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Towards a Blockchain-based Smart Certification System for Higher Education: An Empirical Study

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Abstract: Due to the growing interest in distributed ledger technologies such as blockchain, researchers in different areas, including the higher education sector, are investigating possibilities surrounding blockchain adoption. Despite this, no guiding framework has been developed for the application of blockchain and related technologies in the use of certificating systems that issue sharable and authentic student credentials. Existing certificating systems are marked by their lack of speed and low reliability and, in certain education systems, they produce social and cultural conflicts. Therefore, this paper offers an analysis of blockchain adoption in this field, focusing especially on the process of producing and sharing higher education certificates. The paper describes the second phase of an ongoing research project by presenting a certificate validation and sharing framework that guarantees authenticity through leveraging the privacy and security features of a blockchain network. The framework also covers the architectural design of a blockchain-based certificating system to solve problems and offer solutions in the context of higher education. Two groups of participants are also included in an empirical study focusing on an evaluation of the proposed framework in relation to its ability to describe and explain blockchain adoption in higher education. The validity and reliability of the framework is tested using a sequential mixed methods design involving the collection of quantitative survey data. It is expected that the proposed framework will have useful applications in different fields where it is necessary to determine whether a satisfactory level of blockchain technology has been maintained in accordance with relevant privacy and security standards. Finally, this study is about attitudes towards the technology and theory of acceptance by users, students and prospective employers, rather than a technological development study.

Keywords: Blockchain adoption, Distributed ledger technology, Higher education institution, Certificates, Decentralised application, Universal modelling language, Trust, Efficiency, Blockchain Adoption Framework

1. Introduction

Blockchain technology has had a powerful impact in various fields in the last few years. Blockchain is a novel innovation that offers a new paradigm for data integrity, reliability and authenticity in the financial industry and beyond. Recently, the education sector has emerged as one of the fields in which investments for blockchain-based systems and services are desirable.

Studies [1], [2] have noted that the major motivation to deploy blockchain in various fields is that it is considered a trustworthy technology that removes the centralisation barrier in transactions between network participants in various industries. In this way, blockchain eliminates the need for a central authority to store and approve network transactions. For this reason, deploying blockchain in the higher education sector is expected to be beneficial as it solves some existing issues, such as printed certificate fraud, cost of issuing certificates and time consumed to verify issued certificates [3]. However, the extant literature lacks a guiding framework for the integration of blockchain and other relevant technologies in the use of certificating systems that issue authentic and sharable student credentials.

This ongoing research aims to build decentralized application for smart certification (DASC) and investigate the acceptance of this system in the scope of higher education in Saudi Arabia. The system objectives are the following: 1) to record student data that may include registered courses, credits, skills and badges; 2) to share student data with authorised parties (e.g., college and university administrators and prospective employers), 3) to help HIEs share data about students' skills and abilities, 4) to help academic instructors easily design and implement unique teaching

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methods that match student needs, 5) to serve as a single repository of information that consolidates students' digital certificates, transcripts and achievements (i.e., badges) from educational institutions. Finally, is to enable students to keep authentic records for all their accreditations, which they then can use as a permanent e-portfolio. This application (DASC) will be tested on the later phase of this research and another work will be used to publish the results.

This paper addresses the concepts and existing literature of blockchain technologies and briefly offers an analysis of blockchain adoption in higher education systems. Moreover, it presents a framework that is tested for the integration of blockchain and other relevant technologies into the Higher Education certificating system for issuing authentic, verifiable, and sharable student credentials. Thus, the findings from this study evaluate the potential of acceptance of blockchain technology as a viable solution to provide the higher education systems with the concept of smart certificates in the certification process. Finally, the paper proposed a complementary modelling approach for decentralised applications for smart certificates (DASC) in which blockchain distributed technology emerges in the context of higher education.

The structure of the paper's sections is as follows, in section 2, blockchain technology background and related studies on the higher education field are discussed. Then, section 3 presents the proposed Framework and Research Hypotheses with the suggested influential factors. After that, in section 4 the research methodology with the main research instrument's findings and details are described. Then, the discussion part of the study result is presented in section 5. Subsequently, in section 6, the proposed solution aligned with the study's findings are explained. The research limitations of this study, as well as recommendations for future studies, are presented in section 7, followed by our conclusions in section 8.

2. Background

This section presents some relevant background information related to the development of the Blockchain technology revolution, the Blockchain technology adoption in Education sector, the digital credentialing systems, and the Notarisation Blockchain Use Case.

A. Blockchain Revolution

Blockchain can be considered a revolutionary development. It is defined as a distributed record of digital events stored across all participating computers in a linked chain [4], [5]. According to Chen et al., blockchain technology is considered the fourth industrial revolution after the invention of the steam engine, electricity and information technology, and it has been called 'the Internet of Value Exchange' [6]. Contrary to what most people believe, the use of blockchain is not limited to crypto currencies and finance because it also considers, but is not limited to, other applications [7], [8]. Perhaps one of the most common applications is supply chain management [2], though the authors have also considered blockchain in societal, political and other general applications and, of course, education [6], [9], [10], [11]. A classic blockchain application example, however, is bitcoin, which is not equivalent to blockchain; it is simply a blockchain-based application that has been developed [12]. Hence, one of the most important research issues that has arisen recently is the need to focus on other blockchain applications in different fields.

As per Chen et al., blockchain has revolved over three stages, Blockchain 1.0, 2.0, and 3.0. The first stage is the most famous application of blockchain, crypto currency, (e.g., bitcoin) [6], [13], [14]. Bitcoin had been very well known as the blockchain application over any other applications, sometimes it is referred to as the blockchain itself [15]. Zheng et al mentioned that bitcoin market volume was over 10 billion USD in 2016 and was the most exchanged crypto currency over others [16]. In the second stage, Blockchain 2.0, applications over other financial aspects had been developed in stocks, bank cash transactions, loans, and smart contracts. In the third version of the blockchain, Blockchain 3.0, applications of bitcoin have been evolved and extended to cover many other different fields like education, health, and governments [6], [13], [14]. Overall, all three stages have shown the powerful impact of using blockchain as DLT in various fields and domains.

The three main types of blockchain are public (permission less), private (permissioned) and consortium blockchains [13], [17]. In a public blockchain, any participant can access and add to the chain, and all nodes are allowed to join the blockchain network; examples include the Bitcoin and Ethereum blockchains [18]. Private blockchain is a centralised network that is controlled by only one organisation; only a predefined list of participants can access and make transactions in the chain. Consortium blockchain is a combination of public and private blockchains; the participants operate as predefined nodes that can use and participate in the distributed consensus process [13]. Private and consortium blockchains are both considered permissioned blockchains because they are not open for use by any nodes other than invited ones.

The blockchain revolution has gained great importance in both industry and academia owing to its beneficial characteristics, which can be used in various fields. Different studies have noted that blockchain technology has four main characteristics: transparency, immutability, decentralisation and traceability [19]. Sharples et al. also note that one of the major reasons for using blockchain is its ability to offer services and transactions that are characterised by trustworthiness, anonymity, authenticity, reliability and accessibility [20]. Blockchain-based systems have high capability to store more data and share resources amongst all participants; Turkanović et al. describe such systems as flexible, secure and resilient [13]. Most features of blockchain technology are related to providing transparent and secure applications. Blockchain technology helps protect data from being tampered with and provides many other features that can solve various system problems [21].

Like any other system, blockchain technology has many benefits and on the other hand, it comes with challenges that needed to be resolved in order to make it more suitable for different fields. One main challenge is the scalability of a network to transfer a huge amount of data. According to Reyna et al., the limitation of ability to process huge transactions is considered as a major issue as the amount of data to be transferred is increasing rapidly with time, this is clear as an example in bitcoin exchange as data increase by 1 megabyte per block every 10 minutes [22]. Moreover, Zhang et al. added about Ethereum public blockchain has a limited capacity of data to process in order to protect from exposure of data through infinite looping [23]. Many research and studies discussed security as the main advantage of adopting blockchain technology. However, other studies concluded that the security criteria is an obstacle in front of developing blockchain technology [15], [24]. Users can preserve their privacy and security in both private and public blockchain system processes. However, Kondor et al. [24] argued that privacy and security could not be guaranteed because data of the transactions can be exposed by public users.

According to Gartner, in supply chain management systems, the benefits of using applications based on blockchain reside in operations such as goods traceability, tracking counterfeit items or efficient paperwork handling [25]. From this perspective, various large and powerful companies around the world have started to conduct their supply chain systems based on blockchain technology. As examples, Walmart, IBM and Nestle are among these companies that already started their researches to deploy blockchain technology into their systems to improve their process and performance [26], [27].

B. Blockchain in the Education Sector

Turkanović et al. [13] state that different higher education institutions (HEIs) in different countries are considering the adoption of blockchain technology as an aid in designing approaches and solutions for higher education. Several of these systems and solutions have adapted the bitcoin and Ethereum blockchain-based technology. Blockchain technology has been adopted predominantly in various domains and fields because of its accessibility, auditability and distributed storage benefits [13]. Given that the blockchain solution distributes academic records based on an operation decentralized approach, it is associated with significant promise in terms of offering enhanced support for all such processes. In certain cases, when access to university systems or credentials is lost, it is complex for students to substantiate skills and experience. Furthermore, academic certificates typically transcend national borders and, in this way, serve as internationally recognized proof of the certificate owner's knowledge, skills, and abilities [28].

From a technology perspective, the use of Internet-based platforms for higher education processes is not novel. For example, over the past ten years, massive open online courses (MOOCs) have emerged as a core feature of the educational landscape [29]. As the report indicates [29], approximately 7,000 MOOCs are currently available for students across over 700 universities, and there are now around 58 million students enrolled in these programs. As such, since their initial deployment in 2006, MOOCs have become established as a widely-used aspect of the distance learning paradigm [30]. When it comes to exploring online educational technology, MOOC has shown a great impact and has been part of the educational landscape for nearly a decade that considered one of the most distinguished ways for simplifying education sector.

In the education sector, most challenges arise because of the sensitivity of students' academic records and the complexity of management regulation [13]. All data can be recorded and shared with a network of need-to-know parties, including school administrators and prospective employers. Jirgensons et al. show that using blockchain technology may help modernise traditional academic transcripts in HEIs [31]. As noted by Sharma et al., the benefits of using blockchain in Indian education systems include reducing the amount of public spending, enriching and increasing opportunities for the employment of graduates and enlarging the collaboration between public and private sectors in the hiring process [32]. In fact, the above features of blockchain enable new and innovative applications across many fields and environments.

The recent global trend has been to adopt blockchain in different fields owing to its tremendous impact. As Masaaki Isozu, President of Sony Global Education, stated, 'Blockchain technology has the potential to impact systems in a wide variety of industries, and the educational sphere is no exception when educational data is securely stored on the blockchain and shared among permissioned users' [33]. The higher education sector is considered a promising field in which to adopt new technology because of its complicated transactions and the sensitive nature of the data to be processed. Accordingly, adopting blockchain for some vital processes, such as generating learner certificates, could greatly enhance educational outcomes.

Jirgensons et al. [31] indicate that in the United States, MIT Media Lab is the only institute that has established and developed a complete education credentialing system based on blockchain technology. The MIT team depends on the bitcoin framework instead of on Ethereum to develop the credentialing system. Seeing the bitcoin as a stronger technology than Ethereum to hold the transactions was the reason for their selection [28]. Blockcerts have been developed and are known as an open standard for creating, publishing, viewing and validating blockchain-based certificates. Many digital records are registered on the blockchain; they are cryptographically signed, tamper-proof and shareable. The goal behind innovation is that it raises the capacity of the individual's achievements and enables the sharing of official records [34].

The European Credit Transfer and Accumulation System (ECTS) is that concept which is based on the global blockchain and developed with the higher education credit platform named as EduCTX. The planned system is utilized by the advantage of the blockchain system which is, decentralized architecture, anonymity, offering security, longevity, transparency, immutability, and global simplifications. In this regard, there is the creation of the international trusted credentialing system for the higher education institutes [13]. Currently, most HEIs maintain a student's complete course records and transcripts in institute-specific, customised formats. HEI databases are designed and structured such that they can only be accessed by the given institution's staff members through a secure online system with no or very little interoperability with other systems. Educational institutions also tend to adopt specialised systems to maintain course records so they can preserve and secure the proprietary structure of the data in the database. When students apply for career opportunities in foreign countries and have to present their academic degrees and achievements in different languages and against different scoring standards, they face the challenge of having to use course records that are centralised, non-standardised and inaccessible.

C. Digital Credentialing Systems

Credentialing systems are HEI systems used to generate and manage student and alumni certificates, degrees and other achievements and rewards. These types of documents are necessary for university alumni to get jobs that match their degree. With the many issues currently facing university credentialing systems, digitising this process is an ideal way to solve the issues and seize some great opportunities. Existing credentialing systems use analogue operations to manage certificate generation. These systems are slow and unreliable and, in some cases, may raise other cultural and social issues depending on the context of the education system. Creating a digital infrastructure for certificate-generating systems provides an important opportunity to take advantage of many promising new technologies such as blockchain. Nevertheless, as such systems are dealing with highly sensitive data and represent an HEI's professional reputation, both need to be assured. When choosing an appropriate technology, decision makers should have a full awareness of technology design and characteristics in order to guarantee trust in the control of such an important system.

In recent months, according to Apurv [35], there has been increasing interest amongst many HEIs in using blockchain-based digital certificates. The adoption of blockchain technology can help build a certification infrastructure that enables students to control the complete record of their achievements. Thus, it would help the students to have full access to their awards and certificates even in the case where the issuing institute no longer exists [36]. Furthermore, students can share their credentials with other universities and prospective employers while being assured that they will be sharing this information with trusted parties only [35]. Although adopting blockchain technology will offer a number of opportunities to improve on currently used credentialing systems, using the technology does not offer a straightforward process to help overcome all the challenges facing credentialing.

D. Notarisation Blockchain Use Case

In [37], Eric W. reports that blockchain use cases have extended into different fields and domains and are no longer focused only in finance crypto currency. Notarisation is one example of a promising blockchain technology use case that applies blockchain. It is defined as the process of preventing any document's fraud and dishonesty, thus promising all the participants a document that is authentic and trustworthy. Notarisation is a process that authenticates documents and is usually, in most countries, an act executed by the 'notary public', who is responsible for ensuring the authenticity of the document and the signature and that the signer acted without pressure or intimidation. Moreover, notarisation helps fully apply the terms and conditions of the certified documents [38]. The immutability feature of blockchain technology prevents any edit or deletion of records; hence, it is an ideal technology to implement a notarisation process. Given that a blockchain record of a document is immutable, it implements the notarisation mechanism as proof of the authenticity of the document. Blockchain also inherits the concept of decentralised technology that does not rely on a third party who has authority and control, which further enhances the user's trust towards the documents stored on the blockchain (which is in effect the notary public).

As stated by Kirikov in [39], it is highly recommended to automate the process of verifying academic documents and digitally store proceedings of authenticated documents and signatures. In this way, we can guarantee them to be safe from future frauds and manipulations. In the context of biomedical applications, Kleinaki et al. conclude their work of a blockchain-based database query notarisation service by finding the huge benefits that could provide additional functionalities, such as developing the system to improve retrieved results over time [40].

3. Framework and Research hypotheses

This section maintains the research framework with more details about the affected factor that will be examined throughout this study. As stated above, the current situation of generating and validating students' certificates on higher education is still a manual process that depends on hard copy certificates. The main aim of this study is to evaluate the adoption of blockchain technology in the certification process of the higher education sector. In the manner of technology adoption, we describe the process that starts with the user's awareness of the technology and ends with the user embracing the technology and taking advantage of it. We then articulate the factors affecting the adoption of

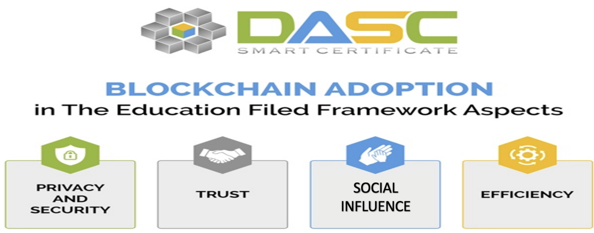

Figure 1. Blockchain Adoption Framework Factors

the decentralised technology, especially blockchain, in the process of generating and validating students' certificates. The next step of this study is to collect the user feedback and testing result of the prototype.

A. Blockchain Adoption Framework and Influential factors

The below framework in Fig. 1 illustrates the main influential factors towards adopting blockchain technology in the higher education sector that we will be testing in the coming work of this research. Mainly, it is about evaluating the certificates issuing system (i.e., DASC). It represents four main factor categories that reflect the essential requirements for the system to be adopted.

Trust: Understanding the meaning of trust involves complications as it is influenced by several quantified and non-quantified properties. In the manner of accepting and using new technology, trust plays a very important factor.

Security and Privacy: Various literature studies have argued that the main reason for embracing blockchain technology is for its security characteristic. However, multiple studies have also demonstrated that security is one of the disadvantages of adopting blockchain technology. Halpin and Piekarska state that the privacy and security of blockchain are the rich emerging fields that are critical requirements for further research [41]. Garcia-Font noted in [42], that identity management is a fundamental part of ongoing blockchain research. At present, almost all major authentication systems depend on the use of usernames and passwords, which is associated with several critical disadvantages and risks. The use of blockchain technology can mitigate many of these disadvantages, promote privacy and security, decentralize the storage of identifiers, and – perhaps most importantly – enable effective identity management to be achieved without the need for conventional username and password-based authentication systems [42].

Social Influence: In the blockchain field, social influence may expand to the user's perception of a service provided by the technology that is highly influenced by other fields and domains' perceptions about adopting the technology. In [43], the unified theory of acceptance and use of technology states that social influence is one of the main four factors that affect the user's decision towards technology adoption.

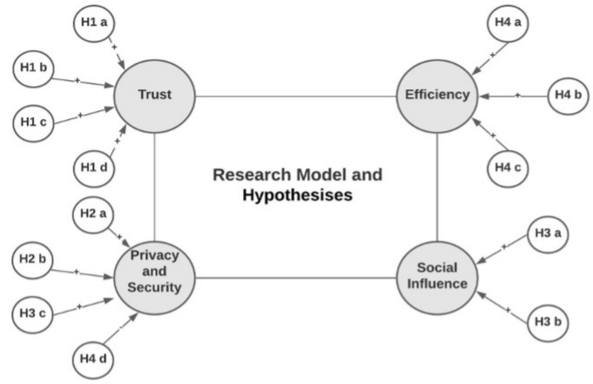

Figure 2. Proposed Research Model

Efficiency: By utilising the blockchain technology, any transaction can be efficiently completed in the decentralised environment. Therefore, it reduces overall cost and enhances transactions efficiency. Moreover, using blockchain decreases the value of transaction fees and the time required to execute the transaction [17].

As stated by Garcia-Font in [42], reducing paper-based work, lower the process's associated administrative costs, and increase the efficiency in routinary processes involving multiple parties are considered as the purposes for several blockchain projects among various fields. Thus, we consider studying the effect of efficiency as a factor in the process of adopting blockchain in higher education.

Finally, these factors are not the only considerations when it comes to examine the acceptance of new technology in the sensitive field such as higher education.

B. Proposed Research Model

To examine the importance of the mentioned factors on the adoption of Blockchain technology, a research model has been proposed that draws from the diverse research on adoption and theoretically tested by the provided empirical study. The model is illustrated on Fig. 2 that shows all the suggested factors with related research hypotheses that are descried in the following section 3-C.

C. Research Question and Hypotheses

To evaluate the system and obtain user feedback, the research hypotheses were distributed across four main factors. The framework shown below illustrates these factors and their influence on the adoption of blockchain technology in the higher education sector. The main object of concern is the evaluation of the proposed certificate issuing systems the dApp for Smart Certificates (**DASC**). This will also be designed along with the main research question to address in this study. In this phase of the research, the following research question is considered:

RQ: How can Blockchain system improve the efficiency of generating academic certificates in the Saudi Arabian higher education systems?

The authors in [43] observed that trust is a major factor that has been investigated in studies of the adoption of technologies that involve handling, storing, or processing sensitive information. Enabling employers and students to have a trustworthy and transparent system, as in a blockchain-based system, would drive the adoption process among higher education institutions. Therefore, we propose several hypotheses, which are presented below.

Hypothesis 1: In the certification process in the higher education sector, an increase in the level of trust toward blockchain technology will increase users' intention to adopt it, given that trust is considered a major determinant of user acceptance.

H1a: Blockchain technology functionality and transparency positively influence user trust toward blockchain adoption in the certification process.

H1b: User knowledge and familiarity about blockchain positively influence user trust toward blockchain adoption in the certification process

H1c: Easy access and convenient sharing of student credentials positively influence user trust toward blockchain adoption in the certification process.

H1d: Trust in applicants' accreditations positively influences employers' decisions toward blockchain adoption in the certification process.

In education, preserving the privacy of students' sensitive information plays an important role, especially when sharing personal and confidential data with others [44]. Due to the definition and features of blockchain technology mentioned above, it is possible to ensure security and privacy.

Hypothesis 2: In the certification process in the higher education sector, an increase in the level of privacy and security provided by blockchain technology will increase users' intention to adopt it, given that this allows for better maintenance of student certificates.

H2a: The privacy of student certificates positively influences users' intention to adopt blockchain technology in the certification process.

H2b: The possibility of eliminating certificate fraud and dishonesty positively influences users' intention to adopt blockchain technology in the certification process.

H2c: The security features of blockchain technology (immutability, security, and reliability) positively influence users' intention to adopt blockchain technology in the certification process.

H2d: The perception of low risk associated with the use of blockchain technology positively influences users' intention to adopt blockchain technology in the certification process.

According to Venkatesh et al., [43], researchers who have studied theoretical models consider social influence to be one of the major extrinsic motivators for technology acceptance and use in different contexts. Hence, studying aspects of the impact of social influence and user awareness is essential to an examination of the adoption of innovative technology, especially when it relates to critical processes such as generating student certificates in higher education.

Hypothesis 3: In the certification process in the higher education sector, level of positive social influence is positively associated with users' intention to adopt blockchain technology.

H3a: Positive social influence positively influences users' intention to adopt blockchain technology in the certification process.

H3b: User awareness positively influences their intention to adopt blockchain technology in the certification process.

Garcia-Font [42] reported that most academic certification systems are still paper-based, which means that verifying their authenticity is typically inefficient. Moreover, other considerations, including time and cost, are significant in the current process of verifying paper-based certificates to prevent manipulation and dishonesty. Providing higher education institutions with a system that functionally validates the authorized holder's certificates with less cost and time could eradicate doubts about certificates.

Hypothesis 4: In the certification process in the higher education sector, an increase in the level of enhanced efficiency and reduce the associated cost in Blockchain technology will increase users' intention to adopt it.

H4a: Information transparency enabled by blockchain technology positively influences the efficiency of the certificating process.

H4b: Cost reduction provided by blockchain technology positively influences the efficiency of the certificating process.

H4c: Blockchain-driven cost reduction, information transparency, and improved efficiency in generating student certificates positively influence users' intention to adopt blockchain technology in the certification process.

Finally, this study concentrated on an investigation of the effect of the above-mentioned factors, the research question, and the research hypotheses. The focal point was to examine the utility of the proposed framework for adopting blockchain in the certification process and to examine its

TABLE I. THE STUDY'S MAIN PARTICIPANTS CATEGORIES

Label	Description
Category 1	Higher Education Students
Category 2	Prospective Employers

applicability to a variety of other processes in the higher education sector. Therefore, testing the research hypotheses is necessary to determine whether a satisfactory level of blockchain technology has been achieved and maintained in accordance with the relevant standards in terms of trust, acceptance, and security.

4. Methodology

This section we discuss how we empirically tested the hypotheses of this study and the proposed research model shown in Fig. 2 An online questionnaire was distributed among higher education students and prospective employers. The student questionnaire was designed to be answered among students in Saudi Arabia Universities, specifically in the universities in Riyadh, the capital city of the country. This survey covers different aspects such as demographic information, technology awareness, current process situation and factors effected the adoption of blockchain in certificating process in Saudi Arabia. The study contains two main categories of participants employer and higher education students (see Table I). The prospective employer is included because they provide the primary drive for this study due to the pressure, they can impose to encourage higher education institutes to adopt blockchain technology to facilitate their process of validating candidates' credentials.

Nevertheless, this study is considered as a preliminary stage in analysing the study's findings where more deep analysis and investigations will be considered in later stages of this research.

For the student's sample, the data were collected from higher education students in various schools such as Science, Technology and Engineering, Business and Economics and Humanities and Art. The study focuses on senior students in their last year (fourth and fifth year) of their study for which issuing their certificate and maintaining their qualifications are main concerns.

For the prospective employer's sample, the data were collected among randomly selected employers from a list of companies working in Saudi Arabia in many fields such as telecommunications, industrials, and IT. The employers who are participated on the study, were selected by the researchers form a well-known website (maroof.sa), which is collaborating with the Saudi Ministry of Commerce.

A. Survey

The six-sections questionnaire consisted of a series of structured items. Socio demographic data were obtained using the items in the first section of the questionnaire, focusing on each participant's gender, age, educational background, and area of specialization. The focus of the second section was each participant's awareness of blockchain technology and the process of generating certificates for educational purposes. The final part of the questionnaire, which encompassed four sections in total, focused on an evaluation of current systems for generating certificates, as well as the factors influencing blockchain adoption in the context of higher education.

Each of the last four sections consisted of a series of statements (ranging from three to six) representing each factor, for which the participants were asked to indicate their level of disagreement or agreement using a 5-point Likert scale. Likert scales, whether they include two points (e.g., only "Agree" or "Disagree") or more, are frequently applied in research in education and the social sciences [45]. Table II shows the scale used in the data collection instrument for the purpose of measuring the participants' responses. Moreover, Table III list all the related items that measure each influential factor for our study.

For the student category of the study, there were in total of 426 responses to the survey where 405 responses agreed to proceed with completing the survey. The authors extracted the 21 responses that refused to agree on the survey consent. The employer sample was 34 responses to the survey, where 8 participants refused on agreeing on the survey contest, and 4 participants did not complete the whole questionnaire. Thus, the total employer participants sample size consists of 22 responses.

The influence of demographical information and characteristics was analysed in order to find out any external influences upon the level of the mentioned factors that would affect the adoption of the blockchain in the higher education field.

In the final version of the study participants for student's category, the gender's distribution for the female participants was 70.4%, while there were 29.4% male participants. Meanwhile, 0.2% of the participants prefer not to specify their gender. The highest participants were in the age between 18-25 years with percentage 60.2% of the sample. In the education level, the majority of the participants was in the undergraduate category with 54.3% percentage which is the target sample of the study, and 21.7% of the participants was bachelor's degree holders. Furthermore, 54% of the sample was fall under Science, Technology and Engineering domains and 12.20% of the participants was from Humanities and Art fields.

On the other hand, for the employer's data the majority of the participants were in the age between 26 and 35 years with 50% percentage, followed by the age 36 and 45 years with 40% of the total responses. In contrast with the student's data, most of the employer were male participants that represents 72.7% of the sample. In the aspect of educational level, 59% of the participants were postgraduates or higher level. Employers sample mostly

TABLE II. THE SURVEY QUESTION'S SCALE

Statements	Strongly Agree	Agree	Fair	Disagree	Strongly Disagree
The process of issuing students certificate takes a lot of time and effort.	1	2	3	4	5

TABLE III. ITEMS TO MEASURE EACH FACTOR IN THE SURVEY

Factor	Items
Trust (T)	-Functionality and Transparency -Knowledge and Familiarity -Easy to Access and Share -Applicants Credentials Authenticity
Social Influence (SI)	-Social effect -User Awareness
Privacy and Security(PS)	-Privacy,Immutability,Security and Reliability -Perceived Risk -Fraud and Dishonesty
Efficiency (E)	-Efficient Smart Certificate -Cost Reduction

derived from Science, Technology and Engineering domain followed by Business and Economics and Humanities and Art successively. Moreover, 33.3% of the participants indicated that they have a moderately level of awareness for the Blockchain technology (see Table IV).

B. Results and Analysis

This section offers a detailed discussion of the survey results and maps the results to the research hypotheses. After obtaining questionnaire data, the data collected through the primary case study questionnaire were checked and pre-processed for statistical tests. The report containing all the survey data was generated using online service **Qualtrics**, and to visualize the results, charts were used. The data were imported into Excel, after which their quality was evaluated. The Statistical Package for the Social Sciences (SPSS) was used for quantitative analysis after completing the data cleaning and pre-processing phases.

- **Data Cleaning**

In terms of the pre-processing phases that were applied to clean the data prior to statistical analysis, its aim was to ensure data completeness and, alongside this, to guarantee that the data were not distorted in any way by the various opinions of specific groups. Since the data were small in size and ordinal, non-parametric tests were applied when suitable [46]. The statistical analysis given as follows offers a description of the results.

- **Reliability of the study**

This section offers a description of the approach used by the authors to evaluate the reliability of the data collection instrument. When evaluating the measurement instrument, both reliability and validity are crucial to consider. In the case of reliability, it defines as the degree to which a measure is consistent, and three types of consistency are considered in psychological research: internal consistency (i.e., consistency across items), inter-rater reliability (i.e., consistency across researchers), and test-retest reliability (i.e., consistency over time) [47].

A data collection instrument is regarded as reliable if it generates comparable results after being applied across similar situations and if it is free from errors to a satisfactory degree. Cronbach's alpha was used as a measure of internal consistency in this research (where the value ranges from 0 to 1), which is one of the most common techniques applied in the literature [48]. Opinions differ about how to interpret Cronbach's alpha values, but a commonly used schema views acceptable alpha values typically range from 0.70 to 0.95.

Tables V and VI indicate the alpha values for each factor and their related items in the framework that were analysed to establish each factor's reliability based on the theoretical framework.

In this research, Cronbach's alpha values in the "Student" category ranged from 0.784 to 0.969, whereas they ranged from 0.752 to 0.876 in the "Employer" category. Since these values exceed the threshold, they are indicative of good internal consistency and reliability. Hence, it is reasonable to conclude that the data collection instrument was comprised of a group of consistent variables that captured the meaning of the framework.

- **Validity of the study**

In the case of validity, this refers to the question of whether the scores associated with a measure actually reflect the variable that is targeted for measurement. In evaluating validity, one of the crucial factors that researchers consider – namely, reliability – has been discussed already.

In the event that a measure has acceptable internal consistency and test-retest reliability, it is reasonable for researchers to be confident that the scores represent the intended object of measurement [47]. To measure the validity of the study's data, Average Variance Extracted (AVE) has been chosen as the most appropriate approach for this kind of research to validate the framework in order to measure the convergent validity. In AVE analysis, factor loadings

TABLE IV. DEMOGRAPHIC CHARACTERISTIC OF THE SURVEY

Characteristics		Students		Employer	
		Frequency (n= 405)	Percentage %	Frequency (n= 22)	Percentage %
Age					
	18 - 25	244	60.24	0	0
	26 - 35	88	21.72	11	50.0
	36 - 45	49	12.09	9	40.9
	46 - 60	21	5.18	2	9.1
	+ 60	3	0.7	0	0
Total		**405**	**100**	**22**	**100**
Gender					
	Female	285	70.4	6	27.3
	Male	119	29.4	16	72.7
	Prefer not to say	1	0.2	0	0
Total		**405**	**100**	**22**	**100**
Education Level					
	High School or equivalent	25	6.17	1	4.5
	Undergrad	220	54.32	0	0
	Bachelor's Degree	88	21.72	8	36.4
	Postgraduate or Higher	72	17.77	13	59.1
Total		**405**	**100**	**22**	**100**
Field Domain					
	Science, Technology and Engineering	208	51.35	12	54.6
	Business and Economics	47	11.60	5	22.7
	Humanities and Art	49	12.20	4	18.20
	Other	101	24.94	1	4.50
Total		**405**	**100**	**22**	**100**

greater than 0.6 show an acceptable level of convergent validity. The values of AVE for the four factors Trust, Social Influence, Privacy and Security, and Efficiency are 0.554, 0.697, 0.549, and 0.804 respectively. Thus, the AVE values are greater that 0.6 threshold , except the trust factor, which indicate the acceptable convergent validity. Thus, the result indicates the model is valid and the framework factors are related.

- **Descriptive Analysis of the Data**

As mentioned before, this research used the Likert scale to measure the participants' views regarding the survey questions. Hence, for analysing the Likert scales, the authors calculated the weighted averages of the provided data with the scale from Strongly Agree=1 to Strongly Disagree=5 (as shown on Table VII), so that the tendency of the combined scores could be ascertained by using an interval length of (0.79).

Numbers entered into SPSS represent 'weight' and the weighted average for the scale needs to be calculated to understand the achieved means values. The results can be interpreted to show the level of acceptance or rejection of each factor in the study's suggested framework (see Table VII).

To attain an overall mean for each factor, the scores from each factor's items were averaged. Table VIII and IX present the summary of the results of the descriptive analysis of each category with an interpretation of all finding results. Form the collected data, the achieved average mean of weighted means determines the level of accepting the adoption of Blockchain technology in the certification process among all related parties.

The average mean for the student's sample data was 2.6 which is moderately acceptable needs more efforts form different associated parties to spread the awareness about blockchain technology. While in the employer's sample, the average mean for the blockchain technology acceptance was 1.72 that indicates high level of acceptance among the employer's survey participants.

In the sample of students, the average mean value for the trust factor with all the involved elements under it was moderately acceptable with an indication of some issues related to understanding the functionality of blockchain technology. Moreover, the leverage benefits from DLT privacy and security factors in the certification process were unclear from the students' point of view, which is reflected in this factor as an average level with 2.81 as the weakest

TABLE V. CRONBACH'S ALPHA TEST FOR EMPLOYERS

Factor	Items	Employer α	Analysis
Trust (T)	17	0.951	Excellent
- Functionality and Transparency	6	0.876	Very Good
- Knowledge and Familiarity	3	0.752	Good
- Easy to Access and Share	3	0.846	Very Good
- Applicants Credentials Authenticity	5	0.864	Very Good
Social Influence (SI)	5	0.835	Very Good
Privacy and Security(PS)	14	0.919	Excellent
- Privacy,Immutability,Security and Reliability	8	0.859	Very Good
- Perceived Risk	3	0.864	Very Good
- Fraud and Dishonesty	3	0.847	Very Good
Efficiency (E)	8	0.873	Very Good
- Efficient Smart Certificate	4	0.795	Good
- Cost Reduction	4	0.817	Very Good

TABLE VI. CRONBACH'S ALPHA TEST FOR Students

Factor	Items	Student α	Analysis
Trust (T)	13	0.957	Excellent
- Functionality and Transparency	6	0.955	Excellent
- Knowledge and Familiarity	3	0.846	Very Good
- Easy to Access and Share	4	0.955	Excellent
Social Influence (SI)	8	0.936	Excellent
- Social effect	4	0.905	Excellent
- User Awareness	4	0.879	Very Good
Privacy and Security(PS)	10	0.937	Excellent
- Privacy,Immutability,Security and Reliability	6	0.957	Excellent
- Perceived Risk	4	0.784	Good
Efficiency (E)	9	0.969	Excellent
- Efficient Smart Certificate	6	0.964	Excellent
- Cost Reduction	3	0.930	Excellent

factor of all four.

Consequently, more effort is needed to educate students about the impact of blockchain technology on their future and credentials. However, the efficiency and social influence factors were at an acceptable level with values greater than 2.59. Therefore, the students were aware of the features of smart certificates and how efficient they can be for generating immutable records for qualifications. This also implies the students' enthusiasm toward realizing the process of validating their qualifications with high honesty.

In the sample of employers, the average mean value for the weighted means of the studied factors was in the highly accepted level. There was a good indication among prospective employers toward blockchain acceptance in the certification process. The trust factor had the lowest level compared to the other three factors, especially in the section on knowledge and familiarity with blockchain technology. This is considered a reflection of employers' need to learn more about the benefits and features of DLT to ensure its trustworthiness. In contrast, privacy and security factors had the highest average mean, which reflects the understanding that blockchain can enable security and privacy for smart certificates. Accordingly, this affects the decisions that employers make about applicants' qualifications. The social influence and efficiency factors achieved a similar average weighted mean regarding the effect of adopting blockchain technology on encouraging educational institutions to operate with the same transparency level in their outcomes. Also, it indicates the perception among employers about the utility of blockchain technology in offering an efficient sharing system for employers and students in higher education. In short, all the weighted means and achieved results collected

TABLE VII. Weighted Mean and Result Interpretation

Likert Scale	Description	Mean Weighted Avg.	Interpretation
1	Strongly Agree	1.00-1.79	Highly Accepted
2	Agree	1.80-2.59	Acceptable
3	Fair	2.60-3.39	Moderately Acceptable
4	Disagree	3.40-4.19	Fairly Acceptable
5	Strongly Disagree	4.20-5.00	Not Acceptable

from the two categories are at an acceptable level with all the considerations that DLT is a new era in the technological field.

5. Discussion

The goal of this empirical study was to evaluate the acceptance of DLT in the certification process in higher education among students and prospective employers. All students and employers were asked about their views on blockchain technology in terms of the factors of *trust, social influence, privacy and security,* and *efficiency*, with detailed items associated with each factor. We regarded prospective employers as the prime driver of the research according to the benefits that stand to be attained if blockchain technology is adopted in the certification process in higher education.

Employers showed substantial interest in blockchain adoption as a way to store prospective applicants' credentials to avoid fraud or dishonesty. In the items about their understanding of the technology's functionality, most of the participants (81%) agreed on blockchain's transparency, making it a suitable option for managing educational certificates. Moreover, a similar percentage (87%) agreed on blockchain's ability to handle all forms of academic credentials, transcripts, and certificates. Likewise, employers believed that the technology provides a high level of trust by eliminating dishonesty through an emphasis on actual learning outcomes and alumni skills and accomplishments. 88% of employers reported that blockchain enables students to share their official documents directly with external parties with the feature of immutability, which guarantees complete trust in the provided certificates. In the section on knowledge and familiarity, most of the participants reported that they were familiar with the benefits associated with using blockchain technology and refused to use it without any knowledge of its functionality. Moreover, the participants were asked about their perceptions of the sharable feature of systems based on blockchain technology, with 93% stating that the technology gives students full access to their certificates at any time. 87% of the participants agreed that blockchain reduces time and effort in the employment process. Regarding the section on the authenticity of applicants' credentials, employers believed that three main features are enabled by blockchain: it helps to streamline the process for prospective employees and guarantee qualified candidates; it allows the organization to check the authenticity of the applicant's credentials; and it opens up the outputs of the institution to applicants worldwide.

In the privacy and security factor, the employers agreed on the general importance of security-related benefits in integrating blockchain technology in higher education. Meanwhile, most of the participants were neutral about believing in the ability of blockchain to maintain a high level of security, including data protection, integrity, and privacy, which leads to an influence on the trust toward it. In the matter of the reliability of blockchain technology, 93% of the participants agreed that blockchain enhances the reliability and transparency of prospective employees' certificates by establishing secure connections between all included parties and easing their interactions. Moreover, most employers agreed that blockchains are useful for authenticating student identities and smart certificates, and they also suggested that the use of the technology can reduce the risk of duplication and fraud.

The perceived risk items were associated with a high level of acceptance, as shown in the weighted mean value in Table VIII. This was supported by a high number of participants agreeing on the perception that the use of blockchain does not lead to privacy or security risks in an organization. Moreover, many employers believed that applicants' credentials and information are secure if the issuer can control who is seeing them. This also helps to reduce fraud and dishonesty in the applicants' credentials. Thus, the result is regarded as a good indication of the participants' confidence while using and verifying the applicants' credentials through blockchain technology.

The efficiency factor addresses user perceptions of the effect of blockchain adoption in higher education, particularly concerning efficient smart certificates and a reduction of the cost associated with the certification process. On the view of smart certificates, 82% of the participants believed that blockchain maximizes the visibility of an institution and observes the impact of their outputs by enabling several measures and evaluating student performance. Also, the participating employers agreed that blockchain allows institutions to interoperate with other university systems and maximize efficiencies via sharing information. On the matter of cost reduction, a majority of the participants agreed that blockchain reduces the cost arising from the process of verifying and authenticating applicants' certificates. They also believed that the blockchain assists in reducing the unnecessary cost associated with transactions and centralized data storage. In short, adopting blockchain is a cost-efficient approach for organizations.

The results of the empirical study reflect the fact that the employers considered the adoption of blockchain technology from the perspective of the social influence factor as it

TABLE VIII. THE SUMMARY OF THE STATISTICAL ANALYSIS RESULTS OF EMPLOYER'S SAMPLE

Factor	Items	Mean	Variance	Standard Deviation	Result Interpretation Interpretation
Trust (T)	17	1.86	2.35	0.62	Acceptable
- Functionality and Transparency	6	1.83	3.36	0.75	Acceptable
- Knowledge and Familiarity	3	2.15	2.22	0.86	Acceptable
- Easy to Access and Share	3	1.85	2.44	0.90	Acceptable
- Applicants Credentials Authenticity	5	1.74	1.38	0.53	Highly Acceptable
Social Influence (SI)	5	1.65	1.48	0.54	Highly Acceptable
Privacy and Security(PS)	14	1.64	2.38	0.47	Highly Acceptable
- Privacy,Immutability,Security and Reliability	8	1.63	1.70	0.46	Highly Acceptable
- Perceived Risk	3	1.64	1.37	0.67	Highly Acceptable
- Fraud and Dishonesty	3	1.67	1.38	0.36	Highly Acceptable
Efficiency (E)	8	1.66	2.92	0.58	Highly Acceptable
- Efficient Smart Certificate	4	1.72	1.23	0.55	Highly Acceptable
- Cost Reduction	4	1.61	1.50	0.61	Highly Acceptable
Blockchain Adoption Acceptance Mean					**1.72**

TABLE IX. THE SUMMARY OF THE STATISTICAL ANALYSIS RESULTS OF STUDENT'S SAMPLE

Factor	Items	Mean	Variance	Standard Deviation	Result Interpretation Interpretation
Trust (T)	13	2.60	5.87	0.67	Moderately Acceptable
- Functionality and Transparency	6	2.46	0.55	0.74	Acceptable
- Knowledge and Familiarity	3	2.82	1.65	0.74	Moderately Acceptable
- Easy to Access and Share	4	2.45	2.40	0.78	Acceptable
Social Influence (SI)	8	2.54	3.68	0.68	Acceptable
- Social effect	4	2.53	1.98	0.70	Acceptable
- User Awareness	4	2.55	2.04	0.71	Acceptable
Privacy and Security(PS)	10	2.81	4.45	0.67	Moderately Acceptable
- Privacy,Immutability,Security and Reliability	6	2.94	3.59	0.77	Moderately Acceptable
- Perceived Risk	4	2.68	1.58	0.63	Moderately Acceptable
Efficiency (E)	9	2.44	4.97	0.74	Acceptable
- Efficient Smart Certificate	6	2.45	3.39	0.75	Acceptable
- Cost Reduction	3	2.42	1.94	0.80	Acceptable
Blockchain Adoption Acceptance Mean					**2.6**

encourages educational institutions to have the same transparency level in terms of their outcomes. Moreover, this technology motivates prospective employees to build the productive skills needed to support their career decisions. Consequently, blockchain adoption in higher education may help to reduce the overwhelming burden of administrative tasks, thereby improving employee productivity.

The results clearly revealed that students were overwhelmed by the existing certification system, which strongly shaped their perception toward new technology adoption. In the trust factor items, 63% of the students agreed on the effect of blockchain's transparency and its immutable features, which make it a trustworthy technology for managing educational certificates. Additionally, most students believed that blockchain can handle all forms of academic credentials, transcripts, and certificates. The participants indicated that implementing a system that eliminates the control of third parties would increase their level of trust in blockchain technology. Moreover, the data indicate that students believed in the ability of blockchain technology to facilitate the sharing of their official documents directly with external parties, thereby embodying the learning outcomes and enhancing the attainment of competencies within the educational scope. However, a low percentage of the responses from the students' indicated a good level of awareness and familiarity with the benefits provided by DLT in the general aspects. In the section on user blockchain awareness, half of the participants revealed that they do not have an adequate perception of the benefits and drawbacks of blockchain adoption in higher education. Accordingly, to ease the process of adopting the concept of smart certificates based on DLT, higher education institutions must improve awareness of the technology among students and other stakeholders. In terms of their views about easily accessing and sharing credentials via blockchain, most of the students agreed that blockchain technology offers full access to their certificates. They also stated that blockchain enables credentials to be shared conveniently with any prospective employers, thereby reducing the time and effort needed to control credentials. This study's results also emphasize the importance of the efficiency of the produced smart certificate by DLT in the certification process in terms of the students' insights about the technology. Based on the concept of blockchain, the proposed system could offer students efficient, sharable, validated, standardized, accessible, and effortless credentials. Also, it is important not to forget the value of reducing the cost and time associated with the process of generating the certificate. The data obtained from students indicate that the efficiency and cost reduction factors positively influence the acceptance of blockchain technology adoption in the certification process.

The social influence factor for this study focused on students' perception of the effect of the social impact and how societal drivers can encourage the intention to adopt blockchain technology in higher education certification processes. Most participants suggested that blockchain adoption in certain higher education institutions would encourage others to seek to attain the same transparency level, thereby having a tremendous effect on adoption decisions. Additionally, most of the participants believed that the reputation of blockchain technology in various fields motivates higher education institutions to adopt DLT. In [43], the authors argued that the social influence factor is a major aspect to investigate when exploring intention to adopt new technology. Hence, as expected, this study's results emphasize that in a higher education context such as Saudi Arabia, this factor has a substantial impact on moving the certification process under the DLT umbrella.

In the security and privacy factor, the vast majority of the participants agreed that security is an important benefit of integrating blockchain technology in higher education. Moreover, data from students indicated high agreement regarding the ability of blockchain to offer high levels of security and privacy for smart certificates stored on the chain, including interactions between connected nodes. Likewise, most of the participants believed in the usefulness of blockchain technology in authenticating student identities and smart certificates. In the section on perceived risk assessment in this study, most participants were neutral about their perceptions of seeing DLT as a risk to their privacy or security in the case of adopting smart certificates. However, 60% indicated a high level of confidence while sharing their credentials through a blockchain-based system. Thus, privacy and security are crucial when handling personal and important data such as students' credentials, especially in the field of blockchain [41], which accounts for the variety of results in our study.

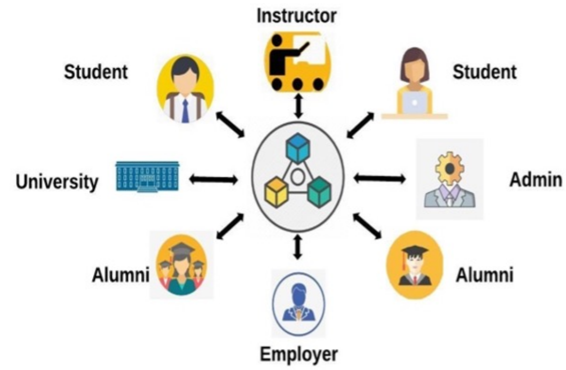

Figure 3. Actors in the Proposed System

In conclusion, both groups of respondents in this study had reasonable perceptions of blockchain technology and a noticeable desire to adopt the technology in higher education. Statistical analysis confirmed that the data collection instrument was valid and applicable in evaluating employers' and students' acceptance levels of blockchain technology. However, the results indicated that students have limited awareness of the benefits, disadvantages, and perceived risks associated with using blockchain technology in the certification process for higher education institutions. Moreover, the data obtained from employers indicate a strong desire to validate applicants' certificates using an immutable and reliable system based on blockchain technology (e.g., DASC) to prevent fraud and dishonesty.

6. Proposed Solution

This section highlights a proposed solution to overcome current problems in the field of higher education, especially in the certification process as we publish in our previous research [49]. It consists of three subsections: the proposed system framework, a high-level conceptual infrastructure and demonstrations of the system logic.

A. *Proposed System DASC and study findings*

Using blockchain technology helps eliminate the need for a third-party authority and enhances the interactions between all related participants. To overcome the above-mentioned challenges and issues in the current process of handling and posting student certificates, we propose the structure and functionality of an App for smart certificates (DASC). As shown in figure 3, the system has five main actors: students, alumni, Admin, instructors and prospective employers.

To achieve the research aims and goals, the DASC should provide solutions to the following questions: What are the benefits of blockchain technology in resolving the current problems faced in the higher education sector

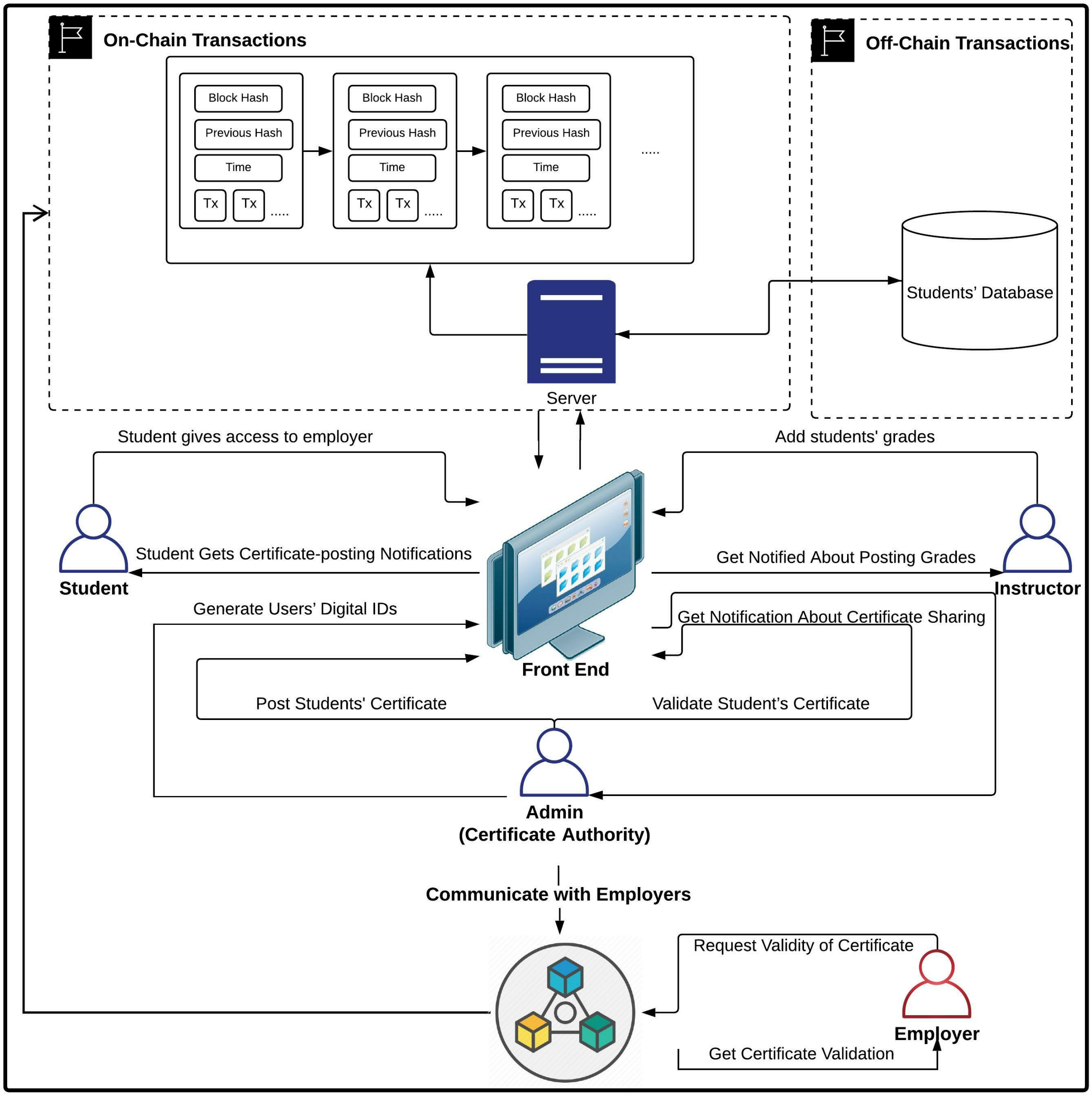

Figure 4. High-Level Conceptual Infrastructure of DASC

when generating learner certificates and accreditations?. The another question about how can blockchain systems improve the efficiency of generating certificates in the higher education sector?.

The aim of the DASC is to record student data, including registered courses, credits, skills and badges. This system should enable the sharing of student data with authorised parties (e.g., university administrators, academic staff and prospective employers). The resulting high level of transparency should help HEIs design and implement unique teaching methods for each student. The DASC should serve as a single repository of information that consolidates students' digital certificates, transcripts and achievements from different educational institutions. Thus, students will be able to keep authentic records of all their accreditations for use as a permanent e-portfolio and full record of their achievements, grades and courses. With prospective employers allowed to check the authenticity of a job candidate's transcript, accreditation fraud and

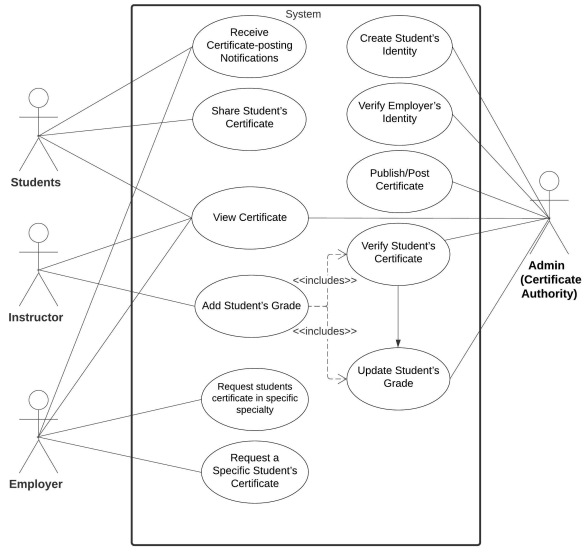

Figure 5. DASC Use Case Diagram

dishonesty will accordingly be eliminated.

From the previous section about the survey findings, the gathered data have been used to enhance the initial proposed model. Statistical analysis revealed that the four suggested factors having a huge influence on their acceptance of the blockchain technology. This indicates that the model structure is valid and approved.

B. High-level Conceptual Infrastructure

Figure 4 shows the DASC's high-level conceptual infrastructure, which represents the blockchain as the left dashed box (noted as **on-chain** transactions), directly connected to the front-end system and centralised database systems (**off-chain** transactions). On-chain transactions are the transactions that take place directly on the distributed ledger network, whereas off-chain transactions describe the external transactions performed outside the distributed ledger [50].

The proposed system (the DASC) allows students to get a single view of their certificate and credentials data with a guarantee of data integrity. Such a view can be shared with external parties with the student's permission. As represented in the conceptual infrastructure, the DASC allows direct interactions between prospective employers and front-end systems which are controlled by system administrators giving the appropriate permissions. DASC allows students to get a single view of their credentials data with a guarantee of data integrity. Such a view can be shared with external parties with the student's permission. As represented in the conceptual infrastructure, the DASC allows direct interactions between prospective employers and front-end systems, which are controlled by system administrators giving the appropriate permissions.

C. Demonstrating the DASC Logic

A major step in developing a software application is to clarify the proposed solution's requirements, scope, limitations, exceptions and expected outcomes by using visual representations. To fulfil this aim, this section presents the logic of the proposed DASC by using UML. UML is defined as a graphical representation for visualising, modelling and documenting object-oriented systems [51]. Using UML standards helps software engineers and developers understand the functions and data attributes of the proposed system [1]. First, use case diagrams are employed to model behavioural structure. Next, sequence diagrams are used to illustrate direct interactions between the system's participants.

- **Use Case Diagram**

This section focuses on the interactions between the actors and the system. Figure 5shows the use case diagram of the DASC that describes system behaviour. The use case diagram is a user-facing diagram that helps in the analysis of the requirements of a problem statement from the use perspective [50]. This diagram shows all the system's actors and the main functionality they can perform while using the system. For instance, students can interact with the DASC in full view of their digital portfolio, receiving updates and sharing certificates or achievements with others. The main actor in the system, Admin, has the authority to create and verify digital identities for other actors, post student certificates, verify student certificates before posting them in the portfolio and updating student grades.

- **Sequence Diagram**

As noted by Ramamurthy, using sequence diagrams helps illustrate the operations and interactions between the user and different objects of the system in a timeline [50]. In the case of the DASC, the system consists of many operations that need to be illustrated in order to emphasise the interactions between the system's actors and objects. System objects include the centralised database that will be used to store the off-chain data.

Data are stored off chain to reach the goal of not storing all related data on the chain. Thus, illustrating the system's main interactions with the actors should facilitate the implementation process for developers [52]. For instance, the Admin actor represents the main certificate authority in the system. For this actor, all the processes revolve around giving privileges, initiating digital identities and issuing student certificates. Figuers 6 and 7 show two main processes from DASC illustrated by sequence diagram standards.

7. Limitations and Future Work

As we can see from previous sections, there is a gap in the existing literature with regard to research into adopting blockchain in the higher education sector. Accordingly, we were motivated to delve into this area and propose

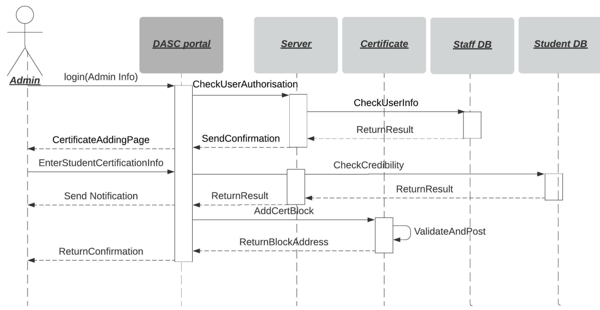

Figure 6. Post Certificate Sequence Diagram

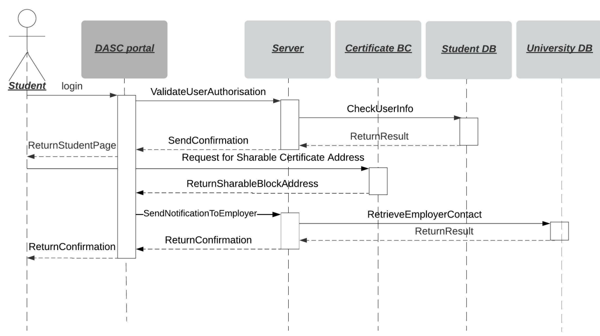

Figure 7. Share Certificate's Process Sequence Diagram

the DASC solution, which should enrich research into the adoption of blockchain technology in higher education. This paper contributes to the research through a review of the current literature about blockchain in higher education. It also highlights the differences between current certificating or credentialing systems (emphasising the issues they have) and the proposed DASC which will adopt blockchain technology. We believe this is a suitable framework because it involves all the prospective actors, processes and data storage units. It logically covers the main problems of the current system, including dishonesty and certificate fraud. Deploying blockchain provides the nature of immutability for student records, and we think this approach will resolve problems in the current credentialing process. In this study, most of the sample is female, which is an important matter to be studied in developing countries such as Saudi Arabia. Thus, this would raise more associations to be investigated among all studied factors in the future work of this research.

At this point, the design phase does not show any data storage problems that may face the system in real life because system scalability could not be explored. If the blockchain is used as a database to store student certificates, then massive numbers of records will be replicated in all chain nodes. This will be the case if, for example, the system stores all the information about the students in the chain, including student ID, name, date of birth, department, courses and badges achieved. Eventually, such a blockchain will suffer from storing and maintaining all these data for each student. This could have a detrimental effect on the expected benefits of the system. Our future research will examine the hypothesized association between factors and employer and student requirements by experimental study to test the prototype of proposed system.

8. Conclusions

Our study provides empirical evidence that the four examined factors have a positive influence on the students and employers' acceptance toward blockchain-based system in the context of certification process on the higher education field. Additionally, this study added several contributions to theory and practice in the field of higher education especially in certification process in the context of developing countries, Saudi Arabia in our case study.

The researchers created the suggested Blockchain technology adoption's model to examine factors revealed by the literature to be likely to influence higher education institutes' intention to adopt smart certification. Then, this provided model has been tested among two categories of participants in which the result of descriptive analysis of the collected data indicates the huge influence of all the proposed factors. Moreover, this paper covers an overview of blockchain technology and discussed the challenges and problems in current higher education systems.

Lastly, it proposed the DASC, a solution to the above-mentioned problems that uses a blockchain-based credentialing system for generating and maintaining student credentials and in this stage of the research, the system will be tested in the coming phase for its validity in experimental study. Where the team will also evaluate and validate the applicability of the implemented solution.

We should verify how efficient the use of blockchain is as a decentralised technology in the higher education sector. Importantly, this is an ongoing research project, and its progress will be reported after we have completed the next phases and future work.

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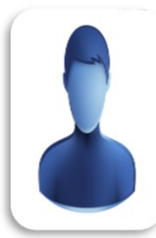

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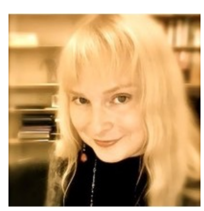

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