International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

PAPER ID: 11A16N

E-LEARNING CHAIN: A SECURE BLOCKCHAIN APPROACH TO E-LEARNING & CERTIFICATION SYSTEMS

Fahad F. Alruwaili [1*]

[1] *College of Computing and Information Technology, Shaqra University, SAUDI ARABIA.*

ARTICLEINFO

Article history:
Received 16 July 2020
Received in revised form 11 September 2020
Accepted 18 September 2020
Available online 26 September 2020

Keywords:
Smart Contract;
e-Learning technology;
eLearning certification;
Cybersecurity;
Distributed Ledger Technology (DLT);
Education; Ethereum;
Decentralized Systems;
Blockchain.

ABSTRACT

Digital transformation revamps many business models and transforms the way people dealing with their day-to-day operations. With the inception of the novel coronavirus i.e. COVID-19, many industries have become very reliant on remote teleworking and the use of all possible online means. Educational institutes are amongst those to innovate and accelerate the adoption of online education and eLearning platforms. However, this rapid trend comes with cybersecurity risks that have not been fully addressed. With these continuing efforts in innovating education delivery, the shift needs a holistic and experiential approach to ensure transparency and authenticity of the delivered educational programs. In this paper, a practical and secure e-Learning Chain (ELC) model using the Distributed Ledger Technology (DLT) and smart contracts to support the learning certification, verification, monitoring, and validation is proposed. The smart contracts are utilized to ensure to support the model certification process for better and secure automation and verification. Further research direction on implementing a blockchain-based e-learning ecosystem and the implications on other educational areas are discussed.

Disciplinary: Educational Technology and Information, Blockchain Technology.

1 INTRODUCTION

Education is one of the most important pillars of future planning (Turkanović et al., 2018). Education plays a vital role in the production of knowledge and its distribution (Arenas R *et al*, 2018). Learning based on the online is accepted and adopted by many educational firms throughout the world during this COVID-19 pandemic to deliver a quality of education, training, certification, and even awarding higher degrees (Harper *et al*., 2004). The term quality education involves learners, environments for learning, content, process, and outcomes. To increase the quality of education, teachers need to apply different instructional methods such as online-based learning, e-learning, etc.

*Corresponding author (Fahad F. Alruwaili). Email: alruwaili@su.edu.sa

and also should carry out proper student evaluation and assessment processes. It is also important that traditional lesson styles should be reformed to safe and online-based especially during this COVID-19 pandemic. Blockchain is a new technology and a revolution that has imposed itself on various areas of life (Zheng *et al*., 2017).

The application of blockchain in education is still in its infancy. Only a small number of educational institutions have started to utilize blockchain-based technology. Most of these institutions are using it for sharing and validating the academic certificates that the students have obtained (Chen *et al*., 2018). However, various researchers in the field of blockchain believe that this technology has can actually revolutionize the education sector due to its security. The blockchain-based technology proposed by (Nespor, 2018) depicted that blockchain-based technology could undercut the educational institutions' central role as certification agents and provide students with more learning opportunities. Various applications of blockchain have been developed by different researchers (Gervais *et al*., 2016, Kosba *et al*., 2016, Khandelwal *et al*., 2020) for the educational purpose. These applications can be classified into twelve categories: management of the certificates, capability building and managing the outcomes of learning, students evaluation for their ability in professional ability, preserving the objects of learning, protecting the environment for collaborative based learning, allowance and transfer of credits, getting the consent of guardian digitally, managing competitions, managing copyrights, improving the association of students in e-learning, reviewing the exam, and bracing the learning lifelong.

Through various researches that have been done earlier in this field in the last few years, still there is a need for extensive research since there were various scientific gaps present in the previous researches. Blockchain and education technologies can work in tandem to improve:

- The transparency and record-keeping e.g. certification process and minimize forged degrees.
- Traceability and file storage of academic programs and any committed changes across different participants.
- Resistant and defense procedures to cyberattack and cybercrime.
- Rewards mechanism via blockchain nodes.
- Lower cost of operations through smart contract and process automation.

This article provides an overview of the application of blockchain in e-learning for providing the certificates by proposing a novel methodology for providing security while issuing certificates in e-learning using the blockchain technology Main target of this paper is to focus on administrators, decision-makers, academicians, and researchers working on providing security using blockchain as a novel technology and how it be applied in the field of education. The main focus of this paper is to propose a tailored e-learning framework based on a lite implementation of blockchain. Further, the paper revises current blockchain technologies with respect to online learning and education in the following sections. In the following subsequent sections, the novel framework i.e. ELC, is analyzed and implemented. The ELC model based on the DLT and smart contracts devised to support the learning certification, verification, monitoring, and validating. Besides, the work suggests a reliable, trusted, and verifiable blockchain-backed repository for academic course work and student/faculty certification.

2 RESEARCH MOTIVATION

The motivation for this work is to address the current challenges faced with misuse of issuing educational credentials by many parties involved in the educational sector. Also, the work suggests a reliable, trusted, and verifiable blockchain-backed repository for academic course work and student/faculty certification. Further, researchers found a phenomenon of an increasing number of people obtaining certificates without actually joining the learning program which indicates a criminal act. This stipulates the government and educational authorities implement an adequate method or a framework to cease such an act. Thus, this paper directs the research to propose the ELC method which will help minimize the number of increasing forged diploma and certificates and enables credible educational programs. The approach does not only enables employers and/or recruiters to verify the authenticity of someone's credentials but also attracts honest learners to engage in such technology to continuously upgrade their skillset academically and professionally known their work is highly protected and verifiable. This transparent and efficient approach allows auditors, cultural bureaus, educational authorities, accreditors, and validators to participate and a trustless fashion. The model utilizes the structure of DLT and smart contracts (Wang et al., 2019) in ELC architecture to allow secure delivery and storage of any educational program/curricular and enables efficient and trusted verification and authorization process.

3 EXISTING RESEARCH

A Smart Contract is an action performed by the computer program which is processed in between two or more entities which are bound to trust each other based on it (Cheng J-C et al., 2018). It can be a set of rules and conditions between two or more entities. Using a smart contract based on blockchain technology, the cost of third-party involvement is reduced between the transaction process by providing security in the transaction. Various researches have been done earlier by different researchers in this field in the last few decades. Blockcerts (Khandelwal *et al*., 2020) which was developed by MIT media lab as an open-source credentialing system coupled with the use of artificial intelligence to provide a platform for creating and verifying learning practices and certification.

Currently, the use of blockchain within education is at the experimental stage (Watters *et al.*, 2016) where blockchain is being employed within some higher education institutions to provide support for degree management and summative evaluation (Sharples and Domingue, 2018; Skiba *et al*., 2018). The reason for this is because blockchain records are far more specific, authentic, and revealed to be anti-theft. The application of blockchain to education leads it towards formative evaluation, the tracking of the educational development of students, and the actual implementation of learning delivery. Several interesting research projects that investigate the application of Blockchain technology to education can be found. There are some efforts from different universities in utilizing blockchain technology to manage students' certificates received from a Massive Open Online Course (MOOC) platforms (Sharples *et al*., 2016). Also, The Massachusetts Institute of Technology (MIT) has developed a credentials based system which works on the blockchain. This system is designed to provide more security and control in the case of certificates provided to the students, and without having to rely on intermediaries such as third-party, employers from the University for validating and verifying the credentials present in it.

A combination of Blockchain technology and cryptography has been applied in concurrence in

*Corresponding author (Fahad F. Alruwaili). Email: alruwaili@su.edu.sa Volume 11 No.16 ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8 Paper ID:11A16N http://TUENGR.COM/V11B/11A16N.pdf DOI: 10.14456/ITJEMAST.2020.323

the process of developing an open platform called the Blockcerts to issue digital certificates (Chen *et al*., 2018). Moreover, the Knowledge Media Institute (KMI) in the Open University has proposed an Open BlockChain project. The main aim of this project is to facilitate a network that can spearhead blockchain projects in higher education. KMI is particularly interested in enhancing standards for badging, certification, and reputation on the web with the use of the blockchain as a trusted ledger (Jirgensons, 2018). Sony Global Education also connected blockchain technology to a global assessment platform that stores and manages degree evidence (Chen *et al*., 2018). Furthermore, Authors (Turkanovic *et al*., 2018) proposed the EduCTX platform that is a decentralized global platform for managing, storing, and sharing digital certificates based on blockchain technology.

Improving the interactions of students' in the participation of e-learning systems is categorized by a different category of application that applies the blockchain technology in order to solve some topics which are connected to the interactivity of students' who were present in the e-learning platform. (Zhong *et al*., 2018) proposed a novel application based on blockchain technology to enhance the engagement of learning. It gives an award in the form of virtual currencies to learners who got top rank. This is based on predefined principles which were already located in the blockchain technology. A review of examination is another category of application that was also identified in this review. By deploying a blockchain technique, the security can be enhanced while evaluating the exam papers using the trusted ledger-based technology. (Mitchell *et al*., 2019) proposed a decentralized application for an examination review called "dAppER." This system was designed by considered the standards of quality assurance while disturbing exam papers by the external examiners. Based on their analysis, their proposed application helped control the quality of examination.

4 ATTRIBUTES OF THE BLOCKCHAIN TECHNOLOGY

A blockchain is a distributed digital record of transactions (Hasanova et al., 2019). The terminology comes from its setup structure where blocks are connected to each other chronologically. These blocks are linked together with each other, and in accordance with the implemented consensus protocol, in a single list which is called a chain. The current implementation of blockchains is now seeing in recording cryptocurrencies transactions. The notion of decentralization is a core component; hence, any involved transactions cannot be altered without the alteration of all concurrent blocks.
The key characteristics of the blockchain include decentralization, persistence, anonymity, and audibility.

4.1 BLOCKCHAIN TECHNOLOGIES

The idea of the blockchain was initially introduced by Satoshi Nakamoto and later in 2009 implemented the 1st digital cryptocurrency known as Bitcoin. The structure of the Blockchain is shown in Figure 1. Blockchain then has become a core component of bitcoin's operation and the de facto inspirational to other projects. It provides a secure exchange and traceability in the event of any failures in case of a security breach. In a shift of paradigm, the blockchain removes centralized authority which is present in-between multiple entities that are processing the financial and other transactions on data using a public ledger which is incorruptible, immutable, and decentralized in nature.

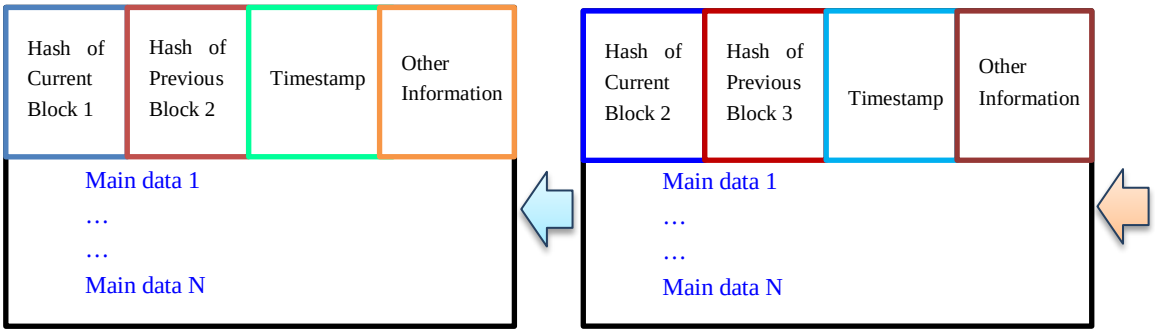

Figure 1: Structure of Blockchain

Blockchain works on different kinds of technologies. A few of them are listed as follows:

4.2 COLORED COINS

Protocols that allow digital assets other than Bitcoin to be transferred in across different blockchains called areas “tokens or coins”. Those coins and/or tokens can be used to transfer digital assets where they can be regarded as a metadata

4.2.1 ETHEREUM BLOCKCHAIN

It is a newly developed Blockchain and it operates using digital contracts known as “Smart Contracts”. The protocol for Ethereum is different from Bitcoin operational blockchain. Blockchain has many potential application models both in the financial and non-financial industries. Multinational companies like IBM, Amazon, etc have started testing the feasibility and discovering new business opportunities, hence innovative use cases will evolve in the coming years. Many banks and governments have already collaborated to explore the implementation of blockchain technologies in their system.

4.2.2 ALTERNATIVE BLOCKCHAINS

This ensures scalability by providing lesser time for validation, more easily programmable, and most importantly, a separate consensus mechanism.

5 PROPOSED METHODOLOGY

The design science research (DSR) methodology is used to support the argument of this paper for devising innovative and secure educational course and credential information systems. The DSR employs a specific set of guidelines and principles to develop the architect of IT solutions (Hevner et al., 2010). The main DSR elements are summarized in Table 1. It starts with identifying the issues and setting the end results, which are discussed in the previous sections. This is followed by designing and developing the appropriate model for the IT solution, which is presented in its architecture (Table 1).

The ELC approach always indicates the data stored in ELC blocks are valid and verified by all participants. The issued certificates and program courses are always validated against any unauthorized or fraudulent certification. The ELC access and authorization is implemented via the use of verified proof of consensus among engaged participants. The selection of engaged participants requires an understanding of multiple factors and criteria to provide a higher level of clearness before issuing a certification, approving a transcript, or approving a program. These sets of criteria are locked into smart contracts to allow efficient automation. Further, the model considers the selection of validators and referees using the country's official authorities coupled with community voting to

*Corresponding author (Fahad F. Alruwaili). Email: alruwaili@su.edu.sa Volume 11 No.16 ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8 Paper ID:11A16N http://TUENGR.COM/V11B/11A16N.pdf DOI: 10.14456/ITJEMAST.2020.323

elect the most suitable subject matter experts in the field of education.

Table 1: Design Science Research (DSR) Constructs

	Guideline	Description
1	Design	The ELC method is suitable for encouraging the transparency, security, and authenticity of education and learning programs. It is set to counter the forgery of academic certificates and fake online programs.
2	Problem Relevance	It is usually costly and difficult to manually, verify ones' credentials and the authenticity and credibility of their certificates. Many HR departments and recruiters from different organizations find it challenging not only verify the resume and credentials of their prospects, but also the credibility of the programs they claim attending. It is also challenging to ensure academic courses and activities are secure against any cyber-attacks or unauthorized access. Therefore, the need for an efficient, transparent, verifiable, and trustless model is critical, hence the ELC. The objective is to develop automated and smart contract enable distributed ledger of educational records and credentials that can be adopted as the next generation of education stakeholders e.g. institutes, authorities, validators, recruiters, etc.
3	Design Evaluation	ELC approach is set to be evaluated using the Ethereum smart contract and DLT ledger to mimic real scenarios of the suggested pilot.
4	Contributions to Research	The ELC approach contributes to the security of academic credentials (certificates, transcripts, activities, etc.) and enables an honest and trustless framework that is resistant to fraudulent credentials.
5	Research Rigor	A rigorous blockchain technology and information security methods are considered in the ELC.
6	Design as a Search Process	The search for an effective, transparent, secure, and verifiable eLearning security solution requires investigating all different implementation and research approaches to arrive at an optimum solution.
7	Research Communication	The results and insights from this work are disseminated to the relevant communities, academic technologists, blockchain, and cybersecurity Subject Matter Experts (SMEs).

5.1 E-LEARNING CHAIN (ELC) SYSTEM ARCHITECTURE

In this section, the conceptual architecture of ELC is presented. The section provides a high-level design of the ELC blockchain, which combines a hybrid implementation (private and public ledger). The goal is to provide a trustless, cost-efficient, and secure eLearning and certification mechanism. The ELC architecture includes participants (cloud users, cloud service providers, validators), consensus algorithms, smart contracts, cryptographic functions, and digital signature. The main ELC system components are described in Figure 2.

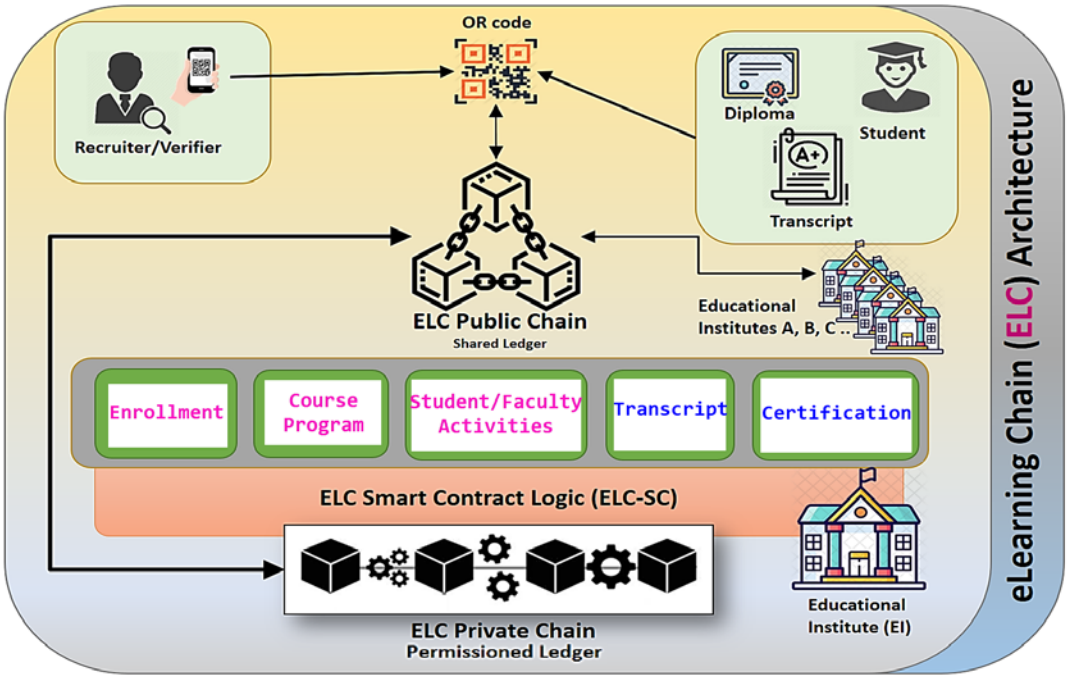

Figure 2: The e-Learning Chain (ELC) System Architecture.

5.2 SMART CONTRACT LOGIC (ELC-SC)

The ELC-SC entails an immutable software with a preset of conditions "if y happens, execute z action" stored in the ELC blockchain. It is considered a deterministic logic to automate the education program decision transactions across the ELC ledger. For example, if students pass the course, then log the grade and move student's eligibility to the next course. Another example, if the student completed all course requirements, then updates the transcript, and issue a verifiable certificate.

The advantages of embedding ELC-SC are

Efficiency: where the automation is the crux of the mini-digital agreements between the student and the institute. Backend processes for enrollment, escrow, and issuance of certificates are logged as per contract agreements/program policies, eliminating the need for middleman/manual work.

Security: ELC-SC is replicated every time new updates are written in a distributed ledger ensuring no central point of failure and high resistance to cyber-attack and availability issues. The ELC-SC safekeeping procedures support the security and privacy of faculty and students' content and activities.

Credibility and Reliability: enables the ELC-SC logic to be redundantly processed and verified by multiple nodes of ELC e.g. Registrar, College, and Accreditor. This counters the existing program, certification manipulation, and substantially reduces the rate of forgery.

Interoperability: ELC-SC can scale to integrate with other institute or authority blockchain and smart contracts, allowing a seamless, verifiable, and creditable process of a student wishing to transfer course credits to different colleges and universities.

Record Management: ELC-SC maintain information and identity management of students' activity lifecycle. It implements an association of students' records and accreditation authorities to facilitate the legitimacy and verification/coherence of credentials**.**

5.2.1 EDUCATIONAL INSTITUTE (EI)

The EI plays a vital role in the ELC ecosystem as the main driver and participant in the ELC chain. It represents the certification authority and provides the underlying infrastructure for the ELC system e.g. integration from legacy and current systems, creation of cryptographic ELC keys (public and private), maintaining the course program, issuing and revoking certificates. The EI should also be ready to integrate with other ELC chains e.g. other universities, accreditors, etc. to enable information exchange via the distributed ledgers that contain, for instance, student profile (course work, transfer of credits, and issued certificates) and other relevant features such as shared services/programs e.g. employers' gate**).**

5.2.2 ELC PUBLIC DLT

The ELC conceptual system provides a publically peer-to-peer shared and federated ledger that contains stored students' profiles based on the need to know the security principle. The ledger allows authorized parties such as auditors and recruiters to verify/cohere the student's credentials. This process can be as simple as scanning the ELC generated-QR-code associated with one's certificate to redirect the verifier to the ELC blockchain. If true, the public DLT should return the validity of the certification, name, and hash of the accreditor, name, and hash of the certification authority, and it goes along with the transcript and course work. Therefore, the ELC public ledger supports the

*Corresponding author (Fahad F. Alruwaili). Email: alruwaili@su.edu.sa Volume 11 No.16 ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8 Paper ID:11A16N http://TUENGR.COM/V11B/11A16N.pdf DOI: 10.14456/ITJEMAST.2020.323

certification authority in aiding for trusted and distributed certification management which in time helps discover and fight fraudulent qualifications and fake learning organizations.

5.2.3 ELC PRIVATE DLT

The private DLT governs the relationship within the education institute and between its colleges and departments. It tracks and logs immutably all the changes to the student profiles, program course work, university activities, and events. The main driver for this component is ELC-SC where a set of scripted agreements, policies, and conditions are stored in ELC private DLT. Modules of the private DLT are:

Enrollment: prospective and transferred students complete all the onboarding requirements where the admission office holds a node within the ELC private chain. Once the student passes the required admission tests and obtains the college approval, the ELC-SC changes the status to "active student" and the academic program engagement starts. A log of this transaction is stored in the private DLT and shared within the institute-engaged parties. This will unlock the next services e.g. student orientation, lecture schedule, etc.

Course Program: this module is set to ensure that the digital syllabus of a specific program has been, carefully, revised, and agreed upon using the ELC consensus algorithm (voting procedure). The approved syllabus hash is stored in the ledger to track changes and updates. This augments the program's credibility and improves program quality. It is recommended to integrate and track measurable metrics/indicators such as learning objectives and learning, to be programmable into ELC-SC.

Student/faculty Activities: to major the performance of a certain student, faculty, or college and to ensure fairness and credit to those who deserve recognition, this module tracks and logs accomplishments, and activities to student/faculty profile as part of his/her academic journey.

Transcript: every semester this module is triggered by ELC-SC upon course completion and to update student profile. The hash of this function is stored in the private DLT and will be made available once the student completes the program or requests a transfer or program and university clearness. The ELC-SC generates a QR code for this transaction hash.

Certificate: upon the successful completion of the program and student score, the ELC-SC is triggered to generate the graduation document which includes student blockchain certificate, transcript, student activities, and any miscellaneous. Every graduate will receive a unique ELC QR code printed in the diploma and points to a cryptographic address in the ELC blockchain for traceability and verification. The private DLT connects with the ELC public ledger only as a system assurance and as service level agreement (SLA) to allow verification and fraud detection.

5.3 STUDENT, RECRUITER, AND AUDITOR

ELC engaged student receives a cryptographic address linked to his/her digital credentials (similar concept to a digital wallet). It ensures the student has trusted, verifiable, and credible credentials. For access simplicity, the QR code can be shared with recruiters or third parties to verify the student history and academic profile. Only upon the student consent, the verification process can move forward, which s/he can allow/reject within the digital credentials wallet. The e-Learning Chain business processes are depicted in Figure 3.

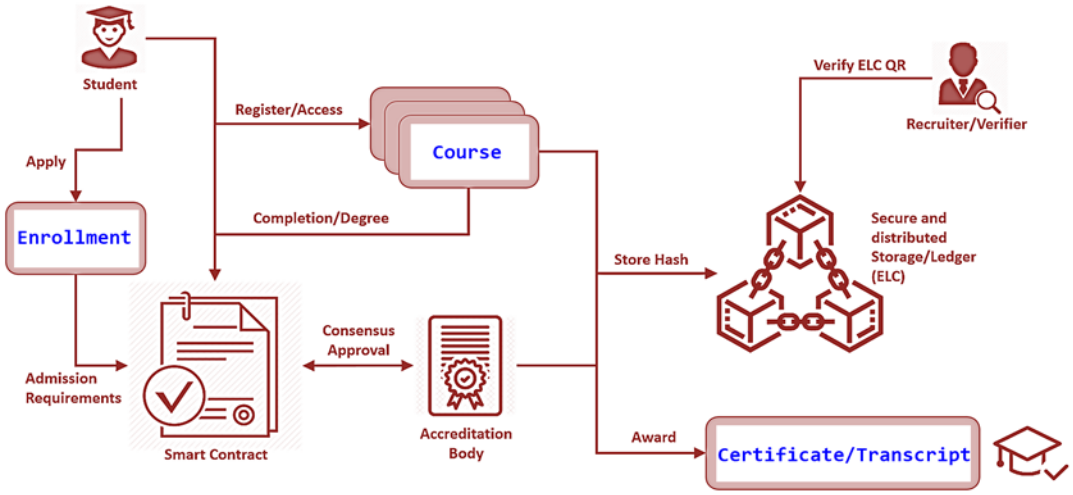

Figure 3. ELC Business Processes.

5.4 ALGORITHM FOR THE DESIGN OF SMART CERTIFICATES

This main module runs in each of the ELC business processes and also in the SC. Initially, the Private Blockchain of SC is accessed in ELC to settle the ongoing course credits of the user who is learning the course. This process is followed in order to decide whether to provide a digital-based certificate or not. If the overall credits are sufficient, then the module automatically generates the digital-based certificate. This certificate is stored in the SC Public Blockchain while completing the process of a double digital signature. The algorithm for designing the smart certificate is as follows:

```
login = Ok, Start_time == 0, credit_course = 0
If login == Valid and Start_time <= 0.4 hour:
    Then: Update learning_particulars;
If login == Not Valid or Start_time == 0.4 hour
    Then: SC = Smart_Contract(learning_particulars);
Address = SC_Address;
Send learning_particulars to address: Execute credit_course=SC_Address(learning_particulars);
If credit_curse = 1
    Then: Add block_credit to SC_Blockchain;
Issue (Smart_contract);
End If
End If
End If
```

6 CONCLUSION

This paper proposed an application of blockchain in e-learning. It sought to develop a model of e-learning based on blockchain-based technology, where the blockchain acts as a safeguarded distributed repository. The main motivation for this proposed methodology is to overcome the current challenges faced by the misuse of issuing educational credentials by many parties involved in the educational sector. A practical and secure ELC model using the Distributed Ledger Technology (DLT) and smart contracts to support the learning certification, verification, monitoring, and validation is proposed. Besides, the work suggests a reliable, trusted, and verifiable blockchain-backed repository for academic course work and student/faculty certification. The Design Science Research (DSR) methodology is also used to support the proposed methodology for devising an innovative and secure educational course and credential information systems. Future work in this area lies in the application of blockchain technology in extending for other e-learning based models.

*Corresponding author (Fahad F. Alruwaili). Email: alruwaili@su.edu.sa Volume 11 No.16 ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8 Paper ID:11A16N http://TUENGR.COM/V11B/11A16N.pdf DOI: 10.14456/ITJEMAST.2020.323

7 AVAILABILITY OF DATA AND MATERIAL

Information can be made available by contacting the corresponding author.

8 REFERENCES

Arenas R, Fernandez, P. (2018). CredenceLedger: A Permissioned Blockchain for Verifiable Academic Credentials. In *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, Stuttgart, Germany, 17-20.

Chen, G., Xu, B., Lu, M., & Chen, N. S. (2018). Exploring blockchain technology and its potential applications for education. *Smart Learn Environ*, 5(1), 511-519.

Cheng, J-C., Lee, N-Y., Chi, C., Chen, Y-H. (2018). Blockchain and smart contract for a digital certificate. In the *2018 IEEE international conference on applied system invention* (ICASI).

Gervais, A., Karame, G. O., Wüst, K., Glykantzis, V., Ritzdorf, H., & Capkun, S. (2016). On the security and performance of proof of work blockchains. In *Proceedings of the 2016 ACM SIGSAC conference on computer and communications security*, 3-16.

Han, M., Li, Z., He, J.S., Wu, D., Xie, Y., Baba, A. (2018). A Novel Blockchain-based Education Records Verification Solution. In *Proceedings of the 19th Annual SIG Conference on Information Technology Education*, Fort Lauderdale, FL, USA, 178-183.

Harper, K. C., Chen, K. Y., David, C. (2004). Distance learning, virtual classrooms, and teaching pedagogy in the Internet environment. *Technology in Society*, 26(4), 585-598.

Hasanova, H., Baek, U. J., Shin, M. G., Cho, K., & Kim, M. S. (2019). A survey on blockchain cybersecurity vulnerabilities and possible countermeasures. *International Journal of Network Management*, *29*(2).

Hevner, Alan, and S. Chatterjee. (2010). Design Science Research in Information Systems, In Design research in information systems, 9-22, Springer Boston.

Jirgensons, M., & Kapenieks, J. (2018). Blockchain and the future of digital learning credential assessment and management. *Journal of Teacher Education for Sustainability*, *20*(1), 145-156.

Khandelwal H., Mittal K., Agrawal S., Jain, H. (2020). Certificate Verification System Using Blockchain. In: Gunjan V., Senatore S., Kumar A., Gao XZ., Merugu S. (eds), *Advances in Cybernetics, Cognition, and Machine Learning for Communication Technologies*, Lecture Notes in Electrical Engineering, 643. Springer, Singapore.

Kosba, A., Miller, A., Shi, E., Wen, Z., & Papamanthou, C. (2016). Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In *2016 IEEE symposium on security and privacy (SP'16)*, 839-858.

Mitchell, I.; Hara, S.; Sheriff, M. (2019). dAppER: Decentralised Application for Examination Review. In *Proceedings of the 2019 IEEE 12th International Conference on Global Security, Safety and Sustainability (ICGS3)*, London, UK, 1-14.

Nespor, J. (2019). Cyber schooling and the accumulation of school time. *Pedagogy, Culture & Society*, *27*(3), 325-341.

Sharples, M., and Domingue, J. (2018). The blockchain and kudos: A distributed system for the educational record, reputation and reward. Adaptive and adaptable learning, Springer, Cham, 490-496.

Sharples, M., Domingue, J. (2016). The Blockchain and Kudos: A Distributed System for

Educational Record, Reputation and Reward. In: Verbert K., Sharples M., Klobučar T. (eds) *Adaptive and Adaptable Learning*, EC-TEL 2016, Lecture Notes in Computer Science, 9891, Springer, Cham.

Turkanović, M., Hölbl, M., Košič, K., Heričko, M., & Kamišalić, A. (2018). EduCTX: A blockchain-based higher education credit platform. *IEEE Access*, *6*, 5112-5127.

Watters, A. (2016). *The blockchain for education: an introduction*. http://hackeducation.com/2016/04/07/blockchain-education-guide.

Zheng, Z., Xie, S., Dai, H., Chen, X., Wang, H. (2017). An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. In *IEEE International Congress on Big data*, 557-564.

Zhong, J.; Xie, H.; Zou, D.; Chui, D.K. (2018). A Blockchain Model for Word-Learning Systems. In Proceedings of the *5th International Conference on Behavioral, Economic, and Socio-Cultural Computing*, Kaohsiung, Taiwan, 130-131.

Dr.Fahad F. Alruwaili is an Assistant Professor in the College of Computing and Information Technology, University of Shaqra, Saudi Arabia. He is a cybersecurity and risk management consultant. He received a BS degree in Computer Engineering from King Fahd University of Petroleum and Minerals, Saudi Arabia. He received an MS degree in Computer, Information, and Network Security with first-class honors from DePaul University, Chicago, IL USA, and an MS degree in Information Systems and Technology with first-class honors from Claremont Graduate University, Los Angeles, CA, USA. He received a PhD degree in Electrical Engineering from the University of Victoria, Victoria, BC Canada. His research interests are in the Technical and Theoretical views of Cybersecurity, Blockchain, and Digital Transformation.