"A Blockchain Distributed Ledger Digital Identity Management System for Official University Transcripts"

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Abstract

This research study analyzed undergraduate computer science students' perceptions of using a Blockchain Digital Identity Management System (BDIMS). Students participated by sending a pseudo official transcript through an actively running Blockchain Distributed Ledger system. An explanatory sequential mixed-method research design was utilized with a primary quantitative analysis followed by a secondary qualitative analysis. A total of 115 students completed a twenty-five item Likert-type survey and one five item open-ended questionnaire. Two research questions guided this study: 1) "Is there a relationship between undergraduate students' *Behavioral Intention* to adopt the BDIMS and their perceptions towards using the BDIMS as measured by six Adoption Factors: 1) *Relative Advantage*, 2) *Perceived Ease of Use*, 3) *Result Demonstrability*, 4) *Compatibility*, 5) *Trialability*, and 6) *Subjective Norm*?" and 2) "How do six adoption factors 1) Relative Advantage, 2) *Perceived Ease of Use*, 3) *Result Demonstrability*, 4) *Compatibility*, 5) *Trialability*, and 6) *Subjective Norm* impact students' *Behavioral Intention* to adopt a Blockchain Digital Identity Management System?". Quantitative findings indicated that *Subjective Norm* is the only statistically significant predictor of students' *Behavioral Intention* to adopt the BDIMS. This is further supported by the qualitative findings which show that *Subjective Norm* has an impact on *Behavioral Intention*. Contrary to quantitative findings, the qualitative findings indicated that *Perceived Ease of Use* affects *Behavioral Intention* to adopt the BDIMS.

Keywords:
Blockchain, Distributed Ledger, Digital Identity Management, Cybersecurity, Cyberpsychology, Diffusion of Disruptive Innovation, Digital Identity Security, Education Document Management, Educational Administration, Technology Adoption

Abbreviations: BDIMS place first mention and also in footnotes of first page of article.

1. Introduction

1.1 Blockchain Distributed LedgerTechnology

Blockchain Distributed Ledger technology is the backbone of Bitcoin; a digital crypto-currency based on a decentralized management philosophy and believed to be created by Satoshi Nakamoto (Nakamoto, 2008), a pseudo name of the unknown inventor/s. Blockchain is, in essence, the combination of time-stamping (Haber & Stornetta, 1991) and peer-to-peer networking. All transactions are recorded on each digital ledger on the Bitcoin network, as opposed to a bank where transactions are recorded centrally within the bank's own transaction management system. The reason for this is that each digital ledger on the network is used to verify against each other's ledgers' authenticity. In other words, the Distributed Ledger is not stored on a centralized system, but rather on every computer connected to a Blockchain network. Every computer or node holds the same copy of the ledger and when a user attempts to make a transaction, their ledger is validated by comparing it to the network of user's ledgers on the Blockchain network. If the user's ledger is identical to the majority of other users' ledgers, then it is validated that the ledger copy has not been tampered with and the transaction is then completed. This technology can also be applied to storing and sending Personally Identifiable Digital Identity (PIDI) information in the same manner except without the crypto-currency. This added level of security allows for the removal of a third party to manage digital identity storage and validation allowing the user complete control of their PIDI information. This secured Blockchain technology applied to managing students' digital identity can bring next generation level security in a world where 14,675,876 student files have been exposed between 2011 and 2014 (Grama, 2014). The need for more security does not come at a better time when foreign entities continuously attempt to infiltrated government digital identity systems. Blockchain would offer security and autonomy to students in managing their PIDI in the form of official transcripts. This study aimed to explore the implementation of a Blockchain Digital Identity Management System (BDIMS) in higher education.

1.2 Purpose

The purpose of this study was to identify which of the adoption factors (Relative Advantage, Perceived Ease of Use, Result Demonstrability, Compatibility, Trialability, and Subjective Norm) impacted students' Behavioral Intention to adopt the BDIMS. The BDIMS was developed specifically for the purpose of this study to access and transfer pseudo official transcripts containing pseudo PIDI Information through an actively running Distributed Ledger Blockchain system. For the purpose of this study, computer science university students participated in accessing and transferring their pseudo official transcripts, containing PIDI information, on a Distributed Ledger Blockchain network. This study would also be the first to develop a framework for studying the diffusion of a disruptive Distributed Ledger Blockchain innovation for digital identity management in higher education as it has been emphasized that there is a need for research studying the impact of the real-world application of Blockchain technology (Risius & Spohrer, 2017). Three main purposes serve this study as it: (1) provides a thorough framework for studying Blockchain diffusion in higher education, both for researchers and policy makers, (2) developed and validated an instrument for studying Blockchain diffusion in higher education, and (3) provides data collected on student perceptions of their use of Blockchain technology

for digital identity management. In an effort to explore the implementation of a BDIMS in Higher Education, two research questions were asked:

RQ1: "Is there a relationship between undergraduate students' *Behavioral Intention* to adopt the BDIMS and their perceptions towards using the BDIMS as measured by six Blockchain Adoption Factors: 1) *Relative Advantage*, 2) *Perceived Ease of Use*, 3) *Result Demonstrability*, 4) *Compatibility*, 5) *Trialability*, and 6) *Subjective Norm*?"

RQ2: "How do six Blockchain implementation factors 1) Relative Advantage, 2) *Perceived Ease of Use*, 3) *Result Demonstrability*, 4) *Compatibility*, 5) Trialability, and 6) *Subjective Norm* impact students' *Behavioral Intention* to adopt a Blockchain Digital Identity Management System?".

2. Theoretical Framework

2.1 Literature Review

Nakamoto's Bitcoin is only 12 years old to date (Nakamoto, 2008), thus the real-world application and research of Blockchain technology or Distributed Ledger technology is in its infancy (Risius & Spohrer, 2017; Rooksby & Dimitrov, 2017; Sharples & Domingue, 2016; Turkanovic, Holbl, Kosic, Hericko, & Kamisalic, 2018). In the education sector, the University of Nicosia in Cyprus, not only offers Blockchain courses, but also writes earned certificates and degrees to the Bitcoin Blockchain network (Southurst, 2014). A growing number of universities today are offering courses in Blockchain technology, such as Stanford, Princeton, Duke, University of California Berkeley, and Universidad Europea Madrid (Khatwani, 2018). Sony Global Education announced the proposal to build a Blockchain based educational certificate storage system in collaboration with the Massachusetts Institute of Technology (Sompolinsky & Zohar, 2017) to digitize student academic records. The National University of La Plata, the Argentinian College, and the Parisian Leonardo da Vinci Engineering School also began developing a similar system to issue academic certificates (Turkanovic et al., 2018). In other contexts, projects include a wide variety of Blockchain use cases, such as an elephant tracking system to tackle ivory poachers (Spruyt, 2017), a food borne illness tracking system that tracks the point of illness to the point of origin for Tyson foods and Walmart (Castillo, 2017), a tuna fish tracing to combat illegal fishing (Visser & Hanich, 2018), and a large-scale document file system for the Maersk shipping company (Castillo, 2018). The Kimberly process has sought implementation of Blockchain technology to potentially end the era of conflict diamonds (Marr, 2018; Parker, 2016) and Blockchain can also store and copyright original artwork, photography, music, and multimedia. Deloitte is working on using Blockchain for commercial real estate (Kejriwal & Mahajan, 2017) and Blockchain may improve the efficiency of electricity grids, which could save electricity and distribute electricity more efficiently (Sikorski, Haughton, & Kraft, 2017). In the financial sector, Blockchain based cryptocurrencies are being used to transfer funds worldwide and has been growing with aims to replace the current Society for Worldwide Interbank Financial Telecommunications (SWIFT) system. SWIFT is an international financial payment network that banks use for transferring different currencies bank to bank. SWIFT is charging banks billions of dollars a year in transfer fees that are paid to the few banks that own SWIFT. Replacing SWIFT would decentralize funds transfer from an otherwise centralized system. The SWIFT system has also been identified as lacking certain qualities that Blockchain crypto-currencies offer, such as timestamping, information tracking and monitoring, and security in information delivery (Korea, Hallikas, & Dahlberg, 2017).

The majority of academic research on Distributed Ledger Blockchain technology concentrates on software engineering topics in security and privacy (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). Empirical and theory-driven research in Blockchain are scarce (Chen et al., 2018; Sharples & Dominque, 2016; Turkanovic et al., 2018), which is not surprising considering it's relatively young age. Risius and Spohrer's (2017) analysis of the current literature on Blockchain technology called for research analyzing the impact of real-world application, features that enhance or constrain diffusion, aspects that make it disruptive, potential costs and benefits, integration to improve services, and improving ease of use. Fabian, Ermakova, and Sander (2016) also call for better understanding of user adoption through inspecting how users perceive their digital data privacy. Research based on trial use of an authentic Blockchain product has not been found, although real-world implementation research of Blockchain technology has been conducted (Chen et al., 2018; Risius & Spohrer, 2017; Sharples & Dominque, 2016; Turkanovic et al., 2018). Based on review of the existing research body discussed in this section, it is apparent that the current study that measures user perceptions of managing their PIDI information on the BDIMS addresses the existing gap in Blockchain literature.

2.2 Blockchain Digital Identity Management Research Framework

An integration of three existing theories serves as the framework for studying Distributed Ledger Blockchain Digital Identity Management in higher education, which include: a) Roger's (1963) Diffusion of Innovation Theory (DIT), (b) Davis' (1989) Technology Acceptance Model (TAM), and (c) Kelman's (1958) Social Influence Theory (SIT). The DIT framework (Rogers, 1963) studies factors related to the adoption of an innovation, explaining the possible barriers and facilitators in the implementation of a disruptive innovation. The Technology Acceptance Model (Davis, 1989), which supports the context of this research study, is primarily based on two constructs: 1) Perceived Usefulness and 2) Perceived Ease of Use, which expand upon the DIT's: 1) Relative Advantage and 2) Complexity constructs in a technology context. The third pillar to this framework is the Social Influence Theory (SIT), which focuses on the subjective beliefs an adopter perceives about a disruptive innovation that the individual has not interacted with before (Kelman, 1958). The SIT takes into consideration the Internalization of one's own belief system on the acceptance of a disruptive innovation. Internalization of one's beliefs is not addressed in the previously mentioned theories. Rather, the Technology Acceptance Model 2 (TAM2) has theoretical foundations in the social pressures of performing a behavior, rather than the Internalization of one's own beliefs. The DIT is a strong framework for evaluating the adoption of an innovation, while the TAM makes an update to the DIT for technological purposes, and the SIT adds the Internalization aspect that allows for the study of participants' beliefs towards using an innovative technology that may align or not with their personal beliefs regarding Blockchain Distributed Ledger Personally Identifiable Digital Identity Management.

3. Methodology

3.1 Research Design

An explanatory sequential mixed-methods research design (Creswell, 2014) best fit in measuring student perceptions of using a Blockchain system for official transcript management. In particular, measuring an innovative technology that little is known about how it's implementation would occur. This particular method is effective in exploring a field that has yet to be explored. It begins with a quantitative phase that determines the development of the following qualitative phase. In other words, the quantitative phase unveils the impact of the factors and the qualitative phase delves deeper into those factors. This method unveils factors of the BDIMS and allows to expand insight on those factors. The BDIMS survey measured ease of use of the BDIMS (Perceived Ease of Use), compatibility with lifestyle (Compatibility), ability to demonstrate working knowledge of the BDIMS (Result Demonstrability), and personal beliefs (Subjective Norm) on Blockchain for digital identity management of official university transcripts.

3.2 Participants

One hundred and fifteen undergraduate computer science students participated in this study. Descriptive statistics of the participant population are as follows: 94 (81.74%) were seniors, 19 (16.52 %) were juniors, and 2 (1.74%) were sophomores. Self-reporting showed that 86 (74.78%) were male, 25 (21.74%) were female, and 4 (3.48%) chose not to disclose. Students were selected using a purposeful sampling technique that allows the researcher to select a particular population (Creswell, 2014). The reasoning behind this was to utilize a population that is familiar with Blockchain technology, otherwise informational material explaining what Blockchain technology is would need be developed for non-computer science students, which may influence participants' perceptions. This ensures content neutrality and avoids researcher bias. Student demographics were composed of Hispanic, Asian, White, African-American, and American-Indian.

3.3 Procedures

Students accessed and sent pseudo official transcript through the BDIMS and immediately afterwards completed a 25 item Likert-type survey. This survey tool is based on three existing valid and reliable surveys analyzing technology acceptance and is validated in this study. After the quantitative results were reviewed, themes were discovered and was the basis for developing a secondary analysis in the form of a qualitative questionnaire which was utilized to further explore in detail the quantitative findings. Students were asked to answer five open ended questions on the questionnaire which focused on Perceived Ease of Use and Subjective Norm and their subsequent impact on the dependent variable Behavioral Intention to adopt the BDIMS.

4. Findings

4.1 Quantitative Results

The initial phase of the Explanatory Sequential Mixed-Method design acquired data from the quantitative survey and was factor analyzed resulting in the reduction of two independent variables from the initial six. The four independent variables underwent a multiple regression analysis to determine whether any of the independent variables were statistically significant predictors of the dependent variable.

4.1.1 Factor Analysis

The twenty-five-item survey was factor analyzed utilizing two separate exploratory factor analyses: the maximum likelihood extraction with an orthogonal rotation (Varimax) and a maximum likelihood extraction with an oblique rotation (Promax). An Eigen value of one criterion was used to identify the number of factors. As a result, the appropriate model was composed of four factors. Of the original six constructs, Result Demonstrability, Compatibility, Perceived Ease of Use, Relative Advantage, Trialability, and Subjective Norm, the factor analysis identified the presence of four factors. The four factors were Perceived Ease of Use, Compatibility, Result Demonstrability, and Subjective Norm. There was no evidence of the presence of separate factors for Relative Advantage or Trialability. However, two items from Relative Advantage loaded on Perceived Ease of Use, and one item from Trialability loaded on Result Demonstrability. There was little difference between the Varimax and Promax solutions, although the Oblique Promax solution was appropriate. The correlations between the factors were .40 or higher. Given the factor analysis, 16 of the 22 items factor analyzed were retained to measure four independent variables (Perceived Ease of Use, Compatibility, Result Demonstrability, and Subjective Norm) and one dependent variable (Behavioral Intention).

4.1.2 Multiple Regression Analysis

A multiple regression analysis of the quantitative data indicated *Subjective Norm* as the sole statistically significant predictor of students' *Behavioral Intention* to adopt the BDIMS. Subjective Norm is students' personal beliefs towards Blockchain technology for Digital Identity Management of PIDI Information. The Blockchain Digital Identity Management Analysis Model was significant, ($F(4,110) = 28.106$, $p < .001$, $R^2 = 48.7\%$) as shown in Table 1, and the four independent variables explained 48.7% of the variance in students' Behavioral Intention to adopt the BDIMS. Perceived Ease of Use, Compatibility, and Result Demonstrability were not significant predictors of Behavioral Intention. Subjective Norm explained a significant amount of unique variance in Behavioral Intention that the remaining three independent variables did not explain. Scale reliability was assessed using Cronbach's Alpha measure of internal consistency and resulted in .79 for Perceived Ease of Use (6 items), .81

for Compatibility (3 items), .67 for Result Demonstrability (3 items), .81 for Subjective Norm (4 items), and .72 for Behavioral Intention (3 items).

Table 1. *Summary of Multiple Regression Analysis (N = 115)*

		BDIMS Implementation Factor Coefficients	
Variable	B	SE B	*β*
Perceived Ease of Use	.000	.049	.002
Compatibility	.129	.102	.117
Result Demonstrability	.092	.073	.091
Subjective Norm	**.508** (p < .001)	.071	.601
R^2	.505		
F for change in R^2	28.106		

4.2 Qualitative Results

The qualitative portion of the study was analyzed through a Thematic analysis lens. Thematic analysis is a method, rather than a methodology, settled within an epistemological lens that allows flexibility for codes and themes to emerge during data analysis, giving the researcher the choice of theoretical framework compared to other methods that are tied to specific theories (Maguire & Delahunt, 2017). Data from open-ended questionnaires were analyzed and results indicated *Subjective Norm* as having an impact on students' *Behavioral Intention* to adopt the BDIMS. The qualitative findings also showed that *Perceived Ease of Use* had an impact on students' *Behavioral Intention* to adopt the BDIMS. This finding is contrary to the findings in the quantitative analysis where *Perceived Ease of Use* did not have a statistically significant impact on *Behavioral Intention* to adopt the BDIMS. An inductive approach to analyzing the a-priori codes was utilized and allowed for the categories to emerge from the qualitative data analysis of the questionnaire responses. Subjective Norm and Perceived Ease of Use are further explained in detail.

4.2.1 Subjective Norm: Cybersecurity & Autonomy

Subjective Norm was expressed by students in terms of two sub-themes: Autonomy and Cyber-Security. Autonomy is expressed as the ability to manage one's own Personally Identifiable Digital Identity (PIDI) without an intermediary. Autonomy displays the impact Subjective Norm has on Behavioral Intention. This suggests that autonomy plays an important role in students' adoption of the BDIMS. Autonomy was intended to measure a student's belief system regarding the management of one's digital identity in the form of a pseudo official transcript. Students expressed their empowerment of having the ability to send their official transcripts to whomever they want and whenever they want. It was expressed that the requirement of authenticating one's identity through a multi-step verification process was not effortless for both the in person and online processes. Students desire having the autonomy to send their official transcripts at their discretion without the need of an intermediary to process the transaction. Autonomy, as expressed through Subjective Norm, has an impact on the Behavioral Intention to adopt the BDIMS.

Cyber-Security is expressed as the need for increased digital identity security. Cyber-security was a prominent sub-theme relating to students' Subjective Norm beliefs and is an important factor in students' Behavioral Intention to adopt Blockchain technology. Cyber-security emerged from the qualitative findings per students' preferences for a higher-level security digital identity management system. The data also unveiled the need for an increased level of digital identity security as shown by student responses and by the data breaches previously occurred in the private and public sectors. Cyber-attacks of well-known and well protected systems have occurred and thus the security threat of one's PIDI information is real. Computer science students desire a digital identity management system that is firmly secure with little to none cyber-security threat. This may be based on the sensitive information contained in an official transcript, such as name, home address, social-security number, identification number, phone number, and grades.

Both Autonomy and Cyber-Security expressed in detail the impact that Subjective Norm has on Behavioral Intention to adopt the BDIMS. Student digital identity cyber-security is a growing concern among law makers, administrators, and students who bear the impact of digital identity theft. According to Grama's (2014) analysis of PRC data, it is estimated that there are far more breaches that have been recorded.

4.2.2 Perceived Ease of Use: User Interface & Request Process

The qualitative results detailed Perceived Ease of Use through two sub-themes: User Interface and Request Process. User-interface is the overall layout of the visual system that users see and use. The user-interface design of the BDIMS that was expressed by students mentioned the minimal number of pages of the system, the arrangement of the layout, and the minimal number of clicks to complete a transaction.

Students preferred a simple and easy to use layout that did not have nested menus and did not require more than two clicks to complete an official transcript transaction. The design of the user interface displayed the impact that Perceived Ease of Use has on Behavioral Intention. This is validated by a previous study in which Eraslan and Kutlu (2019) found that user-friendly interface design impacted students' adoption of and intention to use a learning management system. This is not surprising given the fact that there are several research articles in the field of Human-Computer Interaction and Technology that support these findings.

The next sub-theme expressed under the theme Perceived Ease of Use is Request Process, which explained the impact that Perceived Ease of Use has on Behavioral Intention. The request process of the official transcript on the BDIMS was fast and easy when students compared it to their current legacy system. Students' current system was expressed as a rigorous identity authentication process. Students' current legacy system employs a validation system that requires a multi-step process that requires time and money. Request Process of the official transcript is a multi-step identity verification process that can be completed in person and online. The request process of requesting official transcripts has been expressed as a process that requires multiple steps that make the request process cumbersome as one student explains, "I prefer to consolidate my four different university transcripts into one place that allows me to control my academic information precisely". This student prefers to have all four different transcripts on one system instead of having to request each transcript from each university. Another student expresses this in detail, "I liked how easy it was to request my transcript and having the option to send it to my employer and whomever would like to see it." Students have expressed the rigor of the validation process when requesting official transcripts.

User Interface and Request Process expressed in detail the impact that Perceived Ease of Use had on Behavioral Intention. Perceived Ease of Use was intended to measure the ease of use of the BDIMS interface layout. The findings of this study provide evidence to the importance of an easy to use Blockchain Digital Identity Management System.

5. Discussion

Research in Blockchain for digital identity management in real-world application is scarce and thus not enough data exists to make meaningful comparisons to existing legacy digital identity management systems. This study displays a glimpse into the beginnings of a body of research aimed at the implementation of Blockchain technology for digital identity management. What this found was that **s**tudents' Subjective Norm beliefs about how they perceive their digital identity should be managed was the catalyst in students' adoption of Blockchain Distributed Ledger technology for digital identity management. According to the Social Influence Theory, adoption is an intrinsic subjective analysis that is triggered when the influenced behavior is aligned with the adopter's existing value or belief system (Kelman, 1958). According to this theory, Blockchain digital identity management adoption occurs when students' belief systems of how their digital identity is managed are aligned with how Blockchain technology manages digital identity information. Subjective Norm had an impact on Behavioral Intention through the Internalization of one's belief system with Blockchain technology. Internalization occurs when the adopter feels an intrinsic benefit to accepting the influenced behavior. That intrinsic subjective analysis is triggered when the influenced behavior is aligned with the adopter's existing value or belief system (Kelman, 1958). This research study's findings indicate that adoption is most likely to occur when student beliefs of how their digital identity should be managed are Internalized with how Blockchain manages digital identity information. Previous studies showing Subjective Norm to be a predictor of the adoption of innovative technology, and that this study's findings validate, is Park's (2009) study of university students' adoption of e-learning. In Park's (2009) study Subjective Norm played a significant role in students' behavioral intention to adopt e-learning. This study displayed statistically significant results that Subjective Norm impacts Behavioral Intention and also displayed similar results through qualitative analysis. Although no statistically significant results displayed Perceived Ease of Use as a predictor of BDIMS adoption, students' notion of Perceived Ease of Use was qualitatively expressed in the User-Interface (design of the interface system) and Request Process (process to order official transcripts). This posed a discrepancy between the quantitative and qualitative results as the qualitative findings suggested that Perceived Ease of Use did in fact have an impact on Behavioral Intention to adopt the BDIMS. Students stated the preference for a simple and easy to use user interface without nested menus and an interface with minimal steps and the least possible pages. The request process is composed of a verification process that students have expressed as time consuming and costly. To eliminate the request process would also save on administrative costs.

The findings further validate the theories and model adopted and adapted for this study and are consistent with the theories and model that compose the theoretical framework of this study. The Diffusion of Innovation Theory (Rogers, 1963), the Technology Acceptance Model (Davis, 1989), and the Social Influence Theory (Kelman, 1958) make up the theoretical framework of this study to measure student perceptions on the adoption of Blockchain technology for digital identity management. The findings that this framework uncovered included Subjective Norm and Perceived Ease of Ease as predictors of Behavioral Intention to adopt Blockchain technology. These findings corroborate with the theoretical framework of this study as Subjective Norm and Perceived Ease of Use were measured according to the collaboration of the theories of this study's theoretical framework. The instrumentation displayed this as the survey instrument was tested for internal consistency and the questionnaire instrument was thoroughly coded.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

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