DEVELOPMENT OF A BLOCKCHAIN-AS-A-SERVICE PROTOTYPE TO ELECTRONICALLY CERTIFY ONLINE STUDENT'S ACADEMIC QUALIFICATIONS: A CASE STUDY AT AN ONLINE PRIVATE UNIVERSITY IN THE UNITED STATES

Tikajit Rai

I.D. No. 6072503

A Dissertation Submitted in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in eLearning Methodology

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By: TIKAJIT RAI

Dissertation Advisor: ASST. PROF. DR. POONSRI VATE-U-LAN

Accepted by Graduate School of Business and Advanced Technology Management, Assumption University in Partial Fulfilment of the Requirements for Doctor of Philosophy in eLearning Methodology

K. Phothikitti

……

(Assistant Professor Dr. Kitti Phothikitti)

Dean of Graduate School of Business and Advanced Technology Management

Dissertation Examination Committee:

Nopphon T

…….. **Chair**

(Asst. Prof. Dr. Nopphon Tangjitprom**)**

Poonsri Vate-U-Lan

……**Major Advisor**

(Asst. Prof. Dr. Poonsri Vate-U-Lan**)**

Chanintorn Jitt

…… **Committee Member**

(Asst. Prof. Dr. Chanintorn Jittaviriyanukool**)**

…… **Committee Member**

(Asst. Prof. Dr. Rawin Vongurai**)**

…… **Program Director**

(Dr. Somsit Duangekanong**)**

Date of Examination: October 30, 2021

ABSTRACT

I.D. No.: 6072503

Key Words: BLOCKCHAIN, CONSENSUS MECHANISM, CREDENTIAL, DISTRIBUTED LEDGER TECHNOLOGY, HYPERLEDGER, TECHNOLOGY ADAPTATION MODEL

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The objective of this research was to create a laboratory grade prototype to demonstrate how blockchain-based online certification system can easily verify students' academic qualifications and to investigate among the research participants whether the Perceived Ease of Use (PEoU), the independent variable, of such solution would have influence towards their eventual Behavior Intention to Use (BIU), the dependent variable. There were three specific objectives to achieve this: 1) to create the laboratory grade blockchain-based prototype for demonstration purpose; 2) to test UI/UX of the prototype; and 3) to conduct a survey among participating students at the online private university in the United States.

This research used a mixed method of qualitative and quantitative methods. For the first two objectives, a qualitative method was used, whereas for the last, quantitative method was selected. For the first two, straightforward software testing procedure was adopted with limited testers. For the quantitative research, Pearson's correlation coefficient statistical tool

was used to analyze data from a total of 159 students to determine how the independent variable was related to the dependent variable. The Power*G analysis was used to determine population samples that represented active students at the target university. Further, IOC and Cronbach's Alpha was used to test content validity and reliability of the quantitative research questions. Face validity test was also administered on the infographic guide.

A simple blockchain- and web-based prototype was created along with a supplementary infographic as a guide for the students to understand the experience to effectively participate in the quantitative research. The quantitative data analysis showed that the two variables, PEoU and BIU, were positively correlated, $r(159) =. 68$, $p < .05$. Resultantly, it was concluded that at the significance level of 0.05, the null hypothesis was false. Hence, there were both linear relationships and significance between PEoU and BIU. In other words, the participants did perceive that the prototype was relatively easy to use, and therefore, to this effect, there was a likelihood that they will adapt their behavior to use the service.

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Finally, amid deadly COVID-19 pandemic which challenged the humanity's very existence, if it was not for those individuals who radiated intense positivity despite their loved ones were lost and showed me hope and resiliency even when sustained situation was deeply grim, my scholarly inquiry may have never reached fruition. I am profoundly humbled and inspired by it. As a result, my appreciation towards humanity also expanded infinitely. For my part, my appreciation towards these people and institutions they represented shall only grow over time without any delineation.

Tikajit Rai, Ph.D.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
ASP	Application Service Provider
BaaS	Blockchain as a Service
BI	Business Intelligence
BIU	Behavior Intention to Use
BFT	Byzantine Fault Tolerance
BW	Bandwidth
CBE	Competency-Based Education
CRM	Customer Relationship Manager
DB	Data Block
DID	Decentralized Identifier
DV	Dependent Variable
DLT	Distributed Ledger Technology
FCC	Federal Communications Commission
FAQ	Frequency Asked Questions
GB	Genesis Block
GPA	Grading Point Average
HLC	Higher Learning Commission
IaaS	Infrastructure as a service
ICT	Information and Communications Technology
ID	Identity
IT	Information Technology
IRB	Institutional Review Board
ISP	Internet Service Provider
IOC	Item Objective Congruence
ITU	International Telecommunication Union
IV	Independent Variable
LMS	Learning Management System
MIT	Massachusetts Institute of Technology
NIST	National Institute of Standards and Technology
PaaS	Platform as a Services

PEoU	Perceived Ease of Use
PDF	Portable Document Format
PMI	Project Management Institute
PMP	Project Management Professional
POI	Proof of Importance
POA	Proof of Authority
POS	Proof of Stake
PKI	Public-private Key Infrastructure
RBFT	Redundant Byzantine Fault Tolerance
SaaS	Software As A Service
SEVP	Student and Exchange Visitor Program
SD	Standard Deviation
SDK	Software Development Kit
SPSS	Statistical Package for the Social Sciences
USC	University of Southern California
SSI	Self-Sovereignty Identity
SSIA	Software & Information Industry Association
TAM	Technology Adaptation Model
UI	User Interface
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
U.S.	United States
UX	User Experience
VC	Verifiable Credential
VR	Virtual Reality
ZKP	Zero-Knowledge Proof

CHAPTER I

INTRODUCTION

1.1 Background of the Study

Academic transcript is an integral part of a student's overall scholastic learning experience. For any post-secondary student, if an academic transcript verifies enrollment status and reflects scholastic performance towards a specific program, the degree certificate provides proof of academic attainment. In contrast, a professional development certificate verifies an individual's achievements in developing non-academic but industry specific skills-set and expertise. In the United States, when a student pursued further education in another institution within the country, the student was required to provide official copies of the transcripts. Official copies of transcripts were those that were sent to the pursued institution directly from the alma mater, in a signed and sealed envelope (Walden University, 2020). The rationale behind this requirement of providing sealed hard copies of these documents directly to academic institutions via postal mail was to prevent the possibility of the sender submitting fraudulent documents and make sure that the transcript reached the addressee untampered.

Additionally, in the United States, potential employers also would require a candidate to present proof of both academic and professional achievements during the hiring process. One of the processes to verify a candidate's achievements was identical to that of pursuing further education in another institute as discussed in the preceding section. As a result, candidates were required to request degree and certificate issuing institutes to mail hardcopies of the transcript and degree certificate, and diploma, respectively, to the potential employer. Academic institutions in the United States were fully cognizant of this requirement, including the three universities that are investigated in the research. According to Walden University's

Frequently Asked Questions (FAQs) page (2020), the university offered the fee-based service of mailing official transcripts to both the academic intuitions and employers.

Same also applied to international students and professionals who would want to either continue higher education or seek job opportunities in the United States. Not all academic institutions in other countries may have had transcripts in English language. In case of a transcript being in the local language of the applicant, a certified third-party agency's service could be rendered to translate the document. On the other hand, if the grading system differed from the Grade Point Average (GPA) system of the United States, the earned credits were required to be evaluated by an independent credential evaluation service to determine equivalency. The U.S. Department of Education stated that there was no single authority in the United States for recognition of foreign degrees and other qualifications (U.S. Department of Education, 2008). Therefore, translation and evaluation of the earned degrees and credits outside of the United States were subject to respective internal practices adopted by the domestic academic institutions and the employers.

In the context of foreign students continuing higher education in the United States, there were both reputational and financial reasons why U.S. based higher academic institutions desired international students enrolled in their programs. According to Hegarty (2014), “the number of international students present at a university made a significant contribution to the “personality” of that institution, and to its financial well-being.” It made a logical sense for these institutions to attract foreign students because it increased diversity in their student bodies and out-of-state tuition fees were, in comparison to in-state, better revenue sources. Despite the reputational and financial motivations, due to the absence of a unified process in place to certify

students' academic qualifications among academic institutions globally, history of fraudulent efforts to tamper such important documents, however, were evident.

In the backdrop of international student enrollments increasing in higher academic institutions by 3.2 % in 2015, with 1.19 million in total (U.S. Immigration and Customs Enforcement, 2016), a Northern Virginia Community College in Commonwealth State of Virginia, alone had 150 students investigated for academic transcripts fraudulence (McCarthy, 2015). In the same year, an admissions official at University of Southern California (USC) was embroiled with helping three unqualified international students to gain graduate level admissions for which the official pleaded guilty (Department of Justice, U.S. Attorney's Office, Central District Columbia, 2020). Based on data available at Student and Exchange Visitor Program (SEVP), U.S. Immigration and Customs Enforcement, Depart of Homeland Security, the enrollment in 2018 rose to 1.55 million (U.S. Immigration and Customs Enforcement, 2018). With the 30% enrollment increase over the 3-year period from 2015, logically, the number of fraudulent cases was expected to increase significantly: if not in the same proportion to the then increasing enrollment rate.

In the United States, during the time of the research, the online delivery model for higher education was rapidly growing while acceptance rate of such academic degrees by employers was still less favored. Online program intakes had quadrupled compared to 2015's against its counterparts, the traditional brick-and-mortar universities, with 75% new enrollment growth rate (National Center of Education Statistics, 2018). In the backdrop of growth in online learning demands, in contrast, employer acceptance rate was relatively slow. As observed by Roberto and Johnson (2019), the results indicated that those making selection decisions for hiring employment applicants viewed face-to-face degrees more positively than online degrees.

Furthermore, Roberto & Johnson (2019) also stipulated that the finding was considerably more pronounced for employers making new hiring decisions than for those making promotion decisions. Compared to the rapid transition from traditional to online delivery models, it is interesting to view that the process of acquiring an official copy of a transcript had not made any advancement, whatsoever.

The subject of professional diplomas offered by non-academic organizations was also worth including in the research. Competency-Based Education (CBE) had increasing demands due to an ever-changing market environment. Although relatively new as the U. S. Department of Education released a letter endorsing them only in 2013 (Association of Governing Boards of Universities and Colleges, 2014), the certificates for professional development were relatively more accepted and recognized by employers. For example, a U.S. based Project Management Professional (PMP) certificate from Project Management Institute (PMI) had been around for 34 years (Webster, 1994) and had been a highly recognized certification in the project management domain. The employers seemed to make an exception in such a case, because the electronic copy provided by the applicant would suffice. In other words, the certificate issuing body did not need to mail an official copy of the diploma.

From a view of advancement of Information and Communications Technology (ICT), or Information Technology (IT), service providers had rolled out unified communications services delivering voice, text, and multimedia over multiple wideband mediums. At the time of the research, there were 2,664 Internet Service Providers (ISPs) in the United States offering internet services over a combination of copper, fiber, fixed wireless infrastructure (Broadband Now, 2020). Coupled with cost-effectiveness of broadband due to competition in the internet service market and ICT advancement for last-mile accesses in urban

parts of the country, the local academic institutions were well positioned to deliver rich and interactive content for online consumers. According to the United States Federal Communications Commission (2020), the broadband speed, or bandwidth (BW), was rated at 25 Mbps/3Mbps upload/download for fixed, and 10Mbps/3 Mbps for mobile, respectively. Interestingly though, as of 2018, 25 million individuals out of 326.69 million total U.S. population in the country, which stood at 7.6%, still did not have access to broadband internet access. Most of these people hailed from rural areas where last-mile accessibility was still being developed (FCC, 2020), and followed the global trend where some rural and remote communities in other countries were even likely to remain largely unconnected (ITU, 2019).

In the realm of security and authenticity of documents that were shared electronically, digital signatures that used a mature digital signature technology, the Public-private Key Infrastructure (PKI), made a creditable sense as a potential solution to replace the manual process. However, there were only limited and sporadic developments among some U.S. universities to use it as a mechanism to electronically certify (e-Certify) a person's academic qualifications. University of Notre Dame and University of Southern California, for example, provided e-transcript in Portable Document Format (PDF) that were digitally signed which then students could access using a pre-time-sensitive assigned passcode. The problem was that, in general, neither academic institution at large, nor employers deemed it foolproof to prevent tampering. It was evident that, despite rapid and continual ICT advancements, ever decreasing wideband internet service costs, and growing acceptance of digital experience and footprints in social media, there had not been a working and broadly consensus-based unified solution for sharing electronic academic qualifications between one person or entity to another securely, and time- and cost- efficiently; and that without compromising integrity of the data, and privacy of those who would participate in the transaction.

1.2 Statement of the Problem

From the view of digital customer experience, in which online services were delivered through platform independent user devices and were highly personalized to every customer's needs, the traditional process (termed as manual process in the research) of sharing records of academic qualifications of a person (termed as learner in the research) was excessively rudimentary. For a lifelong learner who would prefer virtual offerings and embark on a continuous learning journey, the manual process severely undermined the idea of complete eLearning experience (Pine & Gilmore, 1998). Further, contrasting observation was that the then ongoing focus on the content delivery model of courses that are designed and developed around the available Learning Management System (LMS) and student experience enhancement tools was substantially high compared to any efforts resourced to enhance the process of creating, tracking, and sharing student's academic and professional qualifications in digital space. Although Showcase e-Portfolio of an individual was prerequisite for both continued education and job placement (Ciesielkiewicz, 2019), the manual process of mailing sealed hard copies of academic qualifications not only undermined the available ICT capabilities and effectiveness thereof, but also broke the expected seamlessness of eLearning experience. The research, therefore, delved deeper from two broad set of problems that the manual process inherently had: time- and cost- inefficiency; and risk of fraudulence through tampering. Following sections discuss the stated problems further.

1.2.1 Inefficient Manual Process for Learners to Share Academic Qualifications

First, for both domestic and international learners, having to request their alma maters to mail the official copy of academic qualifications was not only time inefficient, but the manual process was an impediment to overall digital customer experience in eLearning.

Second, when learners entered the job market, the same manual process was required to be carried out to share the academic qualifications to potential employers. Moreover, for international job opportunities, the waiting period extended beyond weeks for the physical documents to reach the potential employer. In some cases, some employers would not choose to wait that long, reducing an applicant's chance of getting interviews significantly.

Finally, the manual process was equally cost-ineffective. As regular mail would take relatively more days to reach the destination, students needed to resort to a more expensive alternative: the courier services. The local courier service fees in Asia would vary, but for such service, the average cost for mailing documents was US$ 270 (Penn State Office of the University Registrar, 2018; Transcript Request, 2018; and The University of Arizona Office of the Registrar, 2018). This average cost did not include parity in currency exchange rate from one country to another. Therefore, international students from any emerging economies would have to pay more due the strength of U.S. Dollars against their local currencies.

The research does not investigate the cost-inefficiency problem as deep as other stated problems, however. Reason being, first, the research would be too broad and would diverge substantially from the dissertation's focused scope. Second, determining the cost savings due to the proposed solution of the research as a viable substitute of the manual process was rather deemed infeasible because technology investigated for the research was still in its innovation stage and the prototype would be limited only to a laboratory version. Lastly, the pricing models had not taken shape in the industry for possible adaptation of blockchain technology in general towards solving problems that were similar to what the research aimed to address.

1.2.2 Exposed Risk of Fraudulent Academic Qualifications

Although the idea behind using sealed hardcopy of academic qualifications for both continued education and employment scenarios was to detect if the document was tampered did have some merit, it equally exposed the risk of everything it tried to prevent. Considering the incidents of Northern Virginia Community College (McCarthy, 2015) and USC (Department of Justice, U.S. Attorney's Office, Central District Columbia, 2020), it was evident that institutions at times did entirely fail to detect the tampered documents. In the former case, students themselves seemed to have submitted fraudulent academic documents, whereas in the latter, the human interface in the admissions process bore fraudulent behavior.

Related to an employment in which the applicant tampered with the academic qualification, one case that highlighted the degree of fraudulence was hiring of a full-time nursing instructor in the college of applied science, Brown Mackie College Albuquerque, New Mexico, United States, in 2015 (St. Louis Post-Dispatch, 2017). The case involved both stolen identity of a qualified nurse and fraudulent academic qualifications claiming graduate of Georgetown University, Washington D.C., United States. As alarming as it sounded, Monster.com, one of the largest global employment agents, in its survey of 400 applicants and 400 hiring managers in 2019, found a strong correlation with falsifying academic history: "25% claimed they had a degree from a prestigious university instead of their own" (Monster, 2019). To make the trend even more concerning, the same survey found that "Academic Embellishment" as the number one resume lies followed by informing incorrect past employment dates, and made-up skills-set.

The diagnosis of the problems discussed above created an opportunity to conduct this research. The research, therefore, not only investigated solutions to an existing real-life

problem, but also explored technological advancements that helped selecting available and appropriate open-source resources to create a laboratory equivalent of a prototype to use as one of the research instruments to help complete the research.

1.3 Research Objectives

The general research objective was to investigate blockchain frameworks and Distributed Ledger Technology (DLT) to develop a laboratory grade web-based prototype that could simulate blockchain-as-a-service (BaaS) and demonstrate it is secure with privacy protection of the users, it can e-Certify academic credentials on a real-time basis, and whether its ease of use could influence users to adapt to using it if such solution existed. To this effect, there were three specific research objectives for which further investigations were carried out through mix-methods to address the research problems.

1.3.1 To Create a Laboratory Grade BaaS Prototype

First objective was to create a laboratory version of a functional blockchain technology-based prototype to demonstrate how the learner creates an account in the blockchain, receives verifiable academic credentials from the issuing institution, and how the next institution or employer can verify that the credentials are true. The test of the prototype would include standard back-end test and first iteration of usability test by the researcher. The two tests would be carried out through a qualitative method.

1.3.2 To Conduct the Prototype Usability Test

The more comprehensive usability test would be built on to the preliminary usability test that was completed under the first research objective. To complete this iteration of the test, multiple testers would be selected from different professional backgrounds, namely, project manager in ICT or IT field, Webmaster, and academic administrator.

1.3.3 To Investigate Relation Between Ease of Use and Using e-Certify Service

First and second research objectives would play a critical role for the third and final research objective. It would investigate correlation between Perceived Ease of Use (PEoU) of BaaS prototype and Behavior Intention to Use (BIU) to determine whether the former variable would have any relation and significance to the latter one resulting in increased motivation of research participants to using the blockchain type service to e-Certify their academic credentials if it existed. This linear regression type of research instrument was derived from the Technology Adaptation Model (TAM) to frame the quantitative survey questions to collect and analyze the data to test against research's null hypothesis. The survey would be conducted among the population sample of target university as determined by research instruments discussed in Chapter III. The TAM is discussed in detail in the last section of Chapter II.

1.4 Research Questions

The following research questions were considered to achieve each of the three research objectives:

i) What would be the result of preliminary usability test of the prototype?

ii) What would be the result of final usability tests of the prototype?

iii) Would there be a correlation and significance between the two variables: PEoU and BIU?

1.5 Significance of Research

At the time of the research, this graduate academic endeavor appeared to be one of the few first of its kind based on literature found and studied in which frontier technology was used to develop a prototype as a solution to replace what the research has termed as a manual

process. To this effect, the significance of the research was four-fold. First, it created additional knowledge in using blockchain- and DLT- based technologies in the education domain. In it, it would spur innovation and facilitate learning on how consensus mechanisms would be used, and the outcome would be applied to advancement of the blockchain technology itself. The research would also help drive the frontier technology towards maturity for broader acceptance across a multitude of industries.

Second, in the blockchain realm, smart contracts are fundamental to its framework. Using DID and other trust creating schemas, particularly ZKP, creates a solution that does not in fact require smart contracts. It necessitates hybridity between public and private blockchain frameworks which, consequently, the research contributes towards smart-contract-less solution for e-Certifying academic transcripts.

Third, the research helped understand the problem that impacted significant numbers of students, thereby raising public awareness among the three specific target user groups: students; academic institutes; and employers. As a result, it would motivate industry actors to create business development opportunities which, in turn, would enhance overall digital customer experience for target users in eLearning.

Finally, data ownership of educational qualifications by academic intuitions would be disrupted due to the inherent properties of both blockchain and DLT which consequently would eliminate the idea of institutions being the third-party central authority. The policy and governance around data sharing because of this disruption would inevitably facilitate broader conversation on data privacy, co-ownership, monetization of e-Certification service based on blockchain and distributed approach of doing business in general.

1.6 Definition of Terms

Blockchain Business Network: A network created by participants in the blockchain who would abide by policies and rules established and agreed by the participants themselves to approve transactions without any third-party dependency (Szabo, 1997).

Blockchain Technology: A network of distributed shared ledgers across nodes to record transactions. Multiple nodes as governed by the users' rules and policy, it reaches consensus to self-execute a transaction and store its replica on the ledgers of the entire nodes. It is redundant and distributed, because of which it is very difficult for transactions to be rescinded, or forged (Hoy, 2017).

Competency-Based Education (CBE): A learning system in which students are expected to fully acquire defined and prescribed competencies through a self-paced modules that comprises a greater learning outcome constituting the accumulated sets of multiple competencies. Student receives a certificate of completion based on the mastery of prescribed competencies (Matsuzuka, 2020).

Consensus Mechanism: A process in which a certain majority of blockchain network participants agree on a proposed transaction. It takes place prior to updating the ledgers across the nodes of the blockchain. The process is governed by a set of agreed-on rules and procedures that all participants adhere to. Consensus algorithms allows nodes in the blockchain to work together as a group to reach the consensus and creates redundancy to tolerate failure of any nodes during the execution of a transaction. Due to the increasing interest in distributed ledger designs and blockchain, various consensus mechanisms had surfaced and, to list a few, were Proof of work (PoW), Proof of Stake (Po), Proof of Importance (PoI), and Proof of Authority (PoA) (Zhang, et al., n.d.).

Decentralized Identifier (DID): An identifier that enables verifiable and decentralized digital identity of a subject, including that of a person (W3C, 2021), over a given distributed network.

Distributed Ledger Technology (DLT): A form of digital database that is updated and shared a copy to every qualifying node of the blockchain network. The nodes therefore hold the ledger collectively but create and update it independently. In contrast to centralized locations to hold an official copy of the ledger, all network participants would have their own (Norman, 2017).

Linux Foundation Hyperledger Blockchain Project: Linux Foundation was a non-for-profit and non-governmental technology consortium that was founded in 2000. It supported many open-source projects including the Hyperledger. Under the Hyperledger project umbrella, multiple open-source blockchain frameworks were produced, including Indy, Iroha, and Sawtooth (Hyperledger, 2020).

Micro-learning: An approach to learning of a single, specific material through a compact and focused teaching (Maddox, 2018). A micro-learning course therefore could be compared with a chapter of a standard course.

Public Key Infrastructure (PKI): The technology behind digital certificates which uses public and private keys to encrypt and decrypt electronic messages, respectively. Each key has a distinct feature, consequently calculating the private key from the public key was computationally infeasible (Jegadeesan et al., 2021).

Showcase e-Portfolio: A demonstration of "learner competencies and achievements by illustrating what has been learned and does not merely describe what has been learned" (Abrami and Barrett, 2005).

Technology Adaptation Model (TAM): The model that shows how the individual's salient beliefs predict user behavioral intention to use a given system, which, in turn, predicts his/her actual system use (Davis, 1989).

Usability Test: An assessment of user's perception to what extent effectiveness, efficiency, and satisfaction are achieved against baseline goals of a system, product, or service (Barnum, 2020).

1.7 Limitations of the Research

As population samples were active students at a private and 100% online American university, the study was focused only with a specific student group within a single institute that included both undergraduate and graduate students across programs. The study, however, did not investigate whether students in undergraduate programs may have responded differently to the final research questions compared to that of graduate degrees. In addition to this vertical stratification, the horizontal one would be whether students in technology-oriented programs – IT or ICT program for example – would respond to the same questions differently. The research focused only on one university without discriminating between programs and attainment degrees that students were enrolled in. Furthermore, the research neither included traditional university students, nor from hybrid institutes that have both online and face-to-face courses.

There were a number of other types of qualifications which were not considered as part of the research scope. For example, qualifications attained through CBE, Micro-learning, and professional certification programs were not included in the research. Although the same process could be scaled and replicated to e-Certify other types of transcripts and certificates, only limited scope of higher education credentials was focused during the research.

Additionally, there were other types of artifacts that supported the learner's professional development journey but were not included in the research. To name a few, they were digital badges, and letters of recommendations which could be very well e-Certified by the same type of service.

The prototype was limited to a laboratory version to investigate relation and significance between the independent and dependent variables. Therefore, it was not expected to go through some of the standard tests for cloud-based solutions, particularly, network security and load testing. Furthermore, the prototype, as stated in the third objective, was used as part of research instruments to help population samples get high-level understanding of how blockchain and DLT based solutions would work. Hence, the prototype was not expected to be industry tested, or commercial-ready. As far as the technological aspect of the prototype is concerned IBM's open-source Hyperledger blockchain was researched. The inherent limitations of Hyperledger Indy, compared to other public and private blockchain technologies, the prototype also carried forward the same limitations. The limitation was the rationale behind not including the Perceived Usefulness variable in the reduced version of TAM II.

Finally, during the research, numerous blockchain innovations may have taken place. To control the research's scope from overflowing and to manage the progress, the research mainly based its investigation and the findings from the first two years out of the total three-year duration the researcher took to complete the dissertation.

1.8 Scope of Research

The meet the three main research objectives, there were following investigations and artifacts that needed to be completed and delivered, respectively:

i) Qualification attainment level for the research

ii) Selection of U.S. based 100% private online university

iii) Determine population sample size

iv) Design research instruments

v) Data collection and analysis

1.8.1 Qualifications Attainment Level for the Research

Although both academic and professional achievements are subject to blockchain based e-Certification solutions, the research specifically focused only on the higher education qualifications. It was because those with college degrees would fit the population sample requirements as they either continue further education or pursue employment.

1.8.2 Selection of U.S. based 100% Online University

There were few 100% online universities in the United States the research identified. Out of these universities, the one that promoted and welcomed external researchers the most was selected. The selection of the university also factored in accreditations, student enrollment numbers, and pioneering online teaching and learning history.

1.8.3 Determine Population Sample Size

Population sample size was determined to be at least 153 students based on students that were enrolled in both undergraduate and graduate programs at the selected university. Furthermore, the population sample were modeled after those who were active during the time of research at the target university.

1.8.4 Design Research Instruments

During the design of the prototype, there were two types of tests: Back-end and usability. Appropriate research instruments were designed to test and release the functional version of the prototype that would be used for the research.

The prototype was expected to be used as part of the survey instruments to investigate if students will use such solution if they find it easy to use. For this, the necessary research instrument was designed and utilized to collect the data from at least 153 students from the selected university.

1.8.5 Data Collection and Analysis

Based on the research instruments designed, the data was collected, analyzed, and compared against the hypothesis the research framed. Statistical analytical tools as research found appropriate were used to analyze the data. Finally, based on the findings, the research was concluded with its high-lights, discussions, and recommendations.

1.9 Organization of Research Chapters

After this introduction chapter, the following successive chapters are laid out in the text in logical order to discuss the research plan, selected research methods and rationale behind it, how the research was conducted, and finally the findings with recommendations.

i) Literature review

ii) Research methodology

iii) Data analysis and Results

iv) Summary and Conclusion.

CHAPTER II

LITERATURE REVIEW

This chapter constitutes a scholarly review of earlier works related to blockchain technology in general and expected to provide history in the subject matter and relevance of such works to this research. The review process involved online desk research to identify blockchain related resources, followed by study of available scholarly articles, published books, and other online credible sources from the internet.

The literature review sheds light to what blockchain really was and its relevance to the research objectives. Notwithstanding the blockchain technology hype, the technology itself was relatively new at the time of the research; as a result, online available resources were substantially consumed as primary sources for the literature review.

Remainder of the literature then investigated costs and time associated with the manual process of providing official and sealed copy of student's transcripts for both continued education and employment.

2.1 Blockchain

Blockchain's evolution started with Satoshi Nakamoto's paper that was published in 2008 (Nakamoto, 2008). The paper proposed a peer-to-peer digital cash system which gave birth to Bitcoin in 2009. This peer-to-peer network allowed people to make transactions in which they send and receive coins from each other in the form of a token, the Bitcoin. The transactions were bundled into a block, then chain-linked with previous blocks by its hash value. The researcher illustrates in Figure 2.1 how each block is connected to the one before and after, creating the chain of blocks: the blockchain. Each block contains the previous block's hash, therefore, if any of the block is tampered, the mismatch in hash breaks the chain, making it tamperproof. Although the blockchain technologies are available in many types of

frameworks, irrespective of their types, it retains the same fundamental components, which are Genesis Block (GB); Data Block (DB); and Blockchain (Pourmajidi, et al., 2020). GB is the first block of any blockchain and has a predefined set of characteristics. As there are no previous blocks, the index and previous hash are both set to zero. The primary purpose of this block is to indicate the start of a new blockchain (Azaria, et al., 2016).

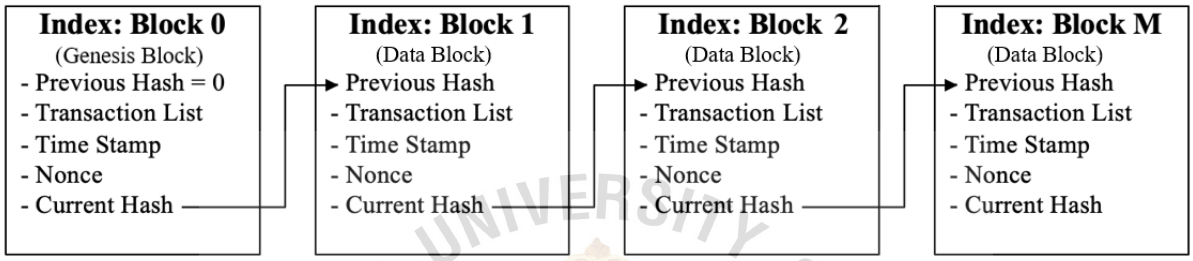

Figure 2.1: Blocks of Blockchain

As shown in Figure 2.1, a DB, more commonly known as a block, contains the following variables: index, timestamp, data (or transaction list), current hash, and previous hash. The first element, index, is a unique sequential identity (ID) for each block to identify each successive block. The timestamp indicates the time at which the block is created. The data is the most important element of a DB. It contains valuable information which makes it immutable.

Essentially, blockchain is DB linked together through the binding hash of preceding blocks, which is also known as hash binding. The nonce is an arbitrary random number that is used to generate a specific current hash. To achieve hash binding, each block includes a previous hash element. The previous hash is the exact duplicate of the current hash of the previous block. In other words, as shown in Figure 2.1, the current hash of the M-th block becomes the previous hash of block M + 1. (Pourmajidi, et al., 2020). If data in the preceding

block are tampered, the link among all the subsequent blocks down to the most recent block will then be broken.

2.2 Blockchain Nodes

Blockchain is a distributed network of computers, or devices, which are referred to as nodes. Each node, as a distributed ledger, maintains the security and accuracy of the information by keeping a copy of the complete set of ledgers of past transactions. When a new block is successfully created by an authorized network member, the newly created block will be broadcasted to the entire blockchain network, allowing all nodes to update their respective ledger with the most updated information (Tschorsch & Scheuermann, 2016).

2.3 Consensus Mechanism: Redundant Byzantine Fault Tolerance

In distributed ledgers, prior to updating the ledger, a consensus mechanism is the process in which a certain majority of blockchain network participants agree on a proposed transaction. The process is governed by a set of agreed-on rules and procedures that all participants adhere to. Consensus algorithms allow nodes in the blockchain to work together as a group to reach the consensus and creates redundancy to tolerate failure of any nodes during the execution of a transaction. Due to the increasing interest in DLT designs and blockchain, various consensus mechanisms have surfaced and, to list a few, are Proof of work (PoW), Proof of Stake (PoW), Proof of Importance (PoI), and Proof of Authority (PoA) (Zhang, et al., n.d.).

In this article, the Redundant Byzantine Fault Tolerance (RBFT) is of particular interest as it is the consensus mechanism that Hyperledger Indy is inherently compatible with. RBFT is a modified version of Byzantine Fault Tolerance (BFT) consensus mechanism, which uses replication protocols that tolerate arbitrary faults of a fraction of the replicas of the protocol themselves (Aublin, et al., 2013).

In RBFT, multiple instances of the same BFT protocol, each with a primary replica, are executed in parallel on different machines. All the instances order the requests, but only the requests ordered by one of the instances, called the master instance, are actually executed. Meanwhile, the performance of the different instances is closely monitored, to check if the master instance yields expected performance, or not – for example, time taken to execute the instances. If that is not the case, the primary replica of the master instance is considered malicious and replaced by another primary replica. This new approach through RBFT increases the performance to that of other existing most robust protocols when there is no failure and that, under faults, its maximum performance degradation is about 3%, whereas it is at least equal to 78% for existing protocols (Aublin, et al., 2013).

2.4 DID and its Components

A DID is a new type of identifier that enables verifiable, decentralized digital identity of a subject, including that of a person (W3C, 2021), over a given distributed ledger. This is also a globally unique persistent identifier that does not require a centralized registration authority because it is generated and/or registered cryptographically (W3C, 2021). As shown in Figure 2.2, a DID has other supporting components to make the application practically feasible. Following paragraphs describe more on each of the components.

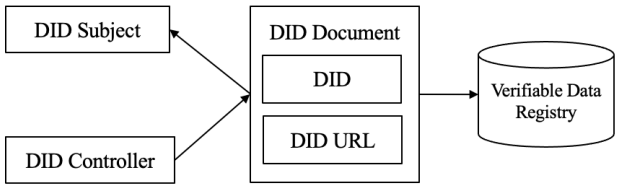

Figure 2.2: High-level View of Interacting DID Entities

Source: World Wide Web Consortium (W3C). (2021). Decentralized Identifiers (DID) v1.0. W3C. https://www.w3.org/TR/did-core/

2.4.1 DID URL

A DID is also a Uniform Resource Identifier (URI) which is used for resources on the Web, parallel to every webpage having its globally unique Uniform Resource Locator (URL) – also referred to as the website address. There is also a DID URL, however, which includes an optional DID path to incorporate other standard URI components such as path, query, and fragment in order to locate a particular resource (W3C, 2021). Both DID and DID URL are part of the overall DID Document.

2.4.2 DID Document

A DID Document describes the DID Subject, DID Controller and Verifiable Data Registry (see Figure 2.2), including mechanisms, such as cryptographic public keys, that the DID subject can use to authenticate itself and prove its association with the DID (W3C, 2021). DID documents storing cryptographic public keys internally, or a resource external to the DID document itself are examples of the DID Document.

2.4.3 DID Subject and Controller

A DID is, by definition, the entity identified by the DID. Anything can be the subject of a DID, including person, group, organization, thing, or concept. In similar fashion, the DID Controller can be an entity including a person, organization, or autonomous software that has the capability to make changes to a DID document. This capability is typically asserted by the control of a set of cryptographic keys used by software acting on behalf of the controller, though it might also be asserted via other mechanisms. A DID can have more than one controller, and the DID subject can be the DID controller itself (W3C, 2021).

2.5 Shared DLT

In a traditional sense, ledgers that record transactions of business within a network were centrally maintained. For example, banks would have their own ledgers centrally hosted in their network. Likewise, businesses which have accounts with the banks would keep their own ledger, as well as a record and evidence to match the bank's. As a result, this traditional process created redundant copies of the ledger by different bookkeepers thereby rendering it an inefficient way of doing business.

In case of DLT, transactions were broadcasted through a network that all parties have agreed to be part of, then each party's bookkeeper updated his or her ledger. In comparison with traditional ledger, there was only one shared system of record, replicated to each party in the form of blockchain. Therefore, each blockchain was distributed (Tapscott & Tapscott, 2016) by design. For example, students, academic institutions, training providers, and employers were part of a blockchain business network. As the student earned grades and attained degrees and CBE certificates from academic institutions, they were stored in the blockchain. As agreed by all, each party could securely access information in real-time from one system of record. In other words, the ledger was shared between participants in the business network, whereas each participant owned a copy. Further, as the ledger was permission-based, each party could see only appropriate transactions. Going back to the example, employers then would have access to information of students related to grades, certificates, and even courses students. In contrast, training providers would have access to only the certificates that they have issued to students.

2.6 Smart Contract in Blockchain

A smart contract is a computer program that has a set of business rules which is embedded in the blockchain itself and is executed at the time of the transaction. It has self-

verifying, self-executing, tamper-resistance properties which allows executing codes without the need of third parties guaranteeing the execution (Szabo, 1997). The content of the smart contract are value, address, functions, and state (Bahga & Madisetti, 2016). Further, these contracts are both trackable and irreversible, and once executed, the updated information is recorded in the ledger. Because of these properties, smart contract is critical in blockchain applications as it enables peer-to-peer transactions and the database can be maintained publicly making it transparent, and at the same time, secure. The other advantage of smart contracts is that it eliminates essentially all paperwork making the process both time and cost effective.

2.7 Privacy in Blockchain

The participants of the blockchain business network share a common system of ledger. In each transaction, the ledger is replicated across different participants of the network through peer-to-peer replication properties of the smart contract. The privacy service is used to determine which participant sees what on the business network. For example, if participant A and B are exchanging assets, and as per contract, both will see the full details of the transaction (Rennock, Cohn, & Butcher, 2018). If a third participant, say bank for example, is not expected to see the transaction as per contract, it will not. This control is implemented via privacy service in blockchain.

Participants need confidentiality between subsets of participants in the business network. Blockchain makes it easier for network users to be pseudonymous (Rennock, Cohn, & Butcher, 2018), and therefore, identity is not linked to the transactions.

2.8 Authentication and Encryption with Public-Private Key

Blockchain identification (ID) takes the center stage for authenticating the transaction. During the transaction, the ID, which is essentially a block of data on the chain, is tied up with a public key that is generated by default and gets ownership of the private key

transferred to the participant who initiated the transaction. Public key cryptography allows the participant to sign the signature that can be verified against the public key stored in the blockchain (Cresitello-Dittmar, 2016). While the cryptography authenticates the participants, it also ensures transactions are done safely and all information are secure at the instance of the transaction.

2.9 Trust in Blockchain

In blockchain applications, participants themselves endorse transactions before committing to the database. On the outset, the business network decides who will endorse the transactions for a blockchain, as a result, the participants are held responsible which, on the other hand, empowers their respective role in the network. Referring to privacy, one of the four elements of blockchain solution, the participants who endorse the transactions are aware of appropriate confidentiality that will always be implicated.

As each transaction is verified and stored in a block which is chained virtually with predecessor and subsequent one, it is a verifiable audit trail that has both provenance and finality properties (Swan 2015). Moreover, as these transactions cannot be modified, inserted or deleted, it provides property immutability as well, thus effectively boosting and reinforcing the trust across the blockchain business network. Also, because of a single system of truth across business network, any disputes thereof can be easily resolved (Swan 2015).

2.10 Types of Blockchains

Although there are many blockchain service providers, Bitcoin is the first well-known blockchain network with its first transaction initiated in January of 2009 (Toffler, 2017). What Bitcoin demonstrated is the implementation of necessary security aspects of DLT, such as central point of failure, double spending (how to avoid double payment in the network), and

immutability. Due to this success in implementation, many business entities are now providing blockchain services for different value propositions (see Table 2.1, with their web addresses).

Table 2.1: Available Blockchains in the Market

#	Names	URL	Open-Source
1	Ripple	https://ripple.com/	Yes, after 5 months
2	Ethereum	http://ethereum.org/	Yes, MIT license
3	NXT	https://nxtplatform.org/	Yes
4	Openchain	https://www.openchain.org	Yes
5	BitShares	http://bitshares.org/	Yes
6	Odem	https://odem.io	No
7	Hyperledger	http://hyperledger.com/	Yes

One way to categorize blockchain solutions are permission-less and permissioned: public blockchains are permission-less; and private and consortium ones are permissioned. Public blockchain, as the name states, allows everyone to view and initiate transitions into the ledger without permissions. In addition, any user can become participants of the business network and can validate transactions. As it operates in the public domain, there is not any single organization controlling the network.

In contrast, private blockchains have a central point for full-access rights, which means, write permissions are granted only to a single administrator. In recent years, however, hybrid blockchains have evolved on public blockchains. A consortium blockchain is very similar to a public blockchain except that only a group of pre-selected nodes, or permissioned nodes, would participate in the consensus process of the blockchain. Hyperledger Indy is such a blockchain. To participate in Hyperledger Indy, the network participant must have permission to become an active node, albeit the blockchain being public (Blockchain technology overview, 2020). Table 2.2 provides some of the popular blockchain brands (Hyperledger Indy SDK, 2018). Hyperledger Indy and Ripple are the ones that are both consortium types of blockchain technologies.

Table 2.2: Blockchain: Types of Access and Validation

#	Blockchain Types	Permissionless	Permissioned
1	Public	Bitcoin	Hyperledger Indy
		Ethereum	Ripple
2	Private	Hollochain	Hyperledger Fabric
		LTO Network	R3 Corda

Source: Hyperledger Indy SDK. (2018). DKMS (Decentralized Key Management System) Design and Architecture V3. https://hyperledger-indy.readthedocs.io/projects/sdk/en/latest/docs/design/005-dkms/DKMS%20Design%20and%20Architecture%20V3.html?highlight=permissioned%20#ledger-architecture

2.11 Zero-Knowledge Proofs

Zero-Knowledge Proof (ZKP) is a complex scheme designed to incorporate encryption techniques to enable a prover to certify the truthfulness of a statement to a verifier without disclosing any more specifics other than the statement itself (Goldreich & Oren, 1994). Further, Goldreich and Oren (1994) study also found that:

"Concerns about data privacy in shared environments are arising as distributed ledger technology is increasingly touted as a decentralized data transaction infrastructure that removes centralized control, in popular domains, such as finance, supply chain, and healthcare. Vital information that could be used to identify an individual, such as date of birth, social security numbers (in the United States.), employment information, and bank statements, is paramount to the safety and financial well-being of the identity owner. To safeguard sensitive information, initial applications of ZKP techniques have surfaced in DLT projects like the zk-SNAKRS protocol in ZCash."

Again, as per Goldreich and Oren (1994), "a true ZKP must possess the following three key properties:

i) Completeness: If the statement is true, an honest prover will convince the verifier.
ii) Soundness: If the statement is false, the verifier will find out the prover is dishonest with very high probability.
iii) Zero knowledge: If the statement is true, no extra information is revealed to the verifier other than the statement being true."

The literature review of the key terms above enables both holistic and detailed-level understanding of how DIDs enabled blockchain, the Hyperledger Indy, and its security features and consensus mechanisms work independently, but as a one integrated system. This acquired knowledge through this review adequately helps fulfill the research objectives. The next sections detail out research methodology and the findings.

2.12 Hyperledger Indy Architecture

Prior to creating the system architecture, a use case of leveraging Hyperledger Indy to e-Certify academic qualifications was created. Hyperledger Indy can be implemented with an easy method of working wherein initially a user provides his or her name as an identifier (Hyperledger Indy SDK, 2018). This identifier is then converted into a unique key known as DID. The key has an associated value with it that is called the DID descriptor object (DDO). Together they form a complete DID record. Users interact with each other using the public and private keys of the DID record, like the public key cryptographic method of Blockchain

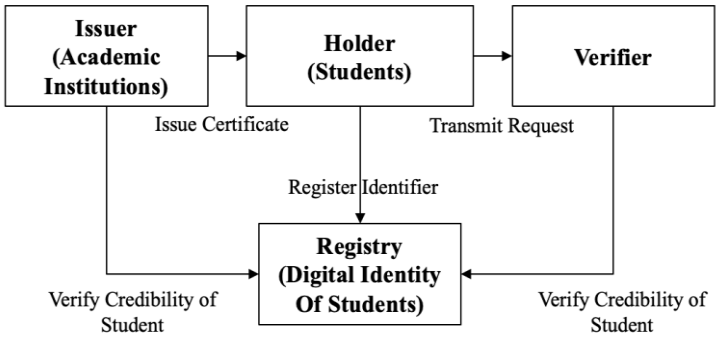

Figure 2.3: High-level Use Case of Blockchain Prototype

Source: Hyperledger Indy SDK. (2018). DKMS (Decentralized Key Management System) Design and Architecture V3. https://hyperledger-indy.readthedocs.io/projects/sdk/en/latest/docs/design/005-dkms/DKMS%20Design%20and%20Architecture%20V3.html?highlight=permissioned%20#ledger-architecture

Figure 2.3 above illustrates the use case of a recent graduate entering the job market. As one of the members of the blockchain business network, the Issuer is the academic institute student graduated from. The institution executes two tasks. First, it asserts the claim about the student's academic qualifications by writing VC as per identifier and schema in the blockchain enabled VDR, or the Registry (see Figure 2.3). Second and last, the academic institution transmits the VC to the Holder, or the graduate in this case.

The Holder creates a profile with his or her name as an identifier to create a DID record that has verifiable presentations of the VC: the academic qualifications. The graduate presents the VC to the Verifier, or the employer in this case (see Figure 2.3). Through the use of ZKP scheme, the Holder does not even need to disclose any information to the Verifier like in the case of showing a physical academic transcript (Hyperledger Indy SDK, 2018). As long as the verification process checks out right that the Holder has in fact all the credentials as per the employer's requirements, the e-Certification process is completed.

The graduate may acquire additional VCs, professional development certificates, for example, and associate them to the same DID for which identifiers and schema can be updated in the blockchain enabled Registry (see Figure 2.3). The Verifier then verifies both identifiers and schema presented by the student in read mode with that of the Registry. The four components in Figure 2.3 are further described below:

i) *Holder:* Student who requests the copy of certified credential from Issuer and controls the credentials.

ii) *Issuer:* Any academic institutions, as well as professional certificate providers qualify as the issuers for issuing & granting credentials to the student who requests for the same after verification.

iii) *Verifier:* Verifier is the entity that checks and verifies the credibility of the student (or requestor) using consensus mechanism.

iv) *Registry:* Repository that holds records of all digital identity users

2.13 Self-Sovereignty Identity (SSI)

In general, Self-Sovereignty Identity is a feature of an identity system, whereby individual users maintain control over when, to whom, and how they assert their identity. When the users are given greater control over how their identity, also referred to as ID, issued by a third and formal party, is managed can also be considered as self-sovereign. Further, nowadays, physical and digital worlds have become tightly connected, making self-sovereignty of digital identity as critical as protecting physical identity (Houtan, et al., 2020).

Self-sovereignty is also closely linked to decentralized identity systems. In contrast, these often don't rely on a third and formal ID provider, but the idea is more on removing control of the identity system from any single point of institutional control. As stated early in the body of text, the Hyperledger Indy's framework is created for DIDs, and features of self-sovereignty are very much inherent with it.

2.14 Cost of Submitting Official Transcript

Within the United States, the universities process the requests of sending an official transcript within 24 hours of receipt and charge an average US$12 for processing and US$30

for mailing, respectively (see Table 2.3). Then between five to seven days, the hardcopy transcript would reach the concerned party. In the case of Walden University, the processing fee was US$15 whereas mailing fee is paid by the applicants (Walden University, 2020). Following table lists processing and mailing fees that some of the U.S. universities charge for transaction within the country:

Table 2.3: Processing and Mailing Fees for US Universities

#	Academic Institutions	Processing Fee	Mailing
1	Penn State University	$10	$30
2	Ashford University	$10	$40
3	Arizona State University	$15	$23

Source: Penn State Office of the University Registrar. (2018). Official Transcripts. https://www.registrar.psu.edu/transcripts/transcripts.cfm

Transcript Request. (2018). How to Order Your Transcripts from the University of Arizona Global Campus. https://www.ashford.edu/transcript-request

The University of Arizona Office of the Registrar. (2018). University of Arizona Transcript. https://www.registrar.arizona.edu/transcripts/

Having alma-mater submit official and sealed transcripts within the U.S. academic institutions and employers were comparatively quicker and less expensive. Contrary to this situation, for international students, the number of days for processing and costs were significantly higher, and the process itself was rather extensive and laborious. If the alma-mater was an international university, then there were following standard ways of verifying and evaluating equivalency, which would consume higher processing fees and substantially more days in processing costs compared to transactions that take place between institutions within the United States:

i) Degree-only verification

ii) Course-by-course verification

iii) Credential evaluation

Table 2.4: International Transcript Evaluation Cost

#	Data Sources	Translation	Evaluation	Shipping	Total
1	WES (2018)	$50	$205	$25	$280
2	ECE (2018)	$50	$195	$25	$270
3	AERC (2018)	$450	$200	$25	$275

(Currency in U.S. Dollars)

The implicated costs for overall paper-based official transcript evaluation costs are illustrated by Table 2.4 above. Based on the data in the table, on an average, translation, evaluation and shipping fee amounted to US$270 for one-time processing fee. When students applied to multiple universities for higher education or companies in the United States, shipping costs increased accordingly. In addition, if there was a preference of each academic institution and employer for third-party service providers, learners then bore multi-fold costs in this scenario. According to Homeland Security, the United States Government, there were collectively over one million international students enrolled in multi-disciplinary degrees in higher education up until the month of March in 2018 (Study in the States, 2018). Out of the total, 77% of all international students were Asians. Based on the average cost of a single transaction of evaluating a transcript, which was US$270 dollars, the total expended fees for Asian students alone amounted to 207.9 million U.S. dollars.

Wait time to complete the evaluation process varied from one country to another based on the quality of service each country's service provider offered. Moreover, there was an additional wait time for the transcript to reach the target international university or employer. To put the actual wait time into perspective, for example, regular postal service in country of Nepal would take up to 15 days to deliver the evaluated transcript to the target university or

employer in the United States. With the local service provider's pace of completing translation and evaluation, the total wait time easily exceeded multiple weeks.

Compared to in the pace of online learning was evolving with technologies such as Virtual Reality (VR) and Augmented Reality (AR) and Artificial Intelligence (AI) for students' enhanced experience in learning, the process of submitting original and sealed copy of transcript to academic institutions and employers was the single most ignored experience in the overall digital learner experience. As a result, learners need to go through laborious and costly processes for their continued education and professional development journey. If academic institutions and training providers would have means to access learner's academic and competency achievements electronically, in real-time and, through a trusted and unified source, this added service would benefit all three stakeholders – students, universities, and employers – making the digital learner experience much better.

2.15 CBE

Standard higher education programs, albeit traditional, hybrid or 100% online, were focused more on teaching, where the assessments in the form of quizzes and semester exams were administered to measure how much learners or students have acquired knowledge and are able to apply. This top-down approach had programmatic packaging of stipulated courses and credits that students were required to fulfill seat time to attain a certain academic degree. Hybrid or 100% online programs provided flexibility to learners in terms of when to finish a course, but not necessarily what specific skills-set or competency students wanted to further.

CBE, in contrast, focused on the results of education. In other words, learner's performances were based on what they can do with what they know. Consequently, CBE was gradually replacing the concept of higher education as it specifies desired outcomes and emphasizes on evidence of student's performance. In March 2013, the U.S. Department of

Education released a letter endorsing CBE, encouraging institutions to seek federal approval for programs that did not rely on credit hours as a measure of learning (Rebecca, Stanley & George, 2014).

At the time of the research, there were already many universities in the United States offering Higher Learning Commission (HLC) approved CBE programs. The programs included program and project management, nursing, accounting, and criminal justice. The students would demonstrate their mastery of the materials through summative and formative assessments, group discussions, presentations, case study, and writing assignments. Once CBE was completed, the learners would receive a certificate of completion.

2.16 Software as a Service (SaaS)

SaaS is centralized software service delivery model in which subscription by a user is licensed. As part of the three delivery models proposed by National Institute of Standards and technology (NIST) (Mell & Granc, 2011) – other two being, Infrastructure as a Service (IaaS) and Platform as a Service (PaaS) – it provides services to users without installing any application locally. Using thin clients, such as web browser alone, users can access SaaS services that include, but not limited to, management information systems, enterprise resource planning, office applications, collaboration tools, content management, LMS, media hosting, and service desk management.

Prior to SaaS, the service delivery model preceded by what was known as Application Service Providers (ASPs). The model differed because ASPs would not have their own software but limited to hosting others'; was a client-server architecture which required software installation in personal computers; and would use separate instances over SaaS' multi-tenets capability. The term SaaS first seemed to have appeared in 2001 in an internal article of Software & Information Industry Association (SIIA) (Software & Information Industry

Association, 2001). The article states that SaaS is “commonly referred to as ASP model”, indicating SaaS model had not evolved and graduated into a next successive service delivery model from ASP. Depending on the service requirements, the three delivery models can be subscribed. In out-of-box solution is required, SaaS is the preferred model.

2.17 Identity Wallet

Identity Wallet is a digital container that belongs to a single digital identity owner. Owner can be a person, or an organization whose identity is associated with an identifiable location on a hardware (Hyperledger Indy SDK, 2018). The owner’s secrets can be kept in distributed fashion in multiple devices through key and relationship management. This in turn guarantees security and privacy of that owner hardware (Hyperledger Indy SDK, 2018). In the blockchain context, Hyperledger Indy wallet stores credentials, encryption and signing keys for transactions relating to verifying credentials.

2.18 Blockcerts

Blockcerts, short for blockchain Certificates, started as one of the Bitcoin blockchain projects at Massachusetts Institute of Technology (MIT) Media Lab with collaboration with Learning Machine. In 2018, the project delivered a tested set of tools, software, and strategies to store and manage digital credentials that are cryptographically signed and tamper-proof (Blockcerts, 2018). After many rounds of prototype enhancements, an open-source project was launched under the flagship of Blockcerts.org for others to test, further develop and deploy Blockcerts across sectors. Blockcerts has following four components:

i) Issuer – Academic institutions and training providers

ii) Certificate – Open badges compliant

iii) Verifier – Any party in the business network

iv) Wallet – electronic repository of students or learners

Although the project provides references for software implementation, documentation, and source code (under MIT open-source license), the solution was very generic and needs significant tailoring to apply for a specific group of participants in Blockcerts network. In this regard, a consortium of institutions, training providers, an employers needed to be formed in coordination with the organization to push this idea to make it a reality.

2.19 Theoretical Model of Technology Acceptance

In the context of users accepting the use of information technology, Davis's original Technology Acceptance Model (TAM), as shown in Figure 2.4, was the most widely applied model of users' acceptance and usage of technology (Venkatesh, 2000). The TAM is rather simple but tested for its validity and reliability since 1989 therefore is a robust framework to understand user acceptance. The model shows how the individual's salient beliefs (perceived usefulness and perceived ease of use) predict user behavioral intention to use a given system, which, in turn, predicts his/her actual system use (Davis, 1989).

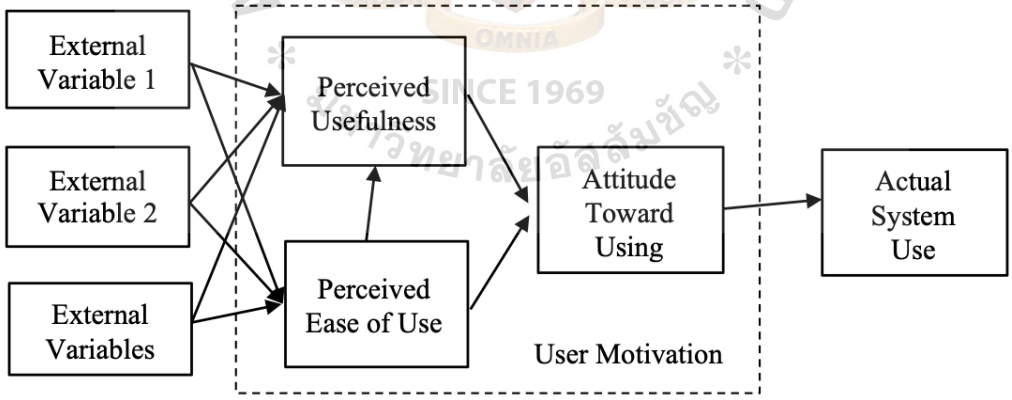

Figure 2.4: Original TAM

Source: Davis, F. D., Bagozzi, R. P. & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. Management Science, 35, 982-1003

Over the years, the TAM model has evolved, and most recently modified TAM is known as TAM 2, as shown in Figure 2.5. The “Attitude Toward Using” in original TAM is replaced by “Behavioral Intention to Use (BIU) indicating either “Perceived Usefulness”, or “Perceived Ease of Use” (PEoU) directly influences user’s behavior over merely his or her attitude toward using the system. In other words, system adoption and usage in TAM 2 takes comparatively quicker.

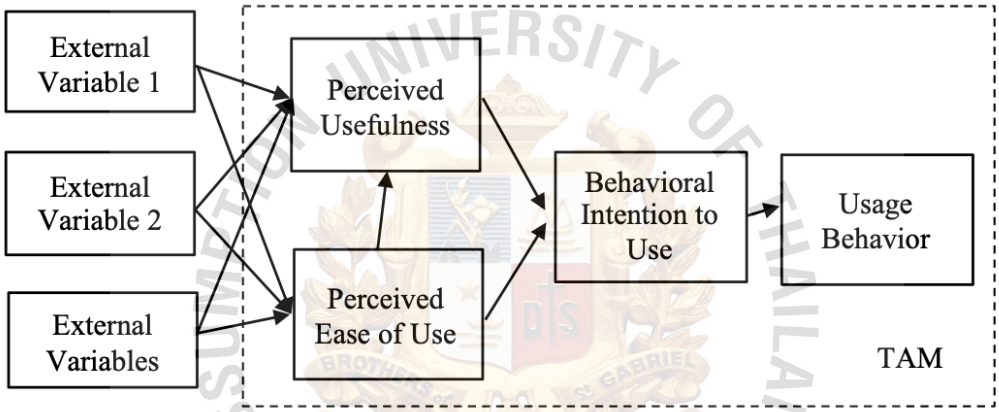

Figure 2.5: Original TAM modified: TAM 2

Source: Venkatesh, V., Davis, F.D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Management Science 46(2):186-204. http://dx.doi.org/10.1287/mnsc.46.2.186.11926

The framework was well suited for the research as well for framing the investigation to understand students’ perception towards BaaS and its influence over behavioral intention to use it. As the research requires also to design, develop, and test the prototype utilizing IBM’s Hyperledger opensource blockchain technology, to limit the scope in research objective 3, the framework is reduced to a sub-set with only one independent and dependent variable (see Figure 2.6). Additionally, as the prototype would not be a commercial-ready application,

considering “Perceived Usefulness” variable in the research would be premature. In fact, considering this variable would undermine the investigation because limitations of the prototype would likely sway the responses of the participants towards merit-less and undesired results. Therefore, the Independent Variable (IV) in this case is PEoU, and Dependent Variable (DV) is BIU. During the survey with sample population, data will be collected to investigate correlation between these two variables.

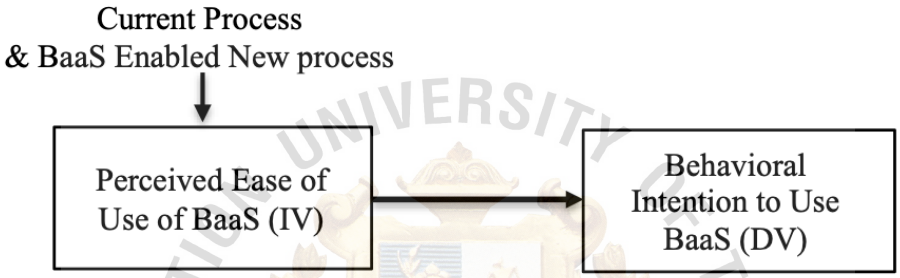

Figure 2.6: Research Framework

Source: Researcher’s deduction from TAM 2

2.20 The Research Conceptual Framework

Based on the research problem, objectives and questions stated in Chapter I, Figure 2.7 provides a pictorial view of the research’s conceptual framework. It includes context, variables and output, concept, and principle.

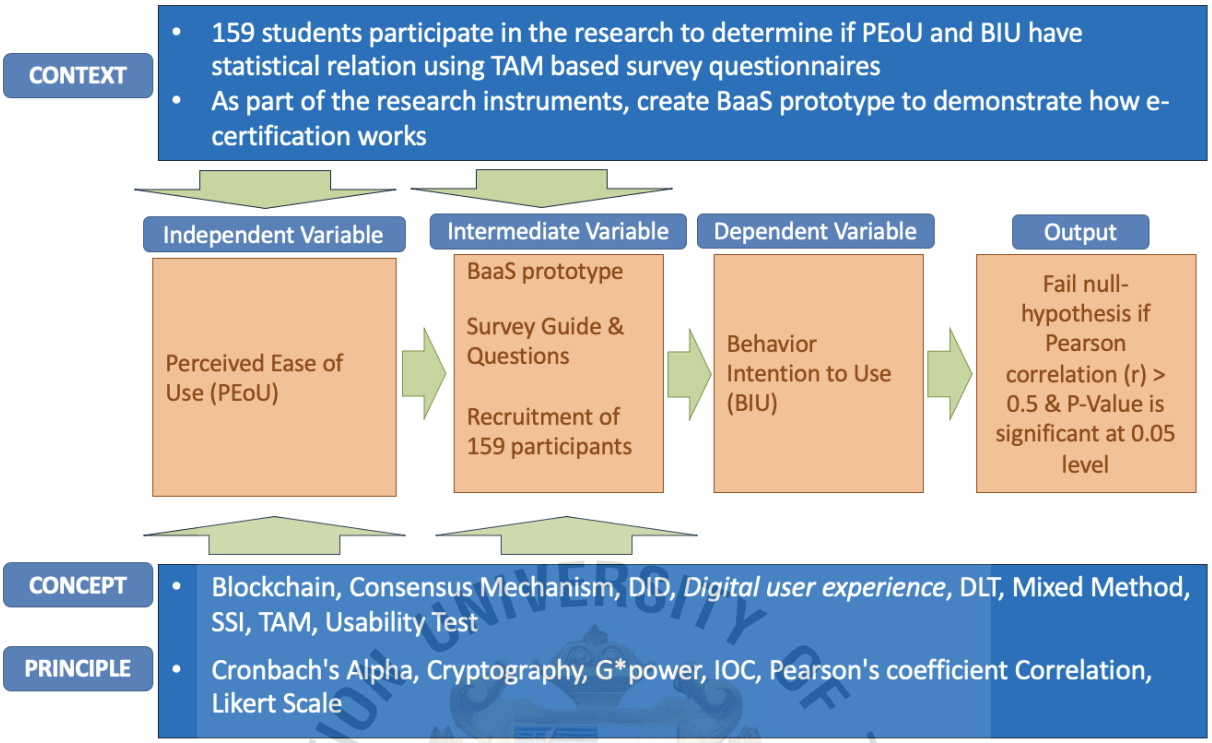

Figure 2.7: The Research Conceptual Framework

First, the context in which the research was conducted had two components. One was the accredited 100% online private higher education institution in the United States. Then at least 153 participants would be recruited. Second, there were following five types of variables that fed into the research output:

i) Independent variable is the PEoU of the participants and is discussed in the previous sections.

ii) Intermediate variables are BaaS prototype, survey questions, and recruitment of at least 153 participants that will collectively influence the BIU of the participants.

iii) Dependent variable is the BIU of the participants and is also discussed in the previous sections.

Finally, concepts and principles considered were following:

i) Concepts of Blockchain, consensus mechanism, DID, Digital user experience, DLT, Mixed Method, SSI, TAM, and usability test were collectively used to create research instruments of the research.

ii) Principles of Cronbach's Alpha, Cryptography, G*power, IOC, Pearson's coefficient Correlation, and Likert Scales were collectively used in the research for various purposes which are discussed in the next chapter.

CHAPTER III

RESEARCH METHODOLOGY

The research conceptual and theoretical frameworks discussed in the previous chapter for development of laboratory version of functional blockchain prototype and investigate if PEoU on operating the prototype has significant relationship with BIU, respectively, laid out the foundation for carrying out the research work to achieve the three research objectives that collectively answered the research questions. To that effect, this chapter discusses, in a methodical order, i) research scope, ii) assumption, iii) design, iv) determining population sample, v) research instrument development, vi) reliability & validity of research instrument, vii) data collection, viii) data analysis methods, and finally, ix) research action plan, for each of the research objectives.

3.1 Research Scope

There were few parameters that helped draw scope boundaries of the research, and it is important to reiterate in this chapter as well. First, the blockchain prototype that was created was limited to laboratory version only. It was because the prototype was part of the research instruments, and the purpose was to simulate overall experience and the workflow of how it would work so that students who would participate in the research would be able to respond to quantitative survey questions that would eventually help test the research hypothesis.

Second, usability testers in achieving objective 2 were not all from the selected university. Rationale behind this was to bring a diverse skills-set and expertise to view the prototype from a design thinking perspective. As a result, testers were a mix of web designer and ICT professionals with User Interface (UI) and User Experience (UX) expertise, students, and an employer.

Finally, during the data collection stage, students within the population sample were provided with an infographic of a prototype to answer the survey effectively. If purpose of the infographic was to explain to the participants what the blockchain prototype is, and why it is secure for both data and privacy.

3.2 Research Assumptions

To help fulfill the third and final research objectives, only students from the population sample participated in the research. Employers and other universities were not part of the participants, because the assumption was that students would drive the demand for such service to replace the *manual* process.

3.3 Research Design: Mixed Method

The overall research to fulfill the three research objectives was carried out through a mixed method. The rationale behind this was that the research objectives are broken down to two parts. First two research objectives complement each other more closely than the third because the first two are related to the usability test of the prototype. First preliminary usability test was conducted by the researcher alone, whereas the second was conducted by diverse testers as discussed in the Research Scope section in this chapter. As the tests are strictly centered towards the prototype's usability, a qualitative approach was deemed appropriate. Based on this rationale, the qualitative survey questionnaires are discussed in the first two research objectives sections below.

The third research objective was about the target population sample's perception on how easy it is to use the prototype and its relationship with their intention to use it. For this reason, a quantitative approach was considered to test the research's hypothesis. As far as analysis of gathered data was concerned, Pearson's Correlation Coefficient tests was deemed appropriate because it would test the direction and significance of relationship between IV (or

PEoU) and DV (or BIU) which is also discussed in TAM framework in the preceding chapter. The research instruments, including null and alternative hypothesis, and survey questionnaires are discussed in the research objective 3 section in this chapter.

3.4 Respondents and Sampling Procedure

3.4.1 Target Population Sample

A U.S. based private 100% online university was selected as the academic institution for the research through critical case purposive sampling method. Table 3.1 shows the top for-profit U.S. based online universities offering a variety of cross-disciplines programs and various degrees and certifications. Walden University had the greatest number of programs with 107, with Phoenix's 85, and Capella's 63, respectively.

Table 3.1: United States Online University Programs and Degrees

#	Universities	Doctoral	Master'	Bachelor's	CBE	Total
1	Walden	36	47	17	7	107
2	Capella	22	24	8	9	63
3	Phoenix	8	30	26	21	85

Sources: Walden University. (2018). *Students, Alumni, Faculty and Employers.* https://www.waldenu.edu/-/media/Walden/files/about-walden/data/data-students-alumni-faculty-employers-sept-2019final.pdf?la=en

Capella University. (2018). Programs. https://www.capella.edu/programs

Phoenix University. (2018). Degrees & Programs. https://www.phoenix.edu/

Walden University also had the highest number of Doctoral programs compared to master's and bachelor's making it a graduate-degree oriented university. In contrast, University of Phoenix, on the other hand, had comparatively more certificate-based programs with 21 against Capella University's 9, and Walden University's 7, respectively. Collectively, the CBE

programs included business, counselling, nursing, project management, psychology, and public health certificates.

3.4.2 Sampling Units

Overall Target University Population

When modeling the baseline to determine population sample size, Walden University's data was used. As shown in Table 3.2, during the time of the research and based on available data, Walden University had 50,360 active students with a significantly higher number of students in graduate programs at 84%. Also, compared to male student numbers, female counterparts were relatively higher as well with 65.3% and 76.5% for undergraduate and graduate programs, respectively. 18.4% and 4% students in undergraduate and graduate programs, respectively, did not disclose their gender.

Table 3.2: Graduate and Undergraduate Students and their Genders

#	Degrees	Enrollment	Male (%)	Female (%)	Undisclosed (%)
1	Graduate	42,336	18.5	76.5	0.4
2	Undergraduate	8,024	16.3	65.3	18.4
	Total Students =	**50,360**			

Sources*:* Walden University. (2018). *Students, Alumni, Faculty and Employers.* https://www.waldenu.edu/-/media/Walden/files/about-walden/data/data-students-alumni-faculty-employers-sept-2019final.pdf?la=en

US Employment Opportunities Based on Education Attainment

According to the U.S. Bureau of Labor Statistics (2018), there were 809 types of professions in 2018. Out of 319 types of professions that required higher education degrees, undergraduate degree holders were into 172 different professions which amounted to 54% of the total (see Figure 3.1). Those with doctoral or professional, master's, and associate degrees

had employment possibilities in 63 (20%), 37 (11%), and 47 (15%), types of professions, respectively.

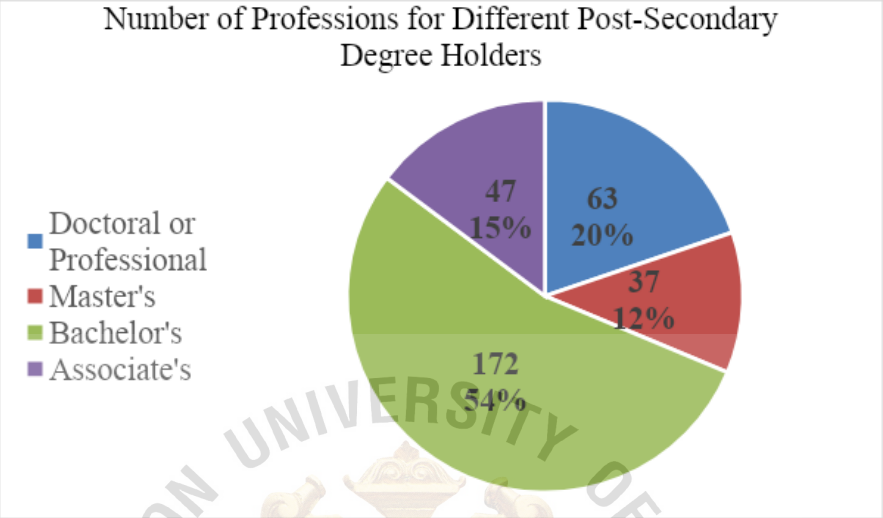

Figure 3.1: Number of Professions for Different Post-Secondary Degree Holders

Source: U.S. Bureau of Labor Statistics. (2018). Education and training assignments by detailed occupation. https://www.bls.gov/emp/tables/education-and-training-by-occupation.htm

In addition to 139 professions that required post-secondary degrees, there were 490 additional types of professions that required only following types of qualifications:

i) High school or equivalent

ii) Post-secondary non-degree award

iii) Some College or no degree

iv) No formal education credentials

Table 3.3: Degree Attained vs. Employed and Who Continued Education

#	Degree Attained	Graduates	Employed (%)	Continued Education (%)
1	Graduate	352,000	80.7	NA
2	Undergraduate	1.1 million	72.3	20.0
3	Associate	374,000	75.0	36.9

Source: U.S. Bureau of Labor Statistics. (2019). College Enrollment and Work Activity of High School Graduates News Release.https://www.bls.gov/news.release/archives/hsgec_04252019.htm

The U.S. Students Continuing Higher Education

The U.S. Bureau of Labor Statistics (2019) also stated that 1.8 million people between the ages of 20 and 29 earned college degrees in 2018 and either joined the work force or continued education for higher degrees. Table 3.3 provides a breakdown of numbers on who joined the workforce and continued education at the year-end based on degrees attained by the graduates.

Table 3.4: Graduate Rate in the United States among Men and women

#	Year	Men	Women
1	**2014**	64.0%	72.7%
2	**2015**	65.8%	72.6%
3	**2016**	67.4%	71.9%
4	**2017**	61.1%	71.7%
5	**2018**	66.9%	71.3%

Source: U.S. Bureau of Labor Statistics. (2020). College enrollment rates of recent high school graduates 16 to 24 years old by sex, race, and Hispanic or Latino ethnicity, October 1993-2019. https://www.bls.gov/opub/ted/2020/66-point-2-percent-of-2019-high-school-graduates-enrolled-in-college-in-october-2019.htm

The U.S. Students Enrolling into College by Gender

Based on the U.S. Bureau of Labor Statistics (2020), from 2014 to 2018, women's, or females' college enrollment rates of recent high school graduates aged between 16 and 24 years had been consistently higher than their counterpart men, or males (see Table 3.4). By extrapolating the five-year data, it was likely that the trend past 2018 had been the same for enrollment rates for both genders.

3.4.3 Determining Population Sample

Based on the data found during the research, there were two observations that can be made to help identify population samples for the main survey of the research. First, what United States Bureau of Labor Statistics data showed was that students who graduated in 2018 with undergraduate degrees were three times more compared to those who graduated with advanced degrees (see Table 3.3). In contrast, only 72.3% of 1.1 million undergraduates, against 80.7% of 352 thousand graduate degree holders, were employed in 2019. This comparative dip in the employment rate was, however, justified by 20% of undergraduates pursuing higher-level degrees.

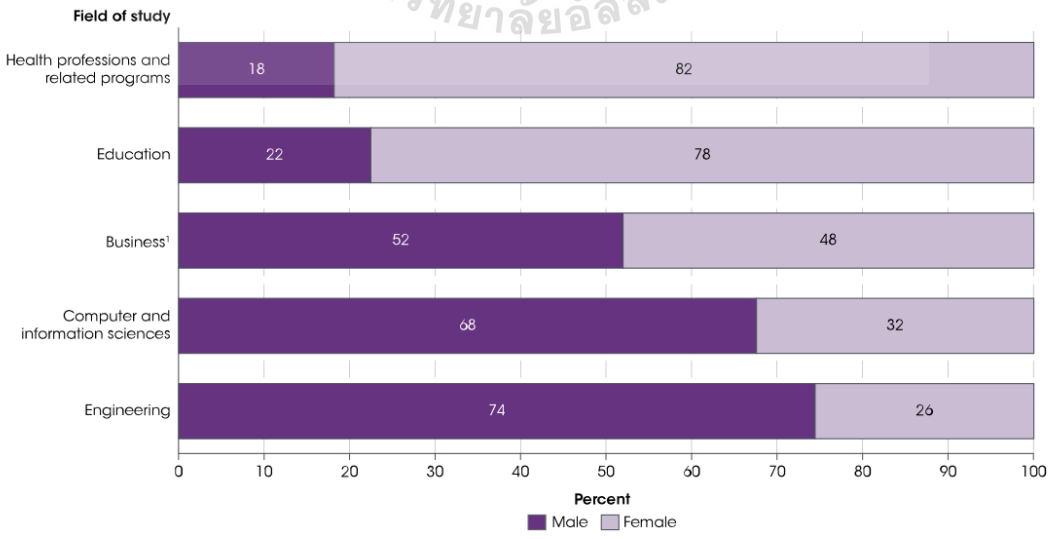

Figure 3.2: Field of Study vs. Gender Distribution

Source: National Center for Education Statistics (2018). *Fast Facts on Distance Learning*. https://nces.ed.gov/fastfacts/display.asp?id=80

In the case of Walden University, it had over 5 times more graduate students than the undergraduate students. The explanation behind this ratio was that the university's focus had been on graduate programs, which correlated with 83 graduate programs against only 17 undergraduate programs, as indicated by Table 3.1. If the total active graduate and undergraduate students are distributed between total numbers of programs in the respective two categories, students per program in graduate level is 510 and 472 for undergraduate level, respectively.

Second, the female enrollment numbers were much higher at Walden University when compared to national trends as shown in Table 3.2. This ratio is consistent with the national data (National Center for Education Statistics, 2020) which indicated that female student enrollment number is much higher in health professions and education as shown by Figure 8 below for master's degrees. The increased ratio of enrollments at Walden University, compared to national trend, was the result of being 100% online with successful nursing and education programs.

Based on the observations above about Walden University, it could be deduced that enrollment numbers per program across undergraduate and graduate levels were uniformly distributed. Women enrollment rates were higher at the university than national trends and distribution in graduate and undergraduate programs were from 76.5% to 65.3%, respectively.

Considering the characteristics of student enrollments at the university, the sample population can be a subset of the entire active students. As 20% undergraduate students were likely to pursue higher education after graduation and 80.7% of students with graduate degrees would join the job market, it was a well-balanced mix of job and degree seekers who potentially

benefit from the blockchain prototype-like service. Further, Although the majority of student body was comprised of female students at 74.7% against 19% of male and 6.3 unknown gender, respectively, targeting relatively more female students as the population sample would not bear any merit because use of the prototype like service was expected to be agnostic to gender, as well as the degree attainments of an individual (see Figure 3.2).

3.4.4 Sampling Procedure and Sample Size

Again, when modeling the baseline to determine population sample, Walden University's enrollment data was used. Then, two specific procedures were considered to determine the sample size for the final quantitative survey. First was Small Sample Techniques by Krejcie & Morgan (1970) and second was using Power*G analysis (Faul, et al., 2009). This considers the total population of Walden University into consideration. At the time of the research, with 50,360 active students in Walden University in all programs and degree levels as shown in Figure 3.5., the population sample size (n) would be 382.

Table 3.5: Active Students at Walden University

Gender	Active students	%
Male	9,568	19.0
Female	37,619	74.7
Unknown	3,173	6.3
Entire Student Population (N) = 50,360		
Sample Population (n) = 382		

Source: Walden University. (2018). *Students, Alumni, Faculty and Employers.* https://www.waldenu.edu/-/media/Walden/files/about-walden/data/data-students-alumni-faculty-employers-sept-2019final.pdf?la=en

The Power*G analysis on the other hand, identified a comparatively smaller sample size based on the instrument that was used in the quantitative research survey: the Pearson's Coefficient Correlation (which is discussed in detail in the section towards the end of this

chapter.) As shown in Figure 3.3, with following sample size input parameters, the population sample size (n) of 153 was determined:

i) **Statistical test type:** Bivariate normal model

ii) **Tail:** One as the correlation travels in a certain direction (either positive or negative

iii) **Correlation p H1:** .20 for a small treatment effect

iv) **Confidence level to avoid Error type I:** 95%

v) Confidence level to avoid Error type II: Power 1-ß err prob: 80%

vi) **Correlation:** NA

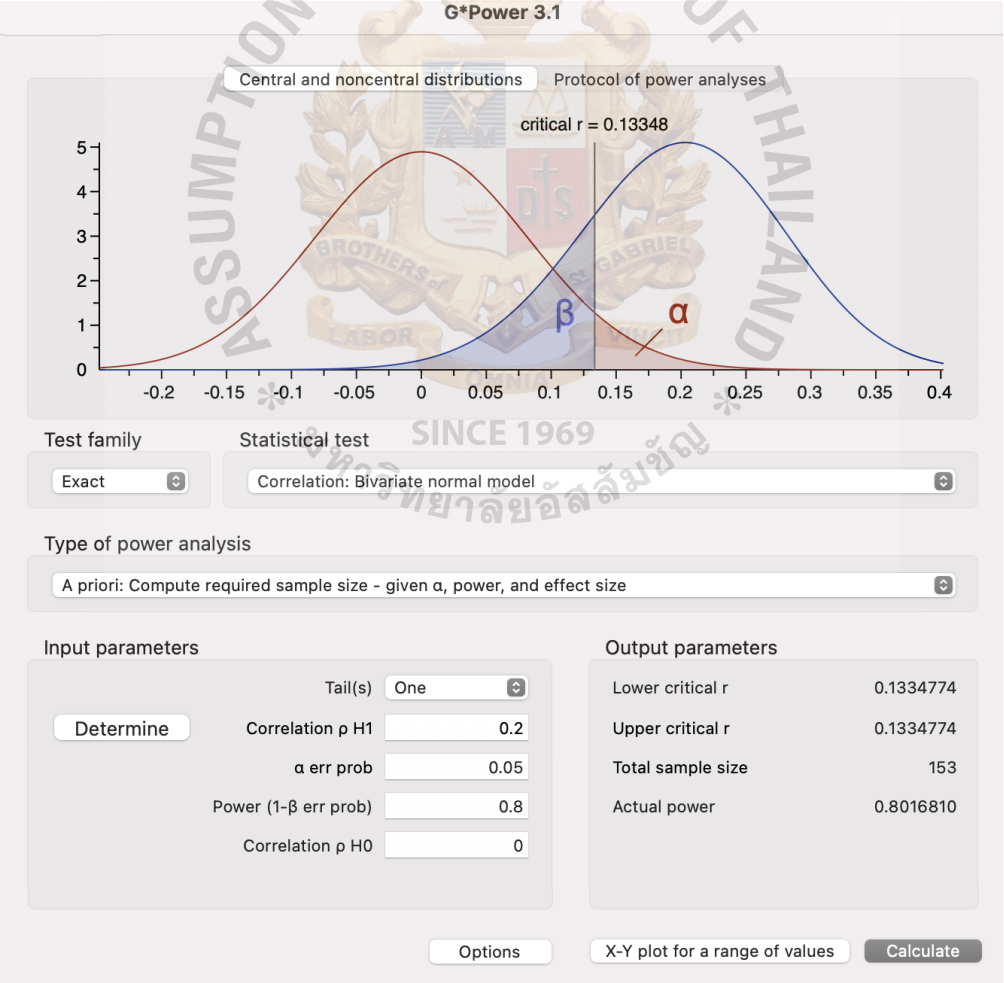

Figure 3.3: G*Power Sample Size Calculation

G*Power sample size of 153 was expected to be as good a sample as that of 382 students based on the Small Sample Techniques. Furthermore, 153 sample size was much more feasible at any universities, based on the conversations the researcher had with the respective doctoral program leaders. As the program leaders would recruit the students to participate in the research voluntarily, but with no association with the courses, getting a commitment from a higher number of participants could have been more challenging and posed a risk of research delay. However, as the quantitative survey was expected to be online, eventually, the students were recruited from 3rd party service provider to administer the survey in the research.

3.5 Research instrument development

For each of the three research objectives, specific research instruments were designed for the investigation. They are discussed in the following subsections.

3.5.1 Research Objective 1: Preliminary Usability Test

The first research objective included design, development of the BaaS prototype and the usability test. During the development of the prototype, mainly, preliminary usability test was conducted to make sure the prototype functioned as expected and minimal UI/UX criteria were achieved (see Table 3.6 and Table 3.7 for test questions). Back-end test, however, was deemed irrelevant because the BaaS could be simulated also through a web-based solution during the data collection stage of the research. Moreover, creating an actual cloud-based prototype was also deemed not only superfluous and infeasible because it would take both significant resource and time, but would also put significantly more weightage to the first research objective. Despite the change, the back-end test is briefly discussed in the chapter as part of the original research method. The research instrument for the qualitative tests is described below.

i) The test environment. Test environment will be researcher's personal desktop computer, or laptop, or a smartphone with following specifications:

- RAM: > 4 GB
- Processor: > 2.2 GHz
- Browser: Mozilla, Safari, IE (most recent versions)
- Internet BW: At least 25 Mbps

ii) Tester(s): Tester is only the researcher for this research objective.

iii) Test types: Qualitative. Black and White box tests and preliminary usability tests.

Table 3.6: Backend-Blackbox test

#	Blackbox test	Results
1	Smoke Testing	Pass/fail
2	Sanity Testing	Pass/fail
3	Integration Testing	Pass/fail
4	System Testing	Pass/fail
5	Regression Testing	Pass/fail
6	User Acceptance Testing (researcher)	Pass/fail

White box tests that will not be run are following:

- Performance testing
- Compatibility testing
- Stress testing
- Scalability testing

Table 3.7: Backend-Whitebox test

#	Whitebox test	Results
1	Segment coverage	Pass/fail
2	Node Testing	Pass/fail
3	Compound Condition Coverage	Pass/fail
4	Basis Path Testing	Pass/fail
5	Data Flow Testing (DFT)	Pass/fail
6	Path Testing	Pass/fail
7	Loop Testing	Pass/fail

Preliminary UI tests are following:

- Check screen validations
- Verify all navigations
- Verify data integrity
- Verify the object states
- Verify the date field and numeric field formats

Preliminary UX tests are following:

- The tests for effectiveness of the system are following:
    - Is the system easy to learn?
    - Are content, color, icons, images used are aesthetically pleasing?
    - Is the system useful and adds value to the target audience?
    - Task success (log in to log out)
    - Response time
- The tests for efficiency of the system are following:
    - Little navigation should be required to reach the desired screen or webpage, and scrollbars should be used infrequently.
    - Uniformity in the format of screen/pages in your application/website.
    - Option to search within your software application or website.
- The tests for accuracy of the system are following:
    - No outdated or incorrect data like contact information/address should be present.
    - No broken links should be present.
- The tests for user friendliness of the system are following:

- Controls used should be self-explanatory and must not require training to operate.
- Help should be provided for the users to understand the application/website.

3.5.2 Research Objective 2: Usability Test

The second research objective builds on to the first one. The rigorous usability test was conducted to release the BaaS prototype for the third research objective. The research instruments for this qualitative test are described below.

i) The test environment. Test environment will be user's desktop computer, or laptop, or a smartphone with following specifications:
   - RAM: > 4 GB
   - Processor: > 2.2 GHz
   - Browser: Mozilla, Safari, IE (most recent versions)
   - Internet BW: At least 25 Mbps

ii) Testers. 6
   - 4 in person (2 students, 1 University admin, 1 employer)
   - 2 remotely (1 Web designer; 1 ICT project manager)

iii) Qualitative. The structured questionnaires were used to measure the qualitative result of the 'Prototype' state of the UX test. (See Appendix A for questionnaires for student, university, and employer, respectively.)

iv) Statistical Analysis: Frequency, percentage and mean.

3.5.3 Research Objective 3: Correlation between PEoU and BIU

The third and final research objective was to investigate a correlation between PEoU and BIU among selected university students and explore whether the former had significant

influence on the latter, or not. To achieve this, the instrument for this quantitative research was a self-administered online survey which was conducted among the population sample. Prior to socializing the survey with the population sample, the survey questions were tested for both their validity and reliability.

As the prototype was limited to only laboratory version, an infographic guide to help survey participants were developed. The survey questionnaires and infographic are included in Appendix B and C, respectively.

3.5.4 Research Instrument for Validity of Reliability Tests

The quantitative research instruments were validated by allowing the survey questionnaires to be tested by the research experts. Further, the survey guide – infographic – was also tested by a media expert. The feedback was incorporated in the final version of the questions and the guide, respectively. Following sections elaborate more on the validity of the research.

i) Item Objective Congruence (IOC) index test was implemented. The draft of the survey questionnaires for both PEoU and BIU were revised based on the advisor feedback and submitted to five experts for IOC index check which assessed evidence involving the degree to which the content of the survey matched a content domain associated with the construct. The acceptable score of each scale item was determined to be more than 0.5. In each set of questionnaires, only one question received lower than 0.5 score. This question was discarded. See Appendix D for the IOC calculation, result, and analysis thereafter. In summary, out of the total 13 questions, only one was discarded because the score was lower than 0.5. As a result, there are 7 PEoU and 5 BIU survey questions, respectively.

Table 3.8: Face Validity Test Result for Question 1

Very easy	37%
Somewhat Easy	34%
Neutral	23%
Somewhat not easy	6%
Not easy at all	0%
	Total = 100%
Mean (x)	4.03
Standard Deviation (SD)	0.92

ii) In addition to a media expert checking the quality of the infographic guide, 35 students participated in the face validity test as well (see Appendix E). The test was to improve the quality of survey experience, in terms of time it takes, whether the instruction and survey questionnaires were easy to understand or not, and if they felt comfortable to answer each and every question or not. It is very closely related to the content validity test and is an estimate of whether a survey appears to measure a certain criterion the research is investigating. The test results were satisfactory and survey questions were not needed to be edited. Following are the responses from the students based on the 4 survey questions and the analysis of the data collected.

Question 1: Is the infographic easy to understand to complete the survey successfully?

As shown in Table 3.8, out of 35 students, 37% and 34% felt that the infographic was very easy and somewhat easy to understand, respectively, in order to complete the survey. Despite 6% felt that the infographic was somewhat not easy to understand, every student did, however, completed the survey, eventually. 23% felt the infographic was neither difficult nor very easy to understand.

The Mean (Table 3.8), which is the same as weighted average Mean, is 4.03 which falls under 'Somewhat easy' category based on Range-Value of the overall responses from the students as shown in Table 3.9. Standard deviation of 0.92 indicates that data are not that dispersed, which is because there are only 6% and 0% respectively for the last two responses in Question 1 (see Table 3.10).

Table 3.9: Scale and Weighted Mean Range-Value for Question 1

Response Criteria	Scale	Range-Value
Very easy	5	4.50 - 5.00
Somewhat easy	4	3.50 - 4.49
Neutral	3	2.50 - 3.49
Somewhat not easy	2	1.50 - 2.49
Not very easy	1	1.00 - 1.49

Table 3.10: Face Validity Test Result for Question 2

Very easy	37%
Somewhat Easy	46%
Neutral	11%
Somewhat not easy	6%
Not easy at all	0%
	Total = 100%
Mean (x)	4.14
Standard Deviation (SD)	0.85

Question 2: Are the survey questionnaires easy to understand to complete the survey successfully?

As shown in Table 3.10, 37% and 46% felt that the survey questions were very easy and somewhat easy to understand, respectively, during the survey. Despite, again, 6% felt that the questions were somewhat not easy to understand, every student did, however, completed the survey. Only 11% felt the survey questions were neither difficult nor very easy to understand. In contrast to the 11%, the responses to 4th question (see section after one below)

of the reliability survey informed that higher number, 20%, of survey participants in fact took relatively longer time (15 minutes) to complete the survey. In other words, those who felt survey questions were somewhat easy or very easy, some of them did take as long a time as those who felt they were either ‘somewhat not easy’ or ‘not easy at all’. Therefore, the survey questions need not be edited, or changed, as survey time did not exceed 15 minutes mark.

Table 3.11: Scale and Weighted Mean Range-Value for Question 2

Response Criteria	Scale	Range-Value
Very easy	5	4.50 - 5.00
Somewhat easy	4	3.50 - 4.49
Neutral	3	2.50 - 3.49
Somewhat not easy	2	1.50 - 2.49
Not very easy	1	1.00 - 1.49

The Mean (Table 3.10), which is the same as weighted average Mean, is 4.14 which falls under ‘Somewhat easy’ category based on Range-Value of the overall responses from the students as shown in Table 3.11. Standard deviation of 0.85 indicates that data are relatively more dispersed than the first set of data from Question 1.

Question 3: How long did it take you to read information about the research and the infographic guide?

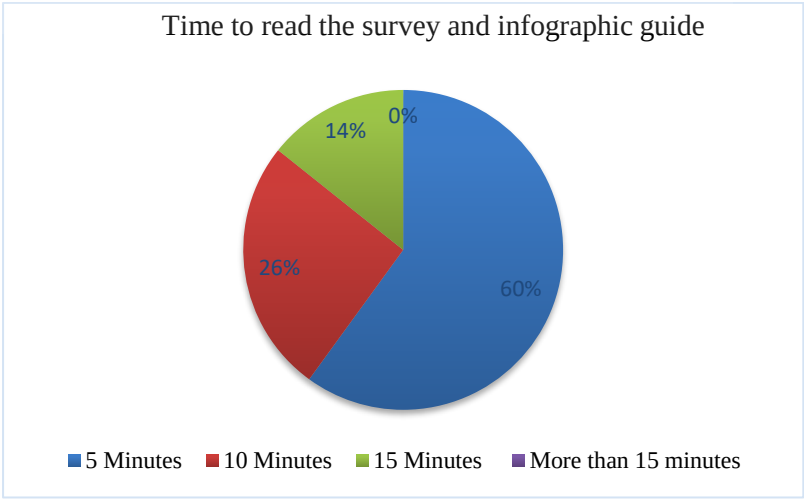

Figure 3.4: Time Taken to Read the Guide

Out of 35 students, 60% and 26% read the infographic within 5 and 10 minutes, respectively, to understand what the prototype does and what is the survey is about (see Figure 3.4). Further, only 14% took up to 15 mins, and one of the 35 students passed the 15 minutes mark.

Question 4: How long did it take you to complete the survey?

For the fourth and final question, 54% and 26% were able to complete the survey within 5 and 10 minutes, respectively. All remaining students (20%) completed the survey within the 15 minutes mark. Although some students felt the guide was somewhat not easy and took longer to read them, having all 35 students completing the survey within 15 minutes mark was evidence that both the guide and survey questions are developed in a manner that final survey participants can complete the survey at 15 minutes mark. As the participant numbers were much higher (at least 153) compared to reliability survey participants, some may pass beyond the 15 minutes mark to complete the survey. This is acceptable as some students may want to take their time to complete the survey.

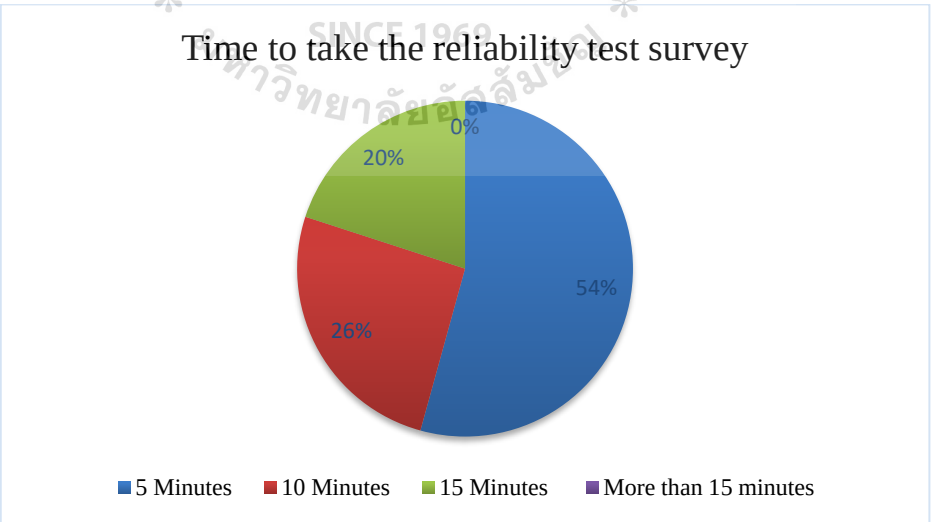

Figure 3.5: Time Taken to Take Reliability Test Survey

Collected data for the tests above are included in Appendix F and G.

3.5.5 Content Reliability of the Quantitative Survey Questionnaires

In addition to the validity of the questionnaires for PEoU and BIU, their reliability was also assessed (see Figure 3.5). For this, Cronbach's alpha, α (or coefficient alpha) was used to measure reliability or internal consistency of the questionnaire. “Reliability” is how effectively the test measures what it should. The analysis done in the test are following:

i) P value: A p-value less than 0.05 (typically ≤ 0.05) was statistically significant. A p-value higher than 0.05 (> 0.05) was not statistically significant, therefore, indicates strong evidence for the null hypothesis. This means that the null hypothesis is retained, and the alternative hypothesis is rejected. However, in this research, the correlation, “r”, is analyzed.

ii) Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures.

iii) There are four major types of descriptive statistics:

- Measures of Frequency: Count, Percent, Frequency.
- Measures of Central Tendency: Mean, Median, and Mode.
- Measures of Dispersion or Variation: Range, Variance, Standard Deviation.
- Measures of Position: Percentile Ranks, Quartile Ranks.

iv) Reliability by Cronbach’s Alpha Coefficient test:

- Out of 5 types of reliability tests, Cronbach’s test was used in the research to measure reliability with the score between scale of -1 and 1 by the expert.

v) 30 Participants were those who understood and knew about blockchain and DLT. The participants were all students.

The reliability test result as calculated by Cronbach's alpha method are listed below:

i) All 12 survey questions scale items earned 0.886 which is higher than 0.7.

ii) PEoU 7 items earned 0.866.

iii) BIU 5 items earned 0.812.

The listed results were satisfactory, and the survey questions were ready to be administered to a population sample of at least 153 at the selected university.

3.5.6 Hypothesis, IV and DV

Referring to the TAM framework discussed in Chapter I, the variables are:

i) IV: PEoU of the students towards the prototype

ii) DV: BIU BaaS to replacing manual process to e-Certify academic qualifications

The survey questionnaires helped investigate if IV had significance and direction towards DV. The analysis tool selected for analysis was Pearson's Coefficient Correlation test, which will be discussed in next the section. Based on the research objective and the variables of the TAM framework, a hypothesis was that there is a significant relationship between the two variables. For the research, null hypothesis and alternative hypothesis pair were developed, and were as follows:

i) H_0: The student's PEoU towards BaaS prototype has no significant relationship on behavioral intention to use it.

ii) H_1: The student's PEoU towards BaaS prototype has a significant relationship on behavioral intention to use it.

If the survey result determined the null hypothesis to be false, then the hypothesis is true between the observed data. Otherwise, there would not be any significant relationship

between perceptions of the students towards the prototype for its ease-of-use and the consequential outcome, their behavioral intention to use it.

3.5.7 Pearson's Coefficient Correlation Test for Statistical Analysis

A parametric statistical test is considered to test the null hypothesis of the research that there is no significant relationship between the IV and the DV. As Pearson's coefficient correlation has a relatively high statistical significance of the relationship and therefore calculates effect of change in DVs when changes occur in IVs, this inferential analysis is deemed appropriate for the research. The analysis draws a line through IVs and DV data sets between +1 and -1 to indicate whether the 'linear' relationship is positive or negative, whereas 0 shows no linear correlation. Additionally, as the observations are continuous in contrast with other types of statistical tests that analyze categorical data, it validated further why this test was appropriate. The Statistical Package for the Social Sciences Application was used to analyze collected data.

3.5.8 The Research action plan

Following were the action plan for the research:

i) Request permission to administer surveys with selected university's undergraduate and graduate students who are active by contacting the Ph.D. program representatives. These students were part of the population sample, as well as those who will be involved with usability and Cronbach's Alpha Coefficient tests.

ii) Design and finalize the draft of the infographic guide.

iii) Design storyboard for the video that will be recorded after proposal defense was completed.

iv) Draft and finalize research questions by testing them through experts and then a validity test.

v) Adapt survey questionnaires to Google Form.

vi) Investigate DID-enabled blockchain technologies to identify most fitting for the prototype.

vii) Plan and schedule design, development and testing of the prototype.

viii) Conduct surveys and report the findings.

3.5.9 Data Collection and the Interpretation Guide

Prior to recruiting the population sample for the survey to achieve the third objective of the research, the researcher met all the requirements at the selected university to qualify as an external researcher. Part of the qualifications were completing required courses related to research ethics, privacy of the research participants, and security of data being collected; informing the Institutional Review Board (IRB) of the purpose and benefits of the research and its approval; and drafting consent form (see Appendix I) for survey participants. The participants were planned to be recruited through the university's Participation Pools to participate in the survey. As an alternative, third party service provider to administer surveys to the target students were also considered.

Although the population sample was determined to be at least 153, a total of 159 students signed up to participate in the survey. As a result, the research analyzed and interpreted all 159 responses. As shown in Table 3.12 and Table 3.13, the Likert charts would have respective rages and interpretations to analyze and interpret the collected data in the quantitative research.

Table 3.12: Likert Chart I for Means

#	Likert Scale	Score	Range	Interpretation
1	Extremely likely	1	1.0 – 1.5	Very high
2	Very likely	2	1.51 – 2.5	High
3	Somewhat likely	3	2.51 – 3.5	Moderate
4	Not likely	4	3.51 – 4.5	Low
5	Not at all likely	5	4.51 – 5.0	Very low

Table 3.13: Likert Chart II for Means

#	Likert Scale	Score	Range	Interpretation
1	Always	1	1.0 – 1.5	Very high
2	Usually	2	1.51 – 2.5	High
3	Sometimes	3	2.51 – 3.5	Moderate
4	Rarely	4	3.51 – 4.5	Low
5	Never	5	4.51 – 5.0	Very low

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CHAPTER IV

DATA ANALYSIS AND RESULTS

4.1 Analysis of Qualitative Survey Results

During the research, the advancement of blockchain applications including for verifying credential grew rapidly. So much so, as per IndustryWired (2020), there were already 10 startups in the blockchain identity management business space. As the services seemed to be relatively cost effective, instead of building the prototype ground up by coding and testing it in its entirety by the researcher, an already existent service was rendered to customize so that the first two objectives are met. The services that were rendered were website hosting and web-based wallets to verify the academic credentials of the population sample. The following sections discuss in detail the services creating a web-based prototype to simulate e-Certification experience and the usability test, and the results.

4.1.1 Service Rendered to Simulation BaaS Prototype

For domain registration and hosting the website to simulate BaaS prototype, GoDaddy.com's service was purchased. To create the workflow of the prototype, a service from the Netherlands based company called Tykn.tech was purchased. Tykn.tech's services included web-based wallet and DID compatible Hyperledger Indy based blockchain. These purchased services were then used to create the prototype that simulated the BaaS experience.

Table 4.1: Test Environment Results

#	Required	Used
1	RAM >4GB	16GB
2	Processor	2.2 GHz
3	Browser: Mozilla, Safari, IE	Frist 2, and Edge
4	Internet BW: >25 Mbps	1Gbps
5	Tester(s)	Researcher

4.1.2 Environment Test Results

The test environment used was the researcher's personal Apple Mac with the specifications shown in Table 4.1. As the personal laptops are as powerful as desktop computers, evidently the Mac fulfilled all the test environment requirements.

4.1.3 UI/UX Test Results

UI/UX test was carried out in two cycles. First by the researcher, followed by the additional testers on test criteria as shown in Table 4.2 and Table 4.3. In the first cycle, same test criteria were tested iteratively by the researcher alone. The second cycle of tests were carried out multiple times as well until each test criterion was passed (see Appendix K for process and test results) by the group of testers. The testers for the second cycle test included a university admin, an employer, an IT project manager, a web designer, and 2 students.

Table 4.2: UI Test Results

#	Test	Results
1	Screen Validation	Passed
2	Navigation	Passed
3	Data integrity	Passed
4	Object states	Passed
5	Field Name	Passed
6	Tester(s)	Passed

Table 4.3: UX Test Results

#	Test	Results
1	Effectiveness	Passed
2	Efficiency	Passed
3	Accuracy	Passed
4	User Friendliness	Passed
5	Tester(s)	Passed

Following are some of the screenshots of http://www.CertifyMe.Today web-based credential verifiable application that simulated the BaaS prototype. The UI/UX of the website

is contemporary, simple, and easy to navigate around (see Figure 4.1). It was also tested for mobile readiness (see Figure 4.2). The workflow is shown in Figure 15 and Figure 16 for an academic institute issuing credentials (the *Issuer*) to a student (the *Holder*) and how an employer (the *Verifier*), for example, requests the *Issuer* to e-Certify the student's credential, respectively.

Figure 4.1: Main Landing Page of CertifyMe.Today

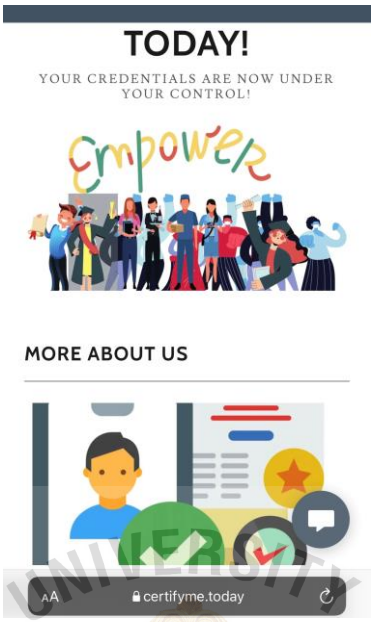

Figure 4.2: Mobile Ready Version of CertifyMe.Today

In the backend, Figure 2.3 (in Chapter II) was adopted using Tykn.tech's framework into the workflow that is shown in Figure 4.3. When an institution (the *Issuer*) issues a credential, it sends a request to the *Holder* by creating a web version of e-Wallet through the student's email address to verify the email address and agree on the consent. Upon agreement, the *Issuer* informs the *Holder* what information will be stored in the credential. Upon consenting, the *Holder* is issued the credential.

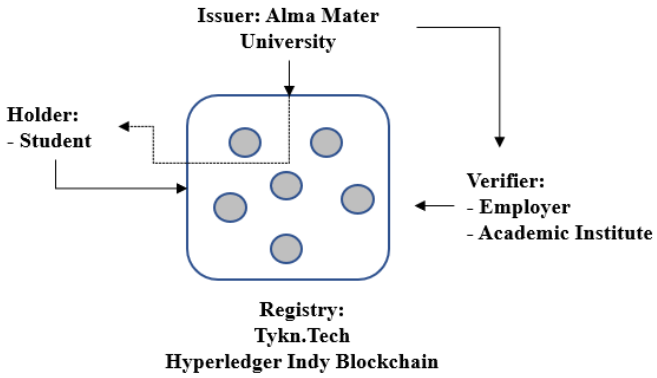

Figure 4.3: Issuing Credential by an Institute

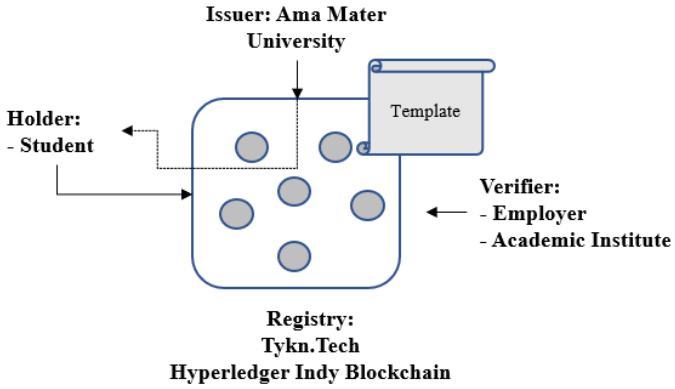

Figure 4.4: Verifying the Credential with Template

Figure 4.4 shows how the credential of the *Holder* is verified by the *Verifier*. A *Proof Request Template* is created between the *Issuer* and the *Verifier* with necessary information needed to be verified. For example, the information to be verified can be, but not limited to, are the student's name, degree attained, start and end date of the school years attended, and GPA. When the *Verifier* requests the *Issuer* about the *Holder*, the *Issuer* sends the proof request to the *Holder* first for consent. The *Holder* receives an email and gives consent to share the information requested by the *Verifier*. As a result, this generates a proof and e-Certifies the credential of the *Holder*. The workflow shows that the *Verifier* actually does not even need to see the information that is on the *Proof Request Template* holding the SSI feature true and maintaining privacy through the ZKP scheme. Finally, Figure 4.5 shows the how the use case interacts between the three entities in the prototype as per the researcher's illustration.

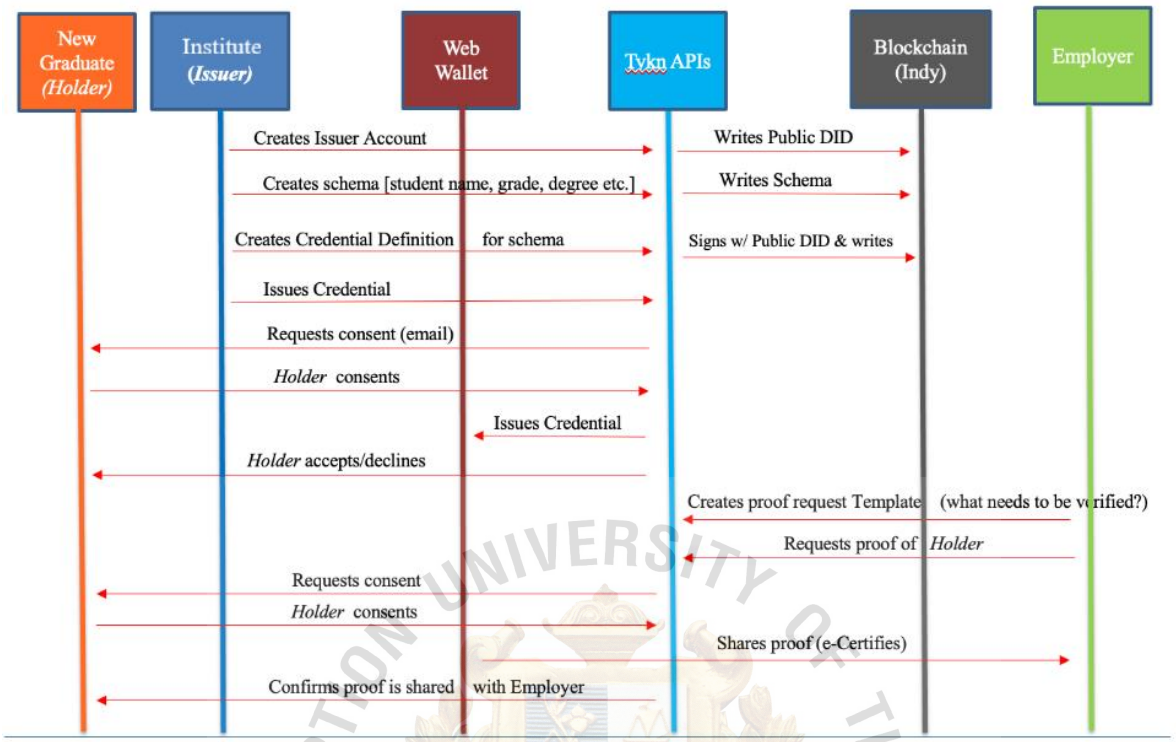

Figure 4.5: Process Flow of Use Case

4.1.4 Backend Test – Not Applicable

The web-based verifiable credential wallet service that was purchased from Tykn.tech did not only offer DID compatible Hyperledger Indy framework, but also the package that had both the nodes and RBFT consensus mechanism. As the researcher only customized the services, backend black and white box tests were not carried out, because the company had such tests already carried out and certified.

4.2 Analysis of Quantitative Survey Results

The collected data from the 159 students were analyzed using Pearson product-moment correlation coefficient to investigate the correlation and significance between the two variables PEoU and PIU. Following two sections discuss the results. Furthermore, the Cronbach's Alpha

test for reliability of the questions was completed for the second time with positive results (see Appendix L).

Table 4.4: PEoU Mean and SD

PEoU	Question	Mean	SD	Interpretation
P1	Learning to operate BaaS would be easy for me.	1.87	0.76	High
P2	I would find it easy to get BaaS to do what I want it to do.	2.24	0.98	High
P3	My interaction with BaaS would be clear and understandable.	1.97	0.66	High
P4	I would find BaaS to be flexible to interact with.	1.80	0.63	High
P5	It would be easy for me to become skillful at using BaaS.	1.95	0.79	High
P6	I would find BaaS easy to use.	1.96	0.68	High
P7	BaaS provides helpful guidance in performing tasks.	1.91	0.7	High
P1-P7	Average	1.96	0.49	High

Population Sample (n) = 159

4.2.1 Analysis of PEoU Results

As shown in Figure 4.5, the Means of all 7 PEoU responses are interpreted as in the "High" category withing the range of 1.51 – 2.5 score based on the stratification designated in Chapter III (see Table 3.12 and Table 3.13 as reference). This can be interpreted as the majority of the students perceived using the BaaS solution relatively easy. When all 7 PEoU Means are compared, survey questions P1 and P2 received the lowest score (see Table 4.4). This implies that the majority of students found it easy to learn to operate BaaS and it is flexible. In contrast, P2 Mean was the highest, implying the students were relatively less sure that they can easily get BaaS do what they want it to do.

4.2.2 Analysis of BIU Results

As shown in Figure 4.5, the Means of all 5 BIU responses are interpreted as in the "High" category withing the range of 1.51 – 2.5 score based on the stratification designated in Chapter III (see Table 3.12 and Table 3.13 as reference). This can be interpreted as most of the students found the moderate to high chance of using and recommending the use of BaaS in near future to e-Certify the academic credentials.

Table 4.5: BIU Mean and SD

BIU	Question	Mean	SD	Interpretation
B1	I intend to use BaaS in the future.	2.25	0.91	High
B2	I predict I will use BaaS in future.	1.99	0.93	High
B3	Assuming that I have access to BaaS, I intend to use it.	1.89	0.75	High
B4	Using BaaS when I near my graduation is a good idea.	1.74	0.88	High
B5	I will strongly recommend that others use BaaS.	1.99	0.78	High
B1-B5	Average	1.87	0.63	High

Population Sample (n) = 159

4.2.3 Overall Analysis of PEoU and BIU Results

The Table 4.4 and Table 4.5 show average Means and SDs of PEoU and BIU, respectively. The average Mean for both PEoU and BIU are relatively close with 1.96 and 1.97, and in "High" range of stratification (see Table 3.12 and Table 3.13 for reference). However, SD for PEoU and BIU are 0.49 and 0.63, respectively. The relatively low SD indicated that overall responses of multiple-choice questions rather scattered around the regression line albeit remained positive.

To interpret the correlation results, Table 4.6 is referred in which conventional approach to interpreting a correlation coefficient was used (Schober et al., 2018). The relationship (r) between the two variables, PEoU and BIU, is 0.680 (see Table 4.7), which falls

into “Moderate correlation” when compared to stratification in Table 4.6. It is, nonetheless, relatively closer towards the “Strong correlation” strata and short only by 0.02 points.

Moreover, Table 4.6 illustrates only one way to interpret the correlation results. Other way of interpretations may change the stratification range entirely. In general, the results can be interpreted as “High correlation”.

Table 4.6: Correlation Interpretation

#	Correlation	Coefficient Interpretation
1	0.00–0.09	Negligible correlation
2	0.10–0.39	Weak correlation
3	0.40–0.69	Moderate correlation
4	0.70–0.89	Strong correlation
5	0.90–1.00	Very strong correlation

Source: Schober, P., Boer, C., Schwarte, L.A. (2018). ANESTHESIA & ANALGESIA. Wolters Kluwer. https://doi.org/10.1213/ANE.0000000000002864

Table 4.7: Pearson Product-Moment of Correlation Between PEoU and BIU

		PSUM	Conclusion
Students PEoU towards BIU	Pearson Correlation Coefficient	.680**	There was a strong, positive, and significant relationship
n= 159	Sig. (2-tailed)	.000	

Based on the Table 4.7, the significance, the P-Value is 0.000, and interpreted as $p < 0.001$, which is less than 0.01. During the population sample selection stage, using G*Power analysis, the confidence level was set to 95%. To make the comparison consistent with this baseline of 95%, it can be stated as 95% of the time, the same relationship will be achieved; and would be otherwise much less than 5% of the time. Consequently, there was a strong and positive correlation with high significance between the two variables PEoU and BIU with

n=159. In other words, if the solution is perceived as easy to use, the participants were likely to change behavior to use it. Referring to the research's null and alternative hypothesis, the result fails the null hypothesis:

i) H_0: The student's PEoU towards BaaS prototype has no significant relationship on behavioral intention to use it.

Consequently, alternative hypothesis holds:

ii) H_1: The student's PEoU towards BaaS prototype has a significant relationship on behavioral intention to use it.

4.2.4 Research Findings of Participants

As shown in Table 4.8, out of 159 participants, 47% were females, followed by 20% males and 6% in the 'other' category. 27% did not wish to disclose their genders.

Table 4.8: Gender of Population Sample

#	Gender	Count	(%)
1	Male	32	20
2	Female	74	47
3	Other	10	6
4	Wish not to disclose	43	27
	Total (n) =	**159**	**100**

Table 4.9: Ages of Population Sample

#	Age	Count	(%)
1	18-24	20	13
2	25-30	48	30
3	31-36	42	26
4	Above 36	10	6
5	Wish not to disclose	39	25
	Total (n) =	**159**	**100**

Majority of the participants were in the age group of between 25-30 years of age. Minority seemed to be those who are above 36 years of age. However, as 25% did not wish to disclose their ages, the minority age group could move to the other categories. Further, 26% of the 159 participants were between the ages of 31 and 36 years, whereas 13% constituted those between the age of 18 and 14 years old. See Table 4.9 for the breakdown of the age groups of the population sample.

As shown in Table 4.10, when compared to degrees the participants were pursuing, 51% were in graduate, whereas 22% were in undergraduate programs, respectively. Significant number of the students, 27%, did not wish to disclose what degrees they were going to attain.

Table 4.10: Degrees Participants Pursuing

#	Degree	Count	(%)
1	Undergraduate	35	22
2	Graduate	81	51
3	Wish not to disclose	43	27
	Total (n)=	**159**	**100**

Majority of participants were planning to get jobs after graduation (see Table 4.11). The research, however, did not investigate what portion of the 66% of 159 participants who would be looking for jobs are in graduate and undergraduate programs. The result also showed that the total of 18% participants were pursuing other degrees either at the same or other universities. The 16% participants of the participants did not wish to disclose whether they would look for jobs or continue education.

Table 4.11: Future Plans of Participants

#	Further study or employment	Count	(%)
1	Further education in current university	15	9
2	Further education in other universities	14	9
3	Get a job	105	66
4	Wish not to disclose	25	16
	Total (n) =	**159**	**100**

4.2.5 Comparison with Other Researchers

There are number of research that suggest that when there is a positive correlation between PEoU and BIU variables, the former is a more plausible predictor for a user to eventually adapt the solution through BIU. In his research, Sonmez (2018) found that as the use of Business Intelligence (BI) and Customer Relationship Management (CRM) systems become more useful, the behavioral intention of the employees to use the system would increase. To this effect, the research concluded that the PEoU of the system is influential in the users' acceptance of the system, which in turn, makes the system successful.

Baji, et al. (2021) also found that PEoU is more of a predictor than “Perceived Usefulness” to influence BIU in contrast with assertion from Davis (1989). They argued that the findings agreed with Park (2009) who studies BIU of university students to use e-learning and found that PEoU could predict both attitude and probable intention to use the service further.

Finally, in a smart city application digital marketing services research, Riantinia, et al. (2021) found that PEoU is proven to influence “Perceived usefulness” which resultantly influences attitude of the users towards BIU. However, “Perceived Usefulness” did not have any influence on BIU. This unidirectional path from PEoU to both “Perceived Usefulness” and attitude to ultimately influence BIU suggests that PEoU does influence BIU directly or

indirectly. Compared to the past three research discussed above, this research's outcome is consistent with their independent but similar outcomes.

CHAPTER V

CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

This section presents conclusion, discussions, recommendations, and further studies of this research.

5.1 Conclusion

Although the title of the research states that the researcher investigates blockchain technology and creates a prototype, the most interesting research question was the final one. As the research participants were from one of the 100% online universities in the United States, the *digital customer experience* driven by the institute's online innovations may have played a role in participant's responses to the surveys. The results from the data analysis did fail the null-hypothesis, and therefore, it was concluded that the student's PEoU towards blockchain-based prototype has a significant relationship on behavioral intention to use it. The data showed that the participants were highly likely to use such a service when they graduate because of the benefits the research showcased the use of a BaaS prototype. It was also important to note that in the research, a reduced version of TAM was used to determine the relationship and significance of PEoU and BIU. Despite the reduction, the findings also bore merit that benefits of the blockchain-based service would outweigh the inefficiency of *manual* process making the relationship of the two variables statistically positive.

5.2 Discussions

As blockchain technology was rapidly being innovated. Therefore, in contrast to the original thinking of the researcher to use Hyperledger Fabric which would save the personal data on the distributed ledger, during the research, DID-enabled blockchain Hyperledger Indy was determined as a more fitting alternative to create the prototype in conjunction with using ZKP, and SSI schemes. Although both Hyperledger and Indy are from Linux Foundation open-

source projects, the latter would not store personal information in the ledger, thereby making it even more secure because of low risks of data being compromised by external threats. As a result, as counterintuitive as it may sound, the Hyperledger Indy does not require *smart contracts* because it is a permissioned blockchain, the result of hybridity between public and private blockchain frameworks. From discovery standpoint, this was one of the highlights of the research.

As highlighted in the text, blockchain itself was a relatively new technology during the research. Despite being an emerging technology, the rapid adoption by industry leaders in the space was evident, however, because the blockchain-based services were being introduced in the market in different flavors to solve variety of real-life problems. As the DID-enabled blockchain was available, integrating ZKP and SSI schemes to create to e-Certify credentials was a logical evolution. By the time research was completed, there had been several initiatives that had started using Hyperledger Indy. Companies like Tykn had just rolled out its SaaS service with combining the features discussed in the research. In contrast, despite the uptake by the industry's businesses, the adoption to use the service by broader user-base seemed slow.

Table 5.1: e-Certification Cost

Share Credentials Up to	Cost	Subscription	Service Type
1000 Recipients	US$ 960	1 Year	Lite/Custom/Premium

Source: Accredible. (2018). *Pricing.* https://www.accredible.com/pricing

Investigation of costs pertaining to developing BaaS or subscribing to one was considered out of scope of the research because of the assumptions that technology being relatively new and inadequate data in the market was available to make any financial projections. Accredible launched its digital badge and certificate service using blockchain in

2017 (Accredible, 2018) with the pricing as shown in Table 5.1. The price seemed competitive with other competitors that include Credly, Badgecraft, Badgecert, Badgelist, and Badgefactor. Referring to the pricing from Accredible (2018), it seemed considerably cost effective compared to developing the service by an academic institute on its own. Hence, for an academic institute, subscribing to the existing service would make more logical and financial sense. Otherwise, resources need to be made available to create its own service that will require research, development and testing, as well as, maintaining it for long-term, resulting in a costly endeavor. This first-look analysis and the assumption thereof is only of the researcher. To validate this assumption, further research is recommended.

5.3 General Recommendations

The research was also an opportunity for both Assumption University and participating university to learn and understand about BaaS for e-Certification service. The practical implication is that the result of the research shows there is a positive and significant relationship between PEoU and BIU of a user, and by that, the institutes can further explore the possibility of adding such service to enhance overall end-to-end eLearning experience of the students.

In assessing the readiness of the students for Assumption University, the omitted variable, “Perceived Usefulness” in the reduced version of the TAM II, can be investigated by subscribing to a test account from the service provider. This way, both independent variables – PEoU and “Perceived Usefulness” – could be tested to have a more definite result on the BIU of the users. This, in turn, would help the institutes to help decide whether it makes a logical and financial sense to integrate the service in its eLearning service.

5.4 Recommendations - Further Studies

The research opens multiple further investigative opportunities. First, to consider a similar type of research with brick-and-mortar university students is a fascinating proposition. In other words, would the research yield entirely different outcomes when compared to a 100% online university albeit the benefit of e-Certifying solution applies to all students?

Second research opportunity is investigating both PEoU and "Perceived Usefulness" with a commercially available e-Certification service to yield, as discussed in the preceding section, a more definite outcome on how these two variables relate to BIU of the users.

Third, equally valuable research to build on to this is how blockchain and DLT can also certify CBE certificates, letter of recommendations, badges as part of the broader *Showcase e-Portfolio* of a lifelong learner. This can build onto including copyrighted materials or content that are consumed through the internet but are exploited through plagiarism. This may also touch "big data" and AI paradigms to mine, analyze, and report to ensure the owners of the contents are rewarded financially.

Fourth is the research opportunity in investigating the cost of subscribing blockchain based e-Certification service based on how lifelong learners continue to add new credentials to their *Showcase e-portfolio* and determine costs of the service over a certain duration of the person's learning journey. In the investigation, the cost savings from replacing centralized server-client solutions can be factored in, as well, which in turn informs institution leaders to make an informed decision.

Finally, due to the SSI scheme, although the idea is powerful as a lifelong learner has more control over his or her credentials, whether this shift has any practical bearing in the

long run will be valuable research to understand how blockchain participants perceive of this change.

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APPENDICES

APPENDIX A: QUESTIONNAIRE FOR USABILITY TEST

Purpose of the tests (the text that will be sent out to the testers for test request)

Mr. Tikajit Rai is doing his PhD in "Development of a blockchain-based system prototype to e-certify online student's academic qualifications: a case study at a private online university in the United States." In the research the blockchain as a Service (BaaS) prototype, which is created using IBM Hyperledger, Java Script, and HTML 5, stores students' higher education qualifications data in distributed digital ledger and secures it by blockchain technology. Members of the blockchain business network – current and former students, universities and employers – can digitally and securely access student's qualifications on-demand.

To test usability of the Alpha version of prototype for further improvements, please, follow the instructions below to use your smart phone or desktop/laptop to go through the experiences, and provide your answer in questionnaire below.

Guide for the university admin

A student named Jane Doe recently graduated from the selected university. As an administrator you are required to enter the student's grades in 4.0 GPA format into BaaS and approve that she has completed all the courses required to attain bachelor's degree in Business Administration. Upon approval, the BaaS stores in its distrusted ledger and secures it by blockchain, then informs Ms. Doe for her review and acceptance. Ms. Doe then can associate the record of her BBA attainment in her e-Portfolio. She can then share both the transcript and the diploma to any participants in the BaaS network when needed. Once you go through both experiences stated above to, please answer the following questions:

1. **Effectiveness of the BaaS prototype**
    - Did you find the prototype easy to learn to use based on the design of the site?
        - Very easy. Why? _____
        - Somewhat easy. What can be improved? _____
        - Not easy. Why? _____

- How well do you think is the User Interface is designed aesthetically?
  - Very pleasing. Why? _____
  - Somewhat pleasing. What can be improved? _____
  - Not pleasing. Why?
- Were you able to complete all tasks in both experiences:
  - Yes.
  - No. What happened, could you provide specific? _____
- Overall response time while you interacted with the BaaS to complete the two experiences was:
  - Satisfactory
  - Not satisfactory. Could you please provide specific so it can be improved? _____
- Do you think the service prototype offers adds real-life value?
  - No, why not? _____
  - Yes, how so? Could you describe? _____

2. Efficiency of the BaaS prototype

- Did you feel like there were many clicks to complete the experiences?
  - No, I did not. How many clicks?
  - Yes, I did. In what controls or specific experience, you felt this way? _____
- Did you find overall theme colors, image's contrasts and resolutions, font types, color and sizes of the content uniform during the experiences?
  - Theme colors: Yes. No, why? _____
  - Image's contrast and resolutions: Yes. No, why? _____

- Font types, color and sizes: Yes. No, why? _____

- Did the Search work during the experiences?
  - Yes. No, why? _____
  - What is the keyword do you use?
    - Specify_____
  - Are you satisfied with the answer?
    - Yes, No, why? _____

3. Accuracy of the BaaS prototype

- Where there any links that navigated you to the wrong page, or site?
  - Never.
  - Yes, which link(s) could you describe? _____
- Where there any broken links?
  - No.
  - Yes, which links(s) could you describe? _____
- Is there any missing label/function that necessary and could not find?
  - No.
  - Yes, Specify_____
- What are unnecessary labels that can be deleted?
  - No.
  - Yes, Specify_____
- Is there any label that cannot understand its function?

4. User Friendliness of the BaaS prototype

- Did you find all controls self-explanatory?
  - Yes.
  - No. Could you provide more information as to why not? _____
- Was help resource used, or not to complete the tasks?
  - No.
  - Yes, was it difficult to find the link?
    - No.
    - Yes, could you explain why? _____
  - Was the content in help easy to understand?
    - Yes.
    - No, could you describe why not? _____

Guide for student

You are part of the blockchain business network in which other parties are universities, and employers. Only these three parties can access your academic qualifications. Hypothetically, you just graduated from the selected university with Bachelor's in Organizational Psychology. The university will create your e-Portfolio in the prototype with the courses you took, your GPA, duration of your studies and approval for your graduation. The electronic version of the transcript and diploma certificate would look just like current hardcopy one (see sample attached – this to be created.)

Again, hypothetically, you are both looking for a job as well as applying for continued education, say Master's in Business Administration in your alma mater institution. For the first experience, you will request the selected university through the prototype to share e-Portfolio to employer Systemic Excellence Global by entering email address: info@systemicexcellence.global into the system. Remember this employer is part for the business network, which means it can accept your request and view your e-Portfolio real time. As the blockchain and DLT securely stores e-Portfolio data based on consensus of the three

groups in the business network, authenticity of the transcript and certificate is guaranteed. Thereby replacing the need for student to send hardcopy of the transcripts to both the employer and the university.

You will have to register first to joining the business network and accept terms and conditions (to be written) to subscribing to this service. There is no fee associated to use the service from the prototype in the research.

For second experience, you will request through prototype a copy to be sent to admission department at the selected university (email will be provided at later date) so that your admission process moves forward.

Once you go through both experiences stated above, please answer the following questions:

1. **Effectiveness of the BaaS prototype**
    - Did you find the prototype easy to learn to use based on the design of the site?
        - Very easy. Why? _____
        - Somewhat easy. What can be improved? _____
        - Not easy. Why? _____
    - How well do you think is the User Interface is designed aesthetically?
        - Very pleasing. Why? _____
        - Somewhat pleasing. What can be improved? _____
        - Not pleasing. Why?
    - Were you able to complete all tasks in both experiences:
        - Yes.
        - No. What happened, could you provide specific? _____
    - Overall response time while you interacted with the BaaS to complete the two experiences was:
        - Satisfactory

- Not satisfactory. Could you please provide specific so it can be improved? _____

- Do you think the service prototype offers adds real-life value?
  - No, why not? _____
  - Yes, how so? Could you describe? _____

2. Efficiency of the BaaS prototype

- Did you feel like there were many clicks to complete the experiences?
  - No, I did not. How many clicks?
  - Yes, I did. In what controls or specific experience, you felt this way? _____
- Did you find overall theme colors, image's contrasts and resolutions, font types, color and sizes of the content uniform during the experiences?
  - Theme colors: Yes. No, why? _____
  - Image's contrast and resolutions: Yes. No, why? _____
  - Font types, color and sizes: Yes. No, why? _____
- Sid the Search work during the experiences?
  - Yes. No, why? _____
  - What is the keyword do you use?
    - Specify_____
  - Are you satisfied with the answer?
    - Yes, No, why? _____

3. Accuracy of the BaaS prototype

- Where there any links that navigated you to the wrong page, or site?

- Never.
- Yes, which link(s) could you describe? _____

- Where there any broken links?
  - No.
  - Yes, which links(s) could you describe? _____
- Were any labels missing?
  - Yes, what are they? _____
  - No.
- Were there any extraneous labels?
  - Yes, which ones are they? _____
  - No.

4. User Friendliness of the BaaS prototype

- Did you find all controls self-explanatory?
  - Yes.
  - No. Could you provide more information as to why not? _____
- Was help resource used, or not to complete the tasks?
  - No.
  - Yes, was it difficult to find the link?
    - No.
    - Yes, could you explain why? _____
  - Was the content in help easy to understand?
    - Yes.

- No, could you describe why not? _____

Guide for employer – Systemic Excellence Global

You are part of the blockchain business network in which other parties are recent graduates who are looking for job, universities that the applicants graduated from, and other employers, like yourself. Only these three types of members access the network for your student's academic qualifications information. Hypothetically, a student named Mr. Tikajit Rai recently graduated from the selected university with Bachelor's in Organizational Psychology. As a network member, the student records department has already created Mr. Rai's e-Portfolio, with transcript and diploma certificate data in the BaaS. The electronic version of the transcript and diploma certificate would look just like current hardcopy one (see sample attached – this to be created.)

Mr. Rai is going through second round of interview at your company. You, as HR lead, have requested him for his transcript and diploma certificate. Through BaaS, he has already requested selected university's student records department to provide you copy of his e-Portfolio. For this your will receive an email (provided by you) to view the documents in questions. As the blockchain and DLT securely stores e-Portfolio data based on consensus of the three groups in the business network, authenticity of the transcript and certificate is guaranteed. Thereby replacing the need for student to send hardcopy of the transcripts to both the employer and the university. All you have to is register first to joining the business network and accept terms and conditions (to be written) to subscribing to this service. There is no fee associated to use the service from the prototype in the research.

Once you go through both experiences stated above to, please answer the following questions:

1. **Effectiveness of the BaaS prototype**
    - Did you find the prototype easy to use based on the design of the site?
        - Very easy. Why? _____
        - Somewhat easy. What can be improved? _____
        - Not easy. Why? _____

- How well do you think is the User Interface is designed aesthetically?
  - Very pleasing. Why? _____
  - Somewhat pleasing. What can be improved? _____
  - Not pleasing. Why?
- Were you able to complete all tasks in both experiences:
  - Yes.
  - No. What happened, could you provide specific? _____
- Overall response time while you interacted with the BaaS to complete the two experiences was:
  - Satisfactory
  - Not satisfactory. Could you please provide specific so it can be improved? _____
- Do you think the service prototype offers adds real-life value?
  - No, why not? _____
  - Yes, how so? Could you describe? _____

2. Efficiency of the BaaS prototype

- Did you feel like there were many clicks to complete the experiences?
  - No, I did not. How many clicks?
  - Yes, I did. In what controls or specific experience, you felt this way? _____
- Did you find overall theme colors, image's contrasts and resolutions, font types, color and sizes of the content uniform during the experiences?
  - Theme colors: Yes. No, why? _____
  - Image's contrast and resolutions: Yes. No, why? _____

- Font types, color and sizes: Yes. No, why? _____

- Sid the Search work during the experiences?
  - Yes. No, why? _____
  - What is the keyword do you use?
    - Specify_____
  - Are you satisfied with the answer?
    - Yes, No, why? _____

3. Accuracy of the BaaS prototype

- Where there any links that navigated you to the wrong page, or site?
  - Never.
  - Yes, which link(s) could you describe? _____
- Where there any broken links?
  - No.
  - Yes, which links(s) could you describe? _____
- Were any labels missing?
  - Yes, what are they? _____
  - No.
- Were there any extraneous labels?
  - Yes, which ones are they? _____
  - No.

4. User Friendliness of the BaaS prototype

- Did you find all controls self-explanatory?
  - Yes.

        - No. Could you provide more information as to why not? _____
    - Was help resource used, or not to complete the tasks?
        - No.
        - Yes, was it difficult to find the link?
            - No.
            - Yes, could you explain why? _____
        - Was the content in help easy to understand?
            - Yes.
            - No, could you describe why not? _____

Guide for Web designer and IT project manager

These two testers will go through the entire set of processes, playing role of student, university, and employer. For this, these testers will go through the guides provided to all three parties. Once you go through both experiences stated above to, please answer the following questions:

1. **Effectiveness of the BaaS prototype**
    - Did you find the prototype easy to use based on the design of the site?
        - Very easy. Why? _____
        - Somewhat easy. What can be improved? _____
        - Not easy. Why? _____
    - How well do you think is the User Interface is designed aesthetically?
        - Very pleasing. Why? _____
        - Somewhat pleasing. What can be improved? _____
        - Not pleasing. Why?

- Were you able to complete all tasks in both experiences:
  - Yes.
  - No. What happened, could you provide specific? _____
- Overall response time while you interacted with the BaaS to complete the two experiences was:
  - Satisfactory
  - Not satisfactory. Could you please provide specific so it can be improved? _____
- Do you think the service prototype offers adds real-life value?
  - No, why not? _____
  - Yes, how so? Could you describe? _____

2. Efficiency of the BaaS prototype

- Did you feel like there were many clicks to complete the experiences?
  - No, I did not. How many clicks?
  - Yes, I did. In what controls or specific experience, you felt this way? _____
- Did you find overall theme colors, image's contrasts and resolutions, font types, color and sizes of the content uniform during the experiences?
  - Theme colors: Yes. No, why? _____
  - Image's contrast and resolutions: Yes. No, why? _____
  - Font types, color and sizes: Yes. No, why? _____
- Did the Search work during the experiences?
  - Yes. No, why? _____
  - What is the keyword do you use?

        - Specify_____

    - Are you satisfied with the answer?

        - Yes, No, why? _____

3. Accuracy of the BaaS prototype

- Where there any links that navigated you to the wrong page, or site?

    - Never.

    - Yes, which link(s) could you describe? _____

- Where there any broken links?

    - No.

    - Yes, which links(s) could you describe? _____

- Were any labels missing?

    - Yes, what are they? _____

    - No.

- Were there any extraneous labels?

    - Yes, which ones are they? _____

    - No.

4. User Friendliness of the BaaS prototype

- Did you find all controls self-explanatory?

    - Yes.

    - No. Could you provide more information as to why not? _____

- Was help resource used, or not to complete the tasks?

    - No.

    - Yes, was it difficult to find the link?

- No.
- Yes, could you explain why? _____

- Was the content in help easy to understand?
  - Yes.
  - No, could you describe why not? _____

APPENDIX B: QUANTITATIVE SURVEY INSTRUCTION AND QUESTIONS

Survey Title:

Blockchain Technology Based Solution to Electronically Certify Your Academic Qualifications

Survey Background:

After you attain your undergraduate or graduate degree, whether you want to look for a job or pursue higher degree in another university, in most cases, you are required to submit your 'official' academic transcript that is sealed and mailed by your Alma Mater. Primary reason behind mailing such hardcopy document is to prevent tampering and maintain integrity of the transcript. Unfortunately, this is a manual process in which you are required to contact the university and request for the service, and it is time consuming. Interestingly, with plethora of online services available and easily accessible through your smartphones, including that of online learning experiences, this step is evidently an exception as the process has not changed all these years.

As one of the two research objectives, I am developing a Blockchain based application, a prototype, named BaaS will demonstrate how easy and secure it will be to electronically certify (e-Certify) student's academic qualifications, in particular the transcript, for his/her potential employer or the university s/he decides to continue his/her education at. The second and final objective is to administer a quantitative survey with the selected university students to investigate if there is a relationship between the two variables: Perceived Ease of Use (PEoU) and Behavioral Intention to Use (BIU). In other words, would students use the web-based application if it is really easy to access and use it without any trouble.

To collect data for investigating the relation between PEoU and BIU, there are two sets of survey questions based on the highly studied Technology Adaptation Model (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989). The attached infographic guide helps you understand how user navigates through the user experience of the BaaS prototype. After going through this guide, please respond to the main 12 survey questions, followed by 6 generic questions about yourself. Your responses will be high valuable to either retain or discard the research's hypothesis that there is a direct and positive relation between PEoU and BIU.

This study will involve you completing the following steps:

i) Read the infographic workflow on how the users interact with the service [2 mins]

ii) Complete the survey that has two sections [7 mins]

- 1st section has 7 multiple choice questions
- 2nd section has 5 multiple choice questions

iii) Complete demographic information [1 min]

iv) Submit the response.

Please, note that the act of responding to the survey questions is voluntary. If you chose not to answer some of the questions, or not participate altogether, it is your decision.

Thank you for your participation I this important study.

Tikajit Rai

Ph.D. Candidate

Assumption University

Screening Questions:

1. Are you an active university student? If yes, go to next question. If otherwise, inform "Thank you for your time. This survey is only for undergraduate students who are currently enrolled in the selected university."

Incentives: Lucky draw $5 Starbucks Gift Card

Survey Questions:

Perceived Ease of Use (PEU)

1 Learning to operate BaaS would be easy for me.

Extremely easy – 1

Very easy – 2

Somewhat easy – 3

Not so easy – 4

Not at all easy - 5

2 I would find it easy to get BaaS to do what I want it to do.

Extremely easy – 1

Very easy – 2

Somewhat easy – 3

Not so easy – 4

Not at all easy - 5

3 My interaction with BaaS would be clear and understandable.

Always – 1

Usually – 2

Sometimes – 3

Rarely – 4

Never – 5

4 I would find BaaS to be flexible to interact with.

Always – 1

Usually – 2

Sometimes – 3

Rarely – 4

Never – 5

5 **It would be easy for me to become skillful at using BaaS**

Strongly agree – 1

Agree – 2

Neither agree nor disagree – 3

Disagree – 4

Strongly disagree – 5

6 **I would find BaaS easy to use.**

Strongly agree – 1

Agree – 2

Neither agree nor disagree – 3

Disagree – 4

Strongly disagree – 5

7 **BaaS provides helpful guidance in performing tasks.**

Strongly agree – 1

Agree – 2

Neither agree nor disagree – 3

Disagree – 4

Strongly disagree – 5

Behavioral Intention to Use (BIU)

8 **I intend to use BaaS in the future.**

Extremely likely – 1

Very likely – 2

Somewhat likely – 3

Not so likely – 4

Not at all likely – 5

9 I predict I will use BaaS in future.

Extremely likely – 1

Very likely – 2

Somewhat likely – 3

Not so likely – 4

Not at all likely – 5

10 Assuming that I have access to BaaS, I intend to use it.

Extremely likely – 1

Very likely – 2

Somewhat likely – 3

Not so likely – 4

Not at all likely – 5

11 Using BaaS when I near my graduation is a good idea.

Strongly agree – 1

Agree – 2

Neither agree nor disagree – 3

Disagree – 5

Strongly disagree – 5

12 I will strongly recommend that others use BaaS.

Extremely likely – 1

Very likely – 2

Somewhat likely – 3

Not so likely – 4

Not at all likely – 5

1. Gender
    a. Male
    b. Female
    c. Other
    d. Wish not to disclose
2. Your age:
    a. 18-24
    b. 25-30
    c. 31-36
    d. Above 36
3. Are you:
    a. Domestic student
    b. International student
4. Are you:
    a. Undergraduate Student
    b. Graduate Student
5. You are pursuing degree in:
    a. Pull-down menu of all the undergrad program + Other
6. Do you plan to continue further education or get a job?
    a. Further education in current university
    b. Further education in other universities
    c. Get a job
    d. Undecided

APPENDIX C: INFOGRAPHIC GUIDE TO TAKE THE SURVEY

APPENDIX D: IOC INDEX RESULTS

In the research all 7 PEoU, will be used in the survey, because all questions passed the IOC test. In contrast, out of 6 BIU questions, only 5 will be used in the survey because #10, or second BIU question failed the IOC test.

PEoU Questions

#	Scale item	*E1	E2	E3	E4	E5	A**	Note
1	Learning to operate BaaS would be easy for me.	1	1	1	1	1	1.00	>0.5, passed
2	I would find it easy to get BaaS to do what I want it to do.	1	1	1	0	1	0.80	>0.5, passed
3	My interaction with BaaS would be clear and understandable.	1	1	1	1	1	1.00	>0.5, passed
4	I would find BaaS to be flexible to interact with.	1	1	1	1	1	1.00	>0.5, passed
5	It would be easy for me to become skillful at using BaaS	1	1	1	0	1	0.80	>0.5, passed
6	I would find BaaS easy to use.	1	1	1	-1	1	0.60	>0.5, passed
7	BaaS provides helpful guidance in performing tasks.	1	1	1	1	1	1.00	>0.5, passed

BIU Questions

	Scale item	*E1	E2	E3	E4	E5	A**	Note
8	I intend to use BaaS when I graduate.	1	1	1	1	1	1.00	>0.5, passed
9	I predict I will use BaaS when I graduate.	1	1	1	0	0	0.80	>0.5, passed
10	I plan to use BaaS in when I graduate.	-1	1	1	-1	-1	-0.20	<0.5, Failed
11	Assuming that I have access to BaaS, I intend to use it.	1	1	1	0	0	0.80	>0.5, passed
12	Using BaaS when I graduate is a good idea.	1	1	1	1	1	1.00	>0.5, passed
13	I will strongly recommend that others use BaaS.	1	0	1	1	1	0.80	>0.5, passed

Notes:

*5 Experts

**Average score

APPENDIX E: FACE VALIDITY QUESTIONS

After 35 students read the infographic guide for the final survey and participate in it, following questions will be asked to assess the reliability of the survey questions:

i) Is the infographic easy to understand to complete the survey successfully?

- Very easy
- Somewhat easy
- Neutral
- Somewhat not easy
- Not very easy

ii) Are the survey questionnaires easy to understand to complete the survey successfully?

- Very easy
- Somewhat easy
- Neutral
- Somewhat not easy
- Not very easy

iii) How long did it take you read the guide?

- 5 Minutes
- 10 Minutes
- 15 Minutes
- More than 15 minutes

iv) How long did it take you to compete the survey?

- 5 Minutes or less
- 10 Minutes
- 15 Minutes
- More than 15 minutes

(Note: Screening survey questionnaires will not be applied to those who will participate in this reliability test.)

APPENDIX F: CRONBACH'S ALPHA TEST ANALYSIS – PEOU

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.866	0.88	7

All scale items earned higher than 0.7.

Item-Total Statistics

	Mean	Std. Deviation	N
P1	2.23	0.877	35
P2	2.31	0.796	35
P3	2.14	0.772	35
P4	2.06	0.684	35
P5	2.54	1.039	35
P6	2.11	0.718	35
P7	1.91	0.742	35

APPENDIX G: CRONBACH'S ALPHA TEST ANALYSIS – BIU

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.812	0.815	5

All scale items earned higher than 0.7.

Item-Total Statistics

	Mean	Std. Deviation	N
B1	2.11	0.932	35
B2	2.11	0.993	35
B3	2.17	0.857	35
B4	2.14	1.061	35
B5	2.14	0.845	35

APPENDIX H: DATA COLLECTION FOR RELIABILITY TEST

7 PEoU Survey Questions and Responses from 35 Students (In Ascending Order)

C	P1	P1	P2	P2	P3	P3	P4	P4	P5	P5	P6	P6	P7	P7
Count	Learning to operate BaaS would be easy for me.	Numerical value	I would find it easy to get BaaS to do what I want it to do.	Numerical value	My interaction with BaaS would be clear and understandable.	Numerical value	I would find BaaS to be flexible to interact with.	Numerical value	It would be easy for me to become skillful at using BaaS.	Numerical value	I would find BaaS easy to use.	Numerical value	BaaS provides helpful guidance in performing tasks.	Numerical value
1	Somewhat easy	3	Somewhat easy	3	Sometimes	3	Sometimes	3	Neither agree nor disagree	3	Neither agree nor disagree	3	Neither agree nor disagree	3
2	Very easy	4	Very easy	4	Usually	4	Usually	4	Neither agree nor disagree	3	Agree	4	Agree	4
3	Somewhat easy	3	Somewhat easy	3	Sometimes	3	Usually	4	Neither agree nor disagree	3	Neither agree nor disagree	3	Neither agree nor disagree	3
4	Extremely easy	5	Very easy	4	Usually	4	Usually	4	Strongly agree	5	Strongly agree	5	Agree	4
5	Very easy	4	Very easy	4	Always	5	Usually	4	Agree	4	Agree	4	Agree	4
6	Very easy	4	Very easy	4	Usually	4	Usually	4	Neither agree nor disagree	3	Agree	4	Agree	4
7	Somewhat easy	3	Somewhat easy	3	Sometimes	3	Usually	4	Neither agree nor disagree	3	Neither agree nor disagree	3	Agree	4
8	Very easy	4	Somewhat easy	3	Usually	4	Usually	4	Agree	4	Agree	4	Agree	4
9	Very easy	4	Very easy	4	Always	5	Always	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
10	Extremely easy	5	Extremely easy	5	Usually	4	Always	5	Agree	4	Agree	4	Strongly agree	5
11	Extremely easy	5	Extremely easy	5	Usually	4	Always	5	Agree	4	Agree	4	Strongly agree	5
12	Extremely easy	5	Extremely easy	5	Always	5	Always	5	Strongly agree	5	Strongly agree	5	Strongly agree	5
13	Somewhat easy	3	Not so easy	2	Usually	4	Usually	4	Agree	4	Neither agree nor disagree	3	Strongly agree	5
14	Extremely easy	5	Extremely easy	5	Always	5	Always	5	Strongly agree	5	Strongly agree	5	Agree	4
15	Very easy	4	Very easy	4	Usually	4	Usually	4	Agree	4	Agree	4	Agree	4
16	Somewhat easy	3	Very easy	4	Sometimes	3	Sometimes	3	Strongly agree	5	Agree	4	Neither agree nor disagree	3

17	Somewhat easy	3	Somewhat easy	3	Usually	4	Usually	4	Neither agree nor disagree	3	Neither agree nor disagree	3	Agree	4
18	Extremely easy	5	Very easy	4	Usually	4	Usually	4	Agree	4	Agree	4	Neither agree nor disagree	3
19	Very easy	4	Very easy	4	Usually	4	Usually	4	Agree	4	Agree	4	Strongly agree	5
20	Very easy	4	Somewhat easy	3	Sometimes	3	Usually	4	Neither agree nor disagree	3	Agree	4	Neither agree nor disagree	3
21	Somewhat easy	3	Somewhat easy	3	Sometimes	3	Usually	4	Agree	4	Neither agree nor disagree	3	Agree	4
22	Somewhat easy	3	Somewhat easy	3	Usually	4	Sometimes	3	Neither agree nor disagree	3	Strongly agree	5	Strongly agree	5
23	Somewhat easy	3	Somewhat easy	3	Sometimes	3	Sometimes	3	Neither agree nor disagree	3	Neither agree nor disagree	3	Neither agree nor disagree	3
24	Somewhat easy	3	Somewhat easy	3	Usually	4	Usually	4	Agree	4	Agree	4	Agree	4
25	Very easy	4	Somewhat easy	3	Sometimes	3	Rarely	2	Neither agree nor disagree	3	Neither agree nor disagree	3	Neither agree nor disagree	3
26	Not so easy	2	Somewhat easy	3	Sometimes	3	Sometimes	3	Neither agree nor disagree	3	Neither agree nor disagree	3	Agree	4
27	Somewhat easy	3	Somewhat easy	3	Sometimes	3	Usually	4	Agree	4	Agree	4	Agree	4
28	Somewhat easy	3	Not so easy	2	Rarely	2	Sometimes	3	Disagree	2	Neither agree nor disagree	3	Neither agree nor disagree	3
29	Extremely easy	5	Extremely easy	5	Always	5	Always	5	Agree	4	Strongly agree	5	Strongly agree	5
30	Extremely easy	5	Extremely easy	5	Always	5	Usually	4	Strongly agree	5	Strongly agree	5	Strongly agree	5
31	Somewhat easy	3	Somewhat easy	3	Usually	4	Usually	4	Neither agree nor disagree	3	Neither agree nor disagree	3	Agree	4
32	Very easy	4	Very easy	4	Always	5	Usually	4	Strongly agree	5	Agree	4	Agree	4
33	Somewhat easy	3	Very easy	4	Usually	4	Usually	4	Agree	4	Agree	4	Agree	4
34	Somewhat easy	3	Very easy	4	Usually	4	Usually	4	Agree	4	Agree	4	Strongly agree	5
35	Somewhat easy	3	Very easy	4	Usually	4	Usually	4	Agree	4	Agree	4	Strongly agree	5

5 BIU Survey Questions and Responses from 35 Students

#	B1	B1	B2	B2	B3	B3	B4	B4	B5	B5
Survey Count	I intend to use BaaS in the future.	Numerical value	I predict I will use BaaS in future.	Numerical value	Assuming that I have access to BaaS, I intend to use it.	Numerical value	Using BaaS when I near my graduation is a good idea.	Numerical value	I will strongly recommend that others use BaaS.	Numerical value
1	Very likely	4	Very likely	4	Very likely	4	Disagree	1	Somewhat likely	3
2	Very likely	4	Somewhat likely	3	Very likely	4	Somewhat agree	3	Very likely	4
3	Not likely	2	Not likely	2	Not likely	2	Agree	4	Somewhat likely	3
4	Not likely	2	Not likely	2	Not likely	2	Strongly agree	5	Strongly likely	5
5	Very likely	4	Extremely likely	5	Very likely	4	Agree	4	Very likely	4
6	Somewhat likely	3	Somewhat likely	3	Very likely	4	Agree	4	Somewhat likely	3
7	Somewhat likely	3	Somewhat likely	3	Somewhat likely	3	Agree	4	Very likely	4
8	Very likely	4	Very likely	4	Very likely	4	Agree	4	Very likely	4
9	Very likely	4	Very likely	4	Very likely	4	Agree	4	Very likely	4
10	Extremely likely	5	Extremely likely	5	Extremely likely	5	Strongly agree	5	Strongly likely	5
11	Extremely likely	5	Extremely likely	5	Extremely likely	5	Strongly agree	5	Strongly likely	5
12	Extremely likely	5	Extremely likely	5	Extremely likely	5	Strongly agree	5	Strongly likely	5
13	Extremely likely	5	Very likely	4	Extremely likely	5	Strongly agree	5	Strongly likely	5
14	Extremely likely	5	Extremely likely	5	Extremely likely	5	Strongly agree	5	Strongly likely	5
15	Very likely	4	Very likely	4	Very likely	4	Agree	4	Very likely	4
16	Not so likely	2	Not so likely	2	Somewhat likely	3	Agree	4	Very likely	4
17	Somewhat likely	3	Not so likely	2	Somewhat likely	3	Agree	4	Very likely	4
18	Somewhat likely	3	Somewhat likely	3	Somewhat likely	3	Disagree	1	Somewhat likely	3

19	Very likely	4	Very likely	4	Very likely	4	Agree	4	Somewhat likely	3
20	Very likely	4	Somewhat likely	3	Very likely	4	Agree	4	Somewhat likely	3
21	Very likely	4	Very likely	4	Somewhat likely	3	Agree	4	Very likely	4
22	Somewhat likely	3	Very likely	4	Somewhat likely	3	Disagree	1	Somewhat likely	3
23	Somewhat likely	3	Somewhat likely	3	Somewhat likely	3	Neither agree nor disagree	2	Somewhat likely	3
24	Very likely	4	Very likely	4	Very likely	4	Neither agree nor disagree	2	Somewhat likely	3
25	Extremely likely	5	Extremely likely	5	Extremely likely	5	Neither agree nor disagree	2	Somewhat likely	3
26	Very likely	4	Extremely likely	5	Extremely likely	5	Neither agree nor disagree	2	Not so likely	2
27	Somewhat likely	3	Somewhat likely	3	Somewhat likely	3	Neither agree nor disagree	2	Somewhat likely	3
28	Very likely	4	Very likely	4	Very likely	4	Agree	4	Very likely	4
29	Extremely likely	5	Extremely likely	5	Extremely likely	5	Strongly agree	5	Extremely likely	5
30	Extremely likely	5	Extremely likely	5	Very likely	4	Neither agree nor disagree	2	Somewhat likely	3
31	Very likely	4	Very likely	4	Very likely	4	Agree	4	Very likely	4
32	Somewhat likely	3	Very likely	4	Very likely	4	Agree	4	Very likely	4
33	Very likely	4	Very likely	4	Very likely	4	Strongly agree	5	Very likely	4
34	Extremely likely	5	Extremely likely	5	Somewhat likely	3	Strongly agree	5	Extremely likely	5
35	Extremely likely	5	Extremely likely	5	Somewhat likely	3	Strongly agree	5	Extremely likely	

4 Face Validity Test Questions and Responses from 35 Students (Part 1)

(In Ascending Order)

#	F1	F1	F2	F2
Count	Is the infographic easy to understand to complete the survey successfully?	Numerical value	Are the survey questionnaires easy to understand to complete the survey successfully?	Numerical value
1	Neutral	3	Neutral	3
2	Somewhat easy	4	Somewhat easy	4
3	Somewhat not easy	2	Somewhat not easy	2
4	Very easy	5	Very easy	5
5	Very easy	5	Somewhat easy	4
6	Somewhat easy	4	Somewhat not easy	2
7	Somewhat easy	4	Somewhat easy	4
8	Somewhat easy	4	Neutral	3
9	Very easy	5	Very easy	5
10	Neutral	3	Somewhat easy	4
11	Neutral	3	Somewhat easy	4
12	Very easy	5	Very easy	5
13	Somewhat easy	4	Somewhat easy	4
14	Very easy	5	Very easy	5
15	Somewhat easy	4	Somewhat easy	4
16	Neutral	3	Somewhat easy	4
17	Somewhat easy	4	Very easy	5
18	Very easy	5	Somewhat easy	4
19	Very easy	5	Very easy	5
20	Somewhat easy	4	Neutral	3
21	Somewhat easy	4	Somewhat easy	4
22	Somewhat not easy	2	Somewhat easy	4

23	Neutral	3	Neutral	3
24	Neutral	3	Somewhat easy	4
25	Very easy	5	Very easy	5
26	Very easy	5	Somewhat easy	4
27	Somewhat easy	4	Somewhat easy	4
28	Very easy	5	Very easy	5
29	Somewhat easy	4	Very easy	5
30	Very easy	5	Very easy	5
31	Very easy	5	Very easy	5
32	Very easy	5	Very easy	5
33	Somewhat easy	4	Very easy	5
34	Neutral	3	Somewhat easy	4
35	Neutral	3	Somewhat easy	4

Likert Scale	%	Likert Scale	%
Very easy	37%	Very easy	37%
Somewhat easy	34%	Somewhat easy	46%
Neutral	23%	Neutral	11%
Somewhat not easy	6%	Somewhat not easy	6%
Not easy at all	0%	Not easy at all	0%
	100%		100%

Statistical Analysis

Sum	69	Sum	65
Mean	1.97	Mean	1.86
SD	0.92	SD	0.85
Variance	0.85	Variance	0.71

4 Face Validity Test Questions and Responses from 35 Students (Part 2)

Time Scale	%
5 Minutes	60%
10 Minutes	26%
15 Minutes	14%
More than 15 minutes	0%
	100%

Time Scale	%
5 Minutes	54%
10 Minutes	26%
15 Minutes	20%
More than 15 minutes	0%
	100%

#	F3	F4
Count	How long did it take you to read information about the research and the infographic guide? (In minutes)	How long did it take you to complete the survey? (In minutes)
1	5	5
2	5	10
3	5	5
4	10	5
5	5	5
6	5	5
7	5	5
8	5	5
9	10	5
10	5	5
11	5	5
12	15	15
13	5	5
14	5	5
15	10	5
16	15	5
17	5	10
18	5	10
19	5	5
20	5	15
21	10	15
22	10	10
23	10	10
24	15	15

25	5	5
26	10	15
27	10	10
28	5	5
29	5	10
30	5	5
31	5	5
32	10	10
33	5	10
34	15	15
35	15	15
	270	290

APPENDIX I: CONSENT FORM

You are invited to take part in a research study about how you feel about using a new technology, particularly, blockchain, to electronically verify your education credentials over traditional way of post-mailing hardcopies of your certificates when organizations – employer or academic institution for continued education for example – need them. This form is part of a process called "informed consent" to allow you to understand this study before deciding whether to take part.

This study seeks 159-160 volunteers who are current students at the university irrespective of program and degree you are enrolled in.

This study is being conducted by a researcher named Tikajit Rai who is a Ph.D. candidate at Assumption university and employee of Adtalem Global Education.

Study Purpose:

The purpose of this study is to find out if the students would consider using a new service, backed by technology called blockchain, if the service is relatively easy to use and replaces a traditional process that is time inefficient and time consuming. The new service can electronically verify academic credentials of the students to whomever they need to provide evidence. Further, the technology is secure and verification process is real-time.

Procedures:

This study will involve you completing the following steps:

- Read the infographic workflow on how the users interact with the service [2 mins]
- Complete the survey that has two sections [7 mins]

- 1st section has 7 multiple choice questions
- 2nd section has 5 multiple choice questions

- Complete demographic information [1 min]
- Submit the response.

Here are the 12 survey questions:

Perceived Ease of Use:

1. Learning to operate BaaS would be easy for me.
2. I would find it easy to get BaaS to do what I want it to do.
3. My interaction with BaaS would be clear and understandable
4. I would find BaaS to be flexible to interact with.
5. It would be easy for me to become skillful at using BaaS
6. I would find BaaS easy to use.
7. BaaS provides helpful guidance in performing tasks.

Behavioral Intention to Use:

8. I intend to use BaaS in the future.
9. I predict I will use BaaS in future.
10. Assuming that I have access to BaaS, I intend to use it.
11. Using BaaS when I near my graduation is a good idea.
12. I will strongly recommend that others use BaaS.

Here are the additional demographic survey questions:

1. Gender: Male/Female/Other/Wish not to disclose
2. Your age:18-24/ 25-30/ 31-36/ Above 36/ Wish not to disclose

3. Degree:

4. Are you a: Domestic/International student?

5. Do you plan to continue further education or seek to getting a job?

    a. Further education in current university

    b. Further education in other universities

    c. Get a job.

Voluntary Nature of the Study:

Research should only be done with those who freely volunteer. So, everyone involved will respect your decision to join or not. If you decide to join the study now, you can still change your mind later. You may stop at any time.

Risks and Benefits of Being in the Study:

Being in this study could involve some risk of the minor discomforts that can be encountered in daily life such as sharing sensitive information. With the protections in place, this study would pose minimal risk to your wellbeing.

This study offers no direct benefits to individual volunteers. The aim of this study is to benefit society by understanding more on use of new technology such as blockchain and how they perceive of disruptive service such as BaaS that will resultantly provide insights to trigger or add to the on-going technological innovations to make everyone's life more comfortable.

Payment:

Randomly selected winners will get $5 Amazon gift card.

Privacy:

The researcher is required to protect your privacy. Your identity will be kept confidential within the limits of the law. The researcher will not ask for your name at any time or link your responses to your contact info. The researcher will not use your personal information for any purposes outside of this research project. Also, the researcher will not include your name or anything else that could identify you in the study reports. If the researcher were to share this dataset with another researcher in the future, the dataset would contain no identifiers so this would not involve another round of obtaining informed consent. Data will be kept secure through storing the password protected storage site. Data will be kept for a period of at most 3 months, after the survey is completed.

Contacts and Questions:

You can ask questions of the researcher by tikajit@gmail.com. If you want to talk privately about your rights as a participant or any negative parts of the study, you can call me at (571) 555 5226.

You might wish to retain this consent form for your records. You may ask the researcher for a copy at any time using the contact info above.

Obtaining Your Consent

If you feel you understand the study and wish to volunteer, please indicate your consent by returning a completed questionnaire.

APPENDIX J: SPSS TOOL ANALYSIS ON 159 STUDENTS DATA

Collated frequency test Results of PEoU and BIU with respective Standard Deviations and Means are provided in the following tables.

Statistics

		P1	P2	P3	P4	P5	P6	P7
N	Valid	159	159	159	159	159	159	159
	Missing	837	837	837	837	837	837	837
Mean		1.87	2.24	1.97	1.80	1.95	1.96	1.91
Std. Deviation		.756	.984	.660	.634	.786	.683	.697

Statistics

		B1	B2	B3	B4	B5
N	Valid	159	159	159	159	159
	Missing	837	837	837	837	837
Mean		2.25	1.99	1.89	1.74	1.99
Std. Deviation		.912	.931	.746	.882	.779

Following tables provide tails of responses each question in the survey received with 12 total of questions. First 7 tables are associated with PEoU survey questions, followed by 5 BIU questions of the survey.

P1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	57	5.7	35.8	35.8
	2	66	6.6	41.5	77.4
	3	36	3.6	22.6	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

P2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	42	4.2	26.4	26.4
	2	57	5.7	35.8	62.3
	3	40	4.0	25.2	87.4
	4	20	2.0	12.6	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

P3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	37	3.7	23.3	23.3
	2	90	9.0	56.6	79.9
	3	32	3.2	20.1	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		

P4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	51	5.1	32.1	32.1
	2	89	8.9	56.0	88.1
	3	19	1.9	11.9	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

P5

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	47	4.7	29.6	29.6
	2	77	7.7	48.4	78.0
	3	33	3.3	20.8	98.7
	5	2	.2	1.3	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

P6

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	40	4.0	25.2	25.2
	2	85	8.5	53.5	78.6
	3	34	3.4	21.4	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

P7

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	46	4.6	28.9	28.9
	2	81	8.1	50.9	79.9
	3	32	3.2	20.1	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

B1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	35	3.5	22.0	22.0
	2	66	6.6	41.5	63.5
	3	42	4.2	26.4	89.9
	4	16	1.6	10.1	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

B2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	51	5.1	32.1	32.1
	2	76	7.6	47.8	79.9
	3	14	1.4	8.8	88.7
	4	18	1.8	11.3	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

B3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	52	5.2	32.7	32.7
	2	75	7.5	47.2	79.9
	3	30	3.0	18.9	98.7
	4	2	.2	1.3	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

B4

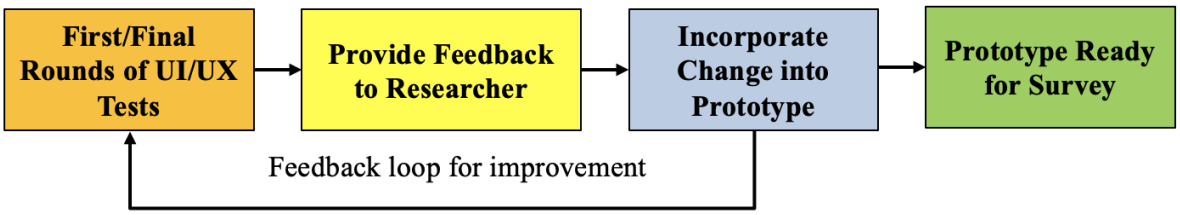
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	66	6.6	41.5	41.5
	2	84	8.4	52.8	94.3
	3	1	.1	.6	95.0
	4	1	.1	.6	95.6
	5	7	.7	4.4	100.0
	Total	159	16.0	100.0	
Missing	System	837	84.0		
Total		996	100.0		

APPENDIX K: UI/UX TEST RESULTS

#		UI/UX Test Questions	University admin		Employer		IT project manager		Web designer		Student # 1		Student #2	
A		**UI Test**												
1		Check Screen Validations												
2		Verify All Navigations												
3		Verify Data Integrity												
4		Verify the object states												
5		Verify the date Field and Numeric Field Formats												
B		**UX Test**												
1		**The effectiveness of the system**												
	a	Is the system easy to learn?												
	b	Are Content, Color, Icons, Images used are aesthetically pleasing?												
	c	Is the system useful and adds value to the target audience?												
	d	Task success (Log in to log out)												
	e	Response time												
2		**Efficiency**												
	a	Little navigation should be required to reach the desired screen or webpage, and scrollbars should be used infrequently.												
	b	Uniformity in the format of screen/pages in your application/website.												
	c	Option to search within your software application or website.												
3		**Accuracy**												
	a	No outdated or incorrect data like contact information/address should be present.												
	b	No broken links should be present.												
4		**User Friendliness**												
	a	Controls used should be self-explanatory and must not require training to operate												
	b	Help should be provided for the users to understand the application/website												

Pass
Can be improved
Fail

UI/UX TEST PROCESS



During the UI/UX, feedback loop was used to continually improve the prototype. To achieve research objective I, the researcher tested the prototype and improved as needed by himself. Then, to achieving research objective II, following testers were engaged on a voluntary basis using the table above to collect test results and to incorporate changes as needed to complete the test:

1. University admin
2. Employer representative
3. IT project manager
4. A web designer
5. Student # 1 (randomly selected)
6. Student #2 (randomly selected)

APPENDIX L: CRONBACH'S ALPHA TEST RESULTS (n=159)

Case Processing Summary

		n	%
Cases	Valid	159	16
	Excluded*	837	84
	Total	996	100

*Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.768	.772	7

For PEoU, all scale items received higher than 0.7, therefore, the result met the reliability test threshold.

Case Processing Summary

		n	%
Cases	Valid	159	16
	Excluded*	837	84
	Total	996	100

*Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.789	0.8	5

For BIU, all scale items received higher than 0.7, therefore, the result met the reliability test threshold.

BIOGRAPHY

NAME & SURNAME: TIKAJIT RAI

DATE OF BIRTH: 30/11/1969

POSITION: Sr. Project Manager, Product Strategy, Innovation and Design, Adtalem Global Education, Chicago, U.S.

EDUCATION:

- MSc. ICT. Assumption University
- BSc. E.E. University of Oklahoma

WORK EXPERIENCE:

- Project Management: 25+ years
- Adtalem Global Education, Walden University, Laureate Education Inc., DNA Solutions & Consulting, Magnus Consulting Group.
- Active International PM Association (IPMA) Project Excellence Award Assessor since 2013.

Volunteering: VP Membership, PMI Washington DC Chapter; Board Member, PM4NGOs; VP, Asia Pacific Federation of Project Management.

AWARDS/PUBLICATIONS

- Gold Winner, International PM Association Achievement Awards in PM, 2013.
- Silver Winner, Green Project Management: Sustainable Project of the Year, 2013.

Publications: Co-author of Program Management for Development Professional and Project Management for Development Professional, 2014.