30.

Data Collection Procedure

In this research, the technique of direct observation was utilized, and an instrument termed an observation checklist was employed to garner data pertinent to each study indicator.

Statement of Hypotheses

H_1: If a Web System with Blockchain is used, applying the RUP Methodology, then the average certificate issuance time is reduced.
H_2: If a Web System with Blockchain is used, applying the RUP Methodology, then the average certificate search and retrieval time is reduced.
H_3: If a Web System with Blockchain is used, applying the RUP Methodology, then the certificate costs are reduced.
H_4: If a Web System with Blockchain is used, applying the RUP Methodology, then the authenticity of certificates is improved.
H_5: If a Web System with Blockchain is used, applying the RUP Methodology, then customer satisfaction is increased.

For hypothesis testing, the following was proposed to test each of the study hypotheses:

μ_1: Population Mean (H_1, H_2, H_3) for Post-Test of G_e
μ_2: Population Mean (H_1, H_2, H_3) for Post-Test of G_e

Where: H_o: $\mu_1 \leq \mu_2$ and H_a : $\mu_1 > \mu_2$

Additionally:
μ_1: Population Mean (H_4, H_5) for Post-Test of G_e
μ_2: Population Mean (H_4, H_5) for Post-Test of G_e

Where: H_o : $\mu_1 \geq \mu_2$ and H_a : $\mu_1 < \mu_2$

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Lastly, for hypothesis testing, two statistical tests were employed: the Student's t-test and the Mann-Whitney U test. These tests were conducted utilizing the statistical software Minitab. This software facilitated both descriptive and inferential analyses of the data, alongside a normality test to ascertain the data distribution.

4. CASE STUDY

For the development of the system, the four phases of the RUP (Rational Unified Process) methodology were executed.

4.1 Initiation Phase

Company Description

The IEEE stands as the foremost professional association globally, striving to drive innovation and technological excellence for humanity's welfare. Through its extensive publications, conferences, technological standards, and superior professional and educational endeavors, the IEEE, along with its members, galvanizes a global community to pursue inventive solutions for an enhanced future. It emerges as a trusted authority on engineering, computer science, and technology discourse worldwide.

The IEEE Peru Section is an organized and registered entity according to the Associations Law of Peru. It is a non-profit organization that aims to promote the development of theory and practice in Electrical Engineering, Electronics, Computer Science, and related disciplines. Additionally, it is dedicated to strengthening technical efficiency and fostering professional ethics among its members. The IEEE Peru Section also strives to maintain good relationships among its members and colleagues, promoting the exchange of knowledge and collaboration in projects of common interest.

Certificate Issuance

The IEEE Peru Section, a registered entity under Peru's Associations Law, is a non-profit organization devoted to advancing the theory and practice in Electrical Engineering, Electronics, Computer Science, and related fields. It also focuses on enhancing technical proficiency and promoting professional ethics among its members. The section actively fosters camaraderie and facilitates knowledge exchange and collaborative endeavors on projects of mutual interest among its members and peers.

The process of certificate issuance is crucial for the IEEE Peru Section, as it documents users' engagement in significant conferences and workshops. These certificates enhance professional value by ensuring and substantiating the participants' acquired achievements and skills.

Requirements

Functional Requirements: Send data regarding certificates to the Blockchain network, check for a certificate's presence in the network, Establish and link APIs for user document submission, Receive data on the server, Generate Smart Contracts on the Blockchain network, Read the internal signature data on the certificate, Verify signatures for validating certificates, Store information related to certificates on the Blockchain, and Issue certificates each with a unique identifier.

Non-Functional Requirements: Resources will be stored in a default service queue, sent data will be stored as a string, The service automatically handles interpreted roles such as Administrator and Observer, Data will be stored in blocks identified by a hash, and The application will avoid storing any private data.

Use Case Model

The system engages directly with various stakeholders involved in the current Certificate Issuance process, including Organizational Unit, IEEE Peru Section (Issuer), and Participant (Recipient).

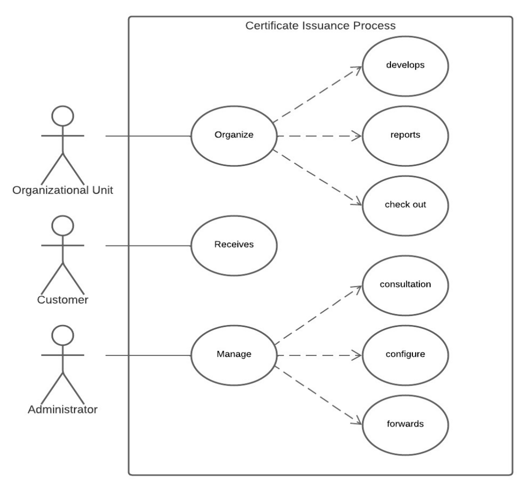

Figure 2: Use Case Diagram for the Certificate Issuance Process

4.2 Elaboration Phase

During this phase, a thorough analysis of the system requirements is undertaken, leading to a precise delineation of these requirements. Moreover, a robust architecture is crafted to serve as a foundation for the system's implementation. Noteworthy emphasis is placed on identifying and managing potential key risks, and the project's feasibility is assessed prior to advancing to the Construction phase. (Refer to Figure 3, Figure 4, Figure 5, Figure 6, and Table 2)

Solution architecture

The architecture of the solution serves as both a visual and conceptual depiction of the system's structure and design. It offers a glimpse into the system's components, their organization, and the interrelationships among them. The architecture elucidates how the system requirements are met and encapsulates the functionality of the system as a cohesive entity.

The structure and design of the system are elucidated, providing a panoramic view of the components encompassing the system, their organization, and the interrelationships among them. The architecture delineates how the system requirements are addressed and how it functions as a unified entity. (See Figure 3)

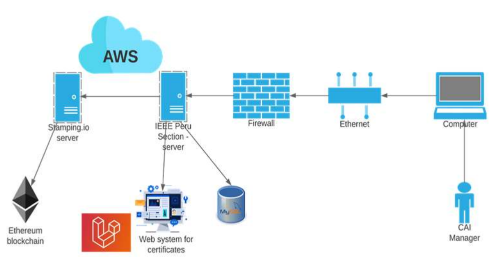

Figure 3: Solution Architecture

Stamping.io Platform Architecture

Figure 4 portrays a simplified rendition of the execution process on the Stamping.io platform.

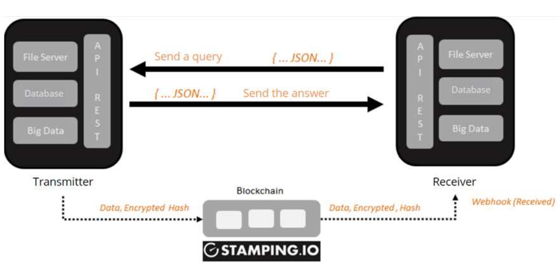

Figure 4: Architecture of Stamping.io

Service/System Architecture

Figure 5 showcases the perspective of each visitor to a Dapp, along with the interaction guiding them through the requests they initiate.

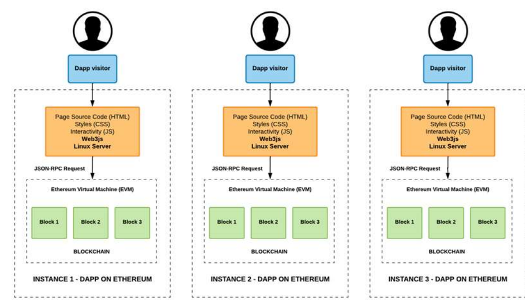

Figure 5: Architecture of a Decentralized Application

Tools

The tools and platforms used for the development of the system were: EC2 Amazon Web Services, Stamping.io, Laravel, Visual Studio Code, and Postman.

Database Model

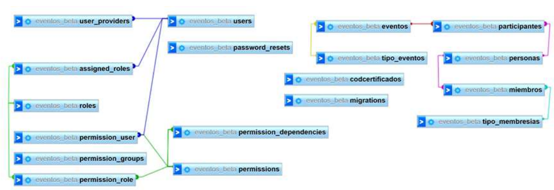

Figure 6: System Database Modeling

Certificate Data Model

Table 2 displays the associated model with the fields outlined in the Certificate.

Table 2: Certificate Data to be Issued.

Name	Variable
Code	cod_cert
Document Type	type_doc
Document Number	document
First Name	name
Last Name	lastname_1
Middle Name	lastname_2
Email	email
Participation	participant_es participant_en
Event Name	event

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Certificate Reason	reason_es reason_en
Issue Date	issued_es issued_en
Signatures	signatures

4.3 Construction Phase

In this phase, the system undergoes implementation, encompassing the majority of development work. Unit and integration testing are conducted, components are fine-tuned, and their adherence to the requirements set in prior phases is confirmed. (Refer to Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11)

Software Development Framework

Throughout the construction of the Laravel-based system, we employed various software development techniques honed during our university education. These techniques furnished a structured and efficient framework for software development.

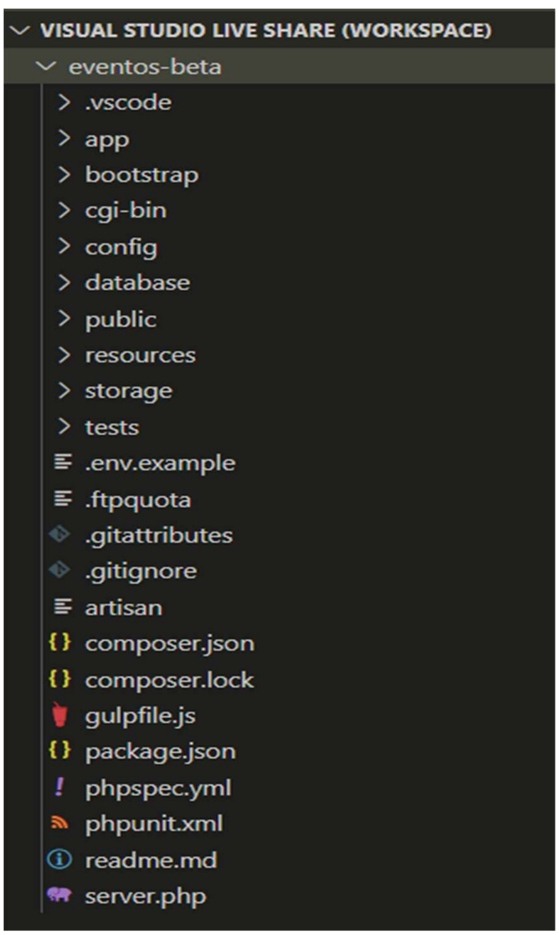

Figure 7: Project Structure

The use of the Stamping.io platform

Figure 7 shows the main platform that manages the transactions of each certificate.

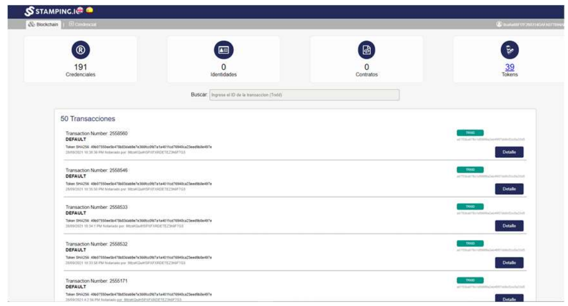

Figure 8: Transactions in Stamping.io

System Development

During the development stage, software is constructed and coded in alignment with the pre-established architecture. This phase encompasses the implementation of various system components, execution of unit tests, and integration of modules. Additionally, comprehensive technical documentation is generated, laying the groundwork for the ensuing Transition Phase.

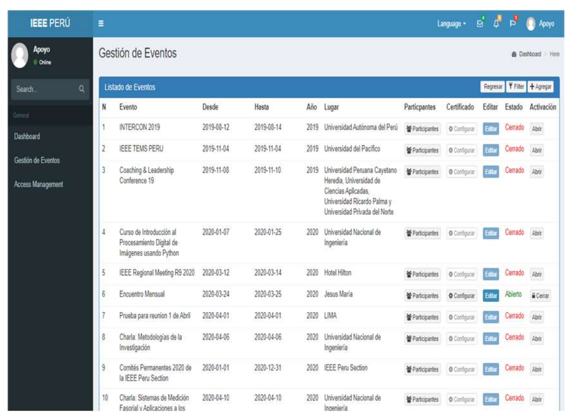

Figure 9: Event Records Visualization

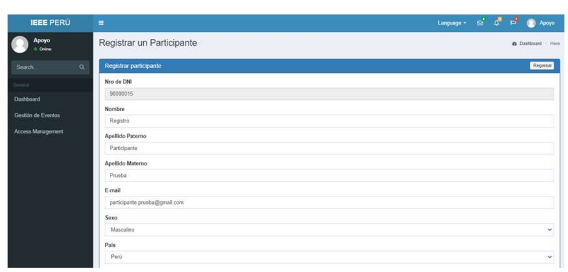

Figure 10: Participant Registration in an Event

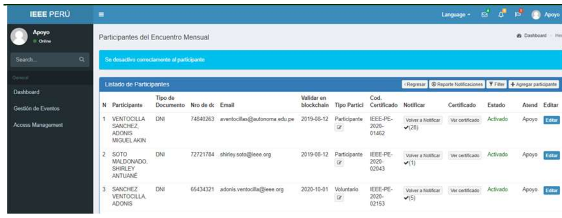

Figure 11: Display of Participants by Event

4.4 Transition Phase

In the Transition phase, the software development life cycle is concluded. In this stage, the final product is delivered to the client, and acceptance testing is conducted to ensure that the software meets the established requirements. Additionally, user training is provided to familiarize them with the system, and data migration is performed to ensure a smooth transition to the new system. During this phase, post-implementation support is provided to address any issues or inquiries that may arise. Finally, lessons learned are gathered to be applied in future projects and to continuously improve the software development processes. (See Figure 12 and Figure 13)

Deployment

Figure 11 exhibits a successful transaction completed within the Stamping platform, confirming the issuance of a Certificate.

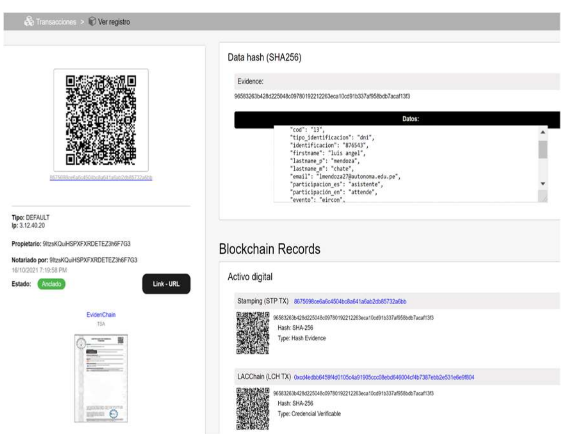

Figure 12: Stamping.io Transaction Anchored in the Blockchain with Certificate Data

Final Product Delivery

Figure 13 highlights the achieved goal of the project, which is to anchor each of the Certificates per event of the IEEE Peru Section in the Blockchain through the Stamping.io platform.

Figure 13: Certificate issued by the Blockchain in Stamping.io

5. EXPERIMENTS, RESULTS AND DISCUSSIONS

5.1 Results: Reduction of I_1, I_2, I_3 and increase of I_4, I_5

Table 3 showcases data collected from the Control Group (Gc) and Experimental Group (Ge) for each research indicator, utilizing the observation form as the data collection tool. The post-test displayed a 14.60% reduction in certificate issuance time compared to the average time. The time for searching and querying certificates saw a 24.84% reduction. Certificate issuance cost decreased by 15.60%. Certificate authenticity increased by 19.19%. Lastly, a 28.00% rise in customer satisfaction level was observed.

Table 3: Results of Post Test (Ge and Gc) of Indicators.

	I1: Average time for certificate issuance (min)		I2: Average time for certificate search and retrieval (min)		I3: Certificate issuance cost (PEN)		I4: Level of certificate authenticity (Likert scale)		I5: Level of customer satisfaction (Likert scale)	
No.	**Postest Gc**	**Postest Ge**	**Postest Gc**	**Postest Ge**	**Postest Gc**	**Postest Ge**	**Postest Gc**	**Postest Ge**	**Postest Gc**	**Postest Ge**
1	17	15	14	8	20	14	Disagree	Neither agree nor disagree	Neither agree nor disagree	I agree
2	17	16	17	16	40	32	I agree	I agree	Neither agree nor disagree	Neither agree nor disagree
3	15	13	12	10	35	29	Totally agree	Totally agree	I agree	Neither agree nor disagree
4	18	14	17	16	40	34	Disagree	I agree	Totally agree	Totally agree
5	15	12	20	14	25	18	Disagree	Neither agree nor disagree	Neither agree nor disagree	I agree
6	16	14	17	12	60	52	Disagree	I agree	Neither agree nor disagree	I agree
7	15	12	16	8	55	47	Disagree	I agree	Neither agree nor disagree	Totally agree
8	19	17	19	12	25	19	I agree	I agree	Totally agree	Totally agree
9	15	12	18	13	25	18	Neither agree nor disagree	I agree	Disagree	I agree
10	15	14	11	9	10	9	I agree	Totally agree	I agree	Totally agree
11	17	16	15	10	30	27	Disagree	Neither agree nor disagree	Neither agree nor disagree	Totally agree
12	16	15	19	12	15	9	Totally agree	Totally agree	I agree	Totally agree
13	17	13	12	10	50	46	I agree	I agree	Neither agree nor disagree	I agree
14	14	15	16	15	45	41	Totally agree	Totally agree	I agree	I agree
15	20	17	10	9	25	18	Neither agree nor disagree	I agree	I agree	Totally agree
16	17	15	12	10	25	19	Disagree	I agree	Neither agree nor disagree	I agree
17	15	14	16	12	55	48	I agree	I agree	Neither agree nor disagree	I agree
18	17	12	13	10	40	39	I agree	Totally agree	Neither agree nor disagree	Totally agree
19	15	13	15	12	20	14	Totally agree	Totally agree	Disagree	Neither agree nor disagree
20	20	18	19	19	30	35	Disagree	Neither agree nor disagree	Neither agree nor disagree	Neither agree nor disagree
21	14	11	15	12	50	44	Neither agree nor disagree	I agree	I agree	Totally agree
22	16	15	10	8	30	26	Disagree	I agree	I agree	Neither agree nor disagree
23	19	15	15	10	60	55	Disagree	Neither agree nor disagree	I agree	Totally agree
24	19	16	12	9	45	39	Neither agree nor disagree	I agree	I agree	Totally agree
25	17	14	20	16	20	14	Disagree	Neither agree nor disagree	Neither agree nor disagree	I agree
26	13	9	18	8	45	38	Totally agree	Totally agree	Neither agree nor disagree	Totally agree
27	17	12	13	7	45	39	Totally agree	Totally agree	Neither agree nor disagree	Totally agree
28	15	14	18	13	55	48	Neither agree	Totally agree	Disagree	Totally agree

							nor disagree			
29	18	15	19	17	30	26	Disagree	Totally agree	I agree	I agree
30	16	13	11	9	45	40	Disagree	I agree	Neither agree nor disagree	I agree

During the research, the technique of direct observation was utilized, employing a stopwatch and cost calculations as measurement instruments. This technique facilitated the acquisition of precise and detailed data regarding the Certificate Issuance process within the IEEE Peru Section. Moreover, the statistical software Minitab was used for analyzing the collected data. The utilization of Minitab enhanced statistical assurance and provided ample evidence in the results, bolstering the validity and reliability of the research findings.

5.2 Normality Test

A normality test was conducted to determine whether the data sample follows a normal distribution. This test is based on comparing the observed values with the expected values under the assumption of normality. In this research, the Anderson-Darling test was specifically used to assess the normality of the data.

I_1: Average time for certificate issuance.

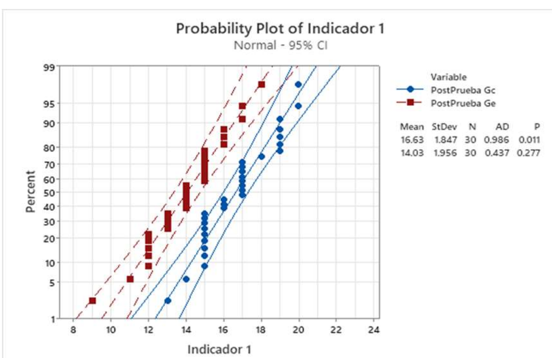

Figure 14: Normality Test for I_1

The results indicate that the values of the indicator exhibit a normal behavior. For indicator I1, both in the PostTest of Ge and the PostTest of Gc, the p-value (0.011 and 0.277) is greater than α (0.05).

I_2: Average time for certificate search and retrieval.

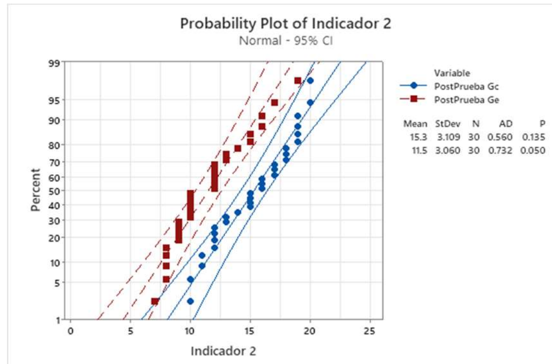

Figure 15: Normality Test for I_2

The results indicate that the values of the indicator exhibit normal behavior. Specifically, for indicator I2, in the Post-Test of Ge and the Post-Test of Gc, the p-value (0.135 and 0.50) is greater than α (0.05).

I_3: Cost of certificate issuance.

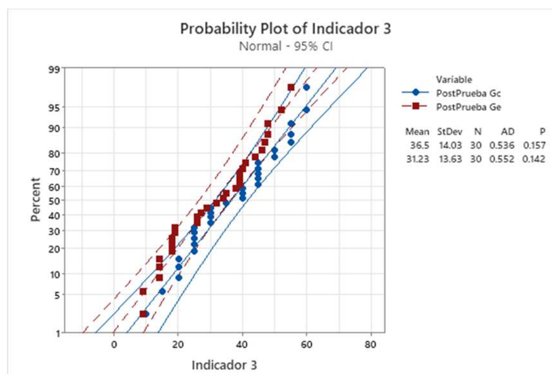

Figure 16: Normality Test for I_3

The results indicate that the values of the indicator follow a normal distribution. This is supported by the fact that for indicator I3, in the Post-Test of Ge and the Post-Test of Gc, the p-value (0.157 and 0.142) is greater than α (0.05).

5.3 Discussion: Effect on Certificate Issuance for Technological Organizations

Using Descriptive Statistics

Table 4 showcases the outcomes of the descriptive statistics for each indicator, as acquired

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through the utilization of the statistical software Minitab.

Table 4: Results with descriptive statistics of the quantitative indicators.

Sample	n	Mean	StDev	AD	p-value
I_1: Post-test (Gc) - Time	30	16.63	1.85	0.986	0.011
I_1: Post-test (Ge) - Time		14.03	1.96	0.437	0.277
I_2: Post-test (Gc) - Time	30	15.3	3.109	0.560	0.135
I_2: Post-test (Ge) - Time		11.5	3.060	0.732	0.050
I_3: Post-test (Gc) - Cost	30	36.5	14.03	0.536	0.157
I_3: Post-test (Ge) - Cost		31.23	13.63	0.552	0.142

Based on the "Anderson-Darling" normality test outcomes, the AD and p-value exceeding (0.05) suggest the data adheres to a normal distribution, suitable for subsequent analysis. With a 95% confidence level, the consistent results in the research indicators' data are reflected through the observed mean and standard deviation.

Table 5: Summary of Results for the quantitative indicators.

Sample	n	95% confidence intervals for the mean	Kurtosis	Asymmetry	Q_3
I_1: Post-test	30	13.303 min	0.342124	-0.286769	15.000
I_1: Post-test		14.764 min			
I_2: Post-test	30	10.375 min	-0.308858	0.684564	13.250
I_2: Post-test		12.693 min			
I_3: Post-test	30	26.142 S/.	-1.22723	-0.05683	41.750
I_3: Post-test		36.325 S/.			

The summary in Table 5 demonstrates that about 95% of values are within two standard deviations from the mean. Kurtosis reveals low peaks, indicating a fairly uniform distribution. The skewness suggests a left-skewed distribution with most values being low. The third quartile (Q3) shows that 75% of values are at or below this point, indicating a concentration of lower values in the sample.

For indicator I_1: The results were similar to those of [5], who found in their research "Framework based on Blockchain for verification of educational certificates" that the average time to issue a certificate in select educational institutions was significantly shorter in the Ge (8 minutes) compared to the Gc (21 minutes). Additionally, in [17], a significant reduction in the time to issue certificates was observed in the Ge (10 minutes) compared to the Gc (35 minutes). These findings are similar to the results found in [16], where the time to issue certificates was optimized using an LMS system, with an average time of 10 minutes in the Ge, compared to 25 minutes in the Gc. Similarly, [11] emphasized the reduction in time through the use of efficient blockchain-based networks, with an average time of 7 minutes in the Ge compared to 15 minutes in the Gc.

For indicator I_2: The results obtained in this study are consistent with previous research. In the study by [15], it was found that the average time for searching and querying certificates in the Ge was significantly shorter (7 minutes) compared to the Gc (11 minutes). Additionally, in [16], a significant reduction in the time for searching and querying certificates was

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observed in the Ge (13.5 minutes) compared to the Gc (18 minutes). These findings are similar to the results found in [18], where Blockchain was implemented in the distributed systems course, with an average time for searching and querying certificates of 15 minutes in the Ge compared to 30 minutes in the Gc. Similarly, [14] demonstrated a significant decrease in the time for searching and querying certificates in Vietnam, with an average time of 5 minutes in the Ge compared to 14 minutes in the Gc using a blockchain-based authentication system.

For indicator I_3: The results obtained in this study are consistent with previous research. In the study by [6], it was found that the cost of issuing certificates in the Ge (34 soles) was lower compared to the Gc (40 soles) using blockchain technology. Additionally, in [11], a significant difference in the cost of issuing digital certificates was observed, with lower cost in the Ge (29 soles) compared to the Gc (32 soles). These findings are similar to the results found in [16], where certificates were validated using blockchain, and it was found that the cost of issuing certificates in the Ge (78 soles) was significantly lower compared to the Gc (93 soles).

With Inferential Statistics

Table 6: Hypothesis testing for quantitative indicators.

Sample	n	H_0	t-value	p-value
I_1: Post-test _ min/cert	30	µ1 < µ2	5.29	0.00
I_1: Post-test _ min/cert				
I_2: Post-test _ min/cert	30	µ1 < µ2	4.77	0.00
I_2: Post-test _ min/cert				
I_3: Post-test _ cost/cert	30	µ1 < µ2	1.47	0.023
I_3: Post-test _ cost/cert				

Table 7: Hypothesis testing for qualitative indicators.

Sample	n	H_0	w-value	p-value
I_4: Post-test _ likert	30	µ1 > µ2	752.00	0.016
I_4: Post-test _ likert				
I_5: Post-test _ likert	30	µ1 > µ2	653.50	0.000
I_5: Post-test _ likert				

Due to all p-values being less than (0.05), the results provide sufficient evidence to reject the null hypotheses (Ho), and the alternative hypotheses were supported. The tests turned out to be statistically significant.

6. CONCLUSIONS AND FUTURE RESEARCH

The burgeoning expansion of Blockchain-centric resources has propelled the Peru Section of IEEE towards embracing this avant-garde technology via the deployment of a robust computing system. This system, grounded in a decentralized Blockchain network, meticulously catalogues participant certificates, ushering in heightened security. The amalgamation of Blockchain technology within the Certificate Issuance paradigm has yielded notable advancements. Present-day tech entities are poised to weigh the adoption of Blockchain, not merely for its contemporary essence but the formidable security apparatus it bestows. The fruition of smart contracts, once deemed elusive, has been realized through Blockchain's advent, facilitating the seamless automation of contractual engagements sans the necessity for trusted intermediaries.

In essence, employing Blockchain technology in the Certificate Issuance process has yielded positive outcomes for the Peru Section of IEEE. Yet, avenues for enhancement and exploring fresh applications in the tech sphere remain. Such forward strides will amplify Blockchain technology's advantages, ensuring proficient and secure oversight of distributed certificates.

For ensuing endeavors, the suggestion is to assimilate more robust and succinct indicators within the devised solution, aiding short- to medium-term decision making. Delving into Agile methodologies could expedite and flexibilize decentralized application development, accommodating evolving requisites. Broadening the implementation of the proposed solution to other tech entities is encouraged, alongside further explorations into Blockchain and smart contract lexicons for proactive certificate management.

Enhancing Blockchain network management is recommended to preserve decentralization and bolster data security. Additionally, it is proposed to develop and optimize specific blockchain protocols for certificate issuance, improving the efficiency and security of the involved web systems; the integration of robust APIs that allow a smooth interaction between web systems and blockchain technology, thus facilitating the issuance and verification of certificates; and the development of dedicated web platforms for the verification of certificates issued through blockchain, providing an easy-to-use interface to validate the authenticity of the certificates.

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