Education 4.0: A Systematic Industrial Case Based Review of Barriers and Applications of Decentralized Trust Using Blockchain

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ABSTRACT

In the past couple of years, widespread technology adoption can be seen in the education sector. Accessibility of the internet and minimum data tariffs have empowered students across the globe to access information and enabled virtual learning. Education 4.0 is a new revolution that aligns learning with the needs of the fourth industrial revolution. However, this new revolution in the education sector has its own set of opportunities and barriers. The objective of this research is to systematically analyze barriers in Information Sharing in the Education Sector across key use cases of Record Keeping, IPR, and Identity Management. The research identifies barriers concerning the above use cases.

Keywords

Blockchain; Education; Interoperability

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Introduction

This research analyses the Barriers faced in Information Sharing in Education Sector in key use Cases of Record Keeping, MOOC and centralized Student Identity in Education Sector and identifies the key Gaps. It categorizes Blockchain Models based on Industry standards and analyses them with the conceptual lens of identified gaps in Education Use Cases to identify the Barriers and Applications of each Blockchain Framework. The gaps are identified based on Literature Survey and verified by conducting Frame-work Analysis with experts in Blockchain and Education Sharing. It concludes by de-fining a capability roadmap of the Gaps and capabilities of Blockchain Models for Education Sector.

Applicability of Blockchain for Information Sharing Barriers in Education Sector

Conceptual Lens of Existing Barriers in Education Sector

As explained by Hartong in [10] Education Technology sector is growing rapidly and is forecasted to produce investments worth US$252 billion by 2020. Global E-Learning market is expected to reach $325 billion in 2025 from $107 Billion in 2015 as per re-port from Research and Markets as mentioned in Forbes. The Researcher has created a Conceptual Lens using the following technique to identify Key Barriers in Education Sector across three Use Cases.

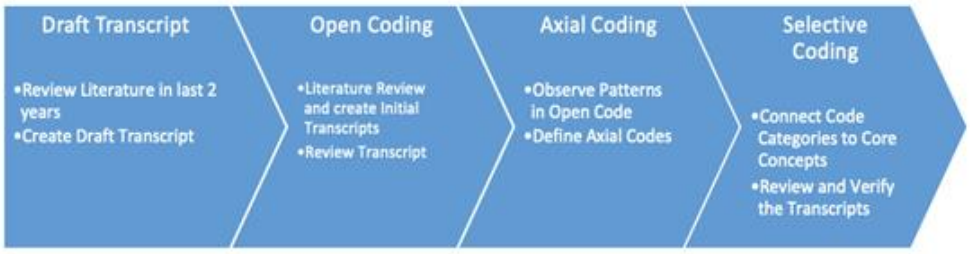

Figure 1. Creation of Conceptual Lens

Record Keeping: Degree mills are organizations that award fraudulent degrees to students without requiring them to meet the educational standards in exchange of commercial applications. UNESCO's International Institute for Educational Planning (IIEP) refers to Degree Mills as "an epidemic of corruption worldwide" in higher education. False academic credentials and degrees from unaccredited institutes are commonplace in the workforce as explained by following worldwide statistics:

- In "Degree Mills: The Billion-dollar Industry That Has Sold Over A Million Fake Diplomas" Allen Ezell highlights that as per estimates there are more than 1 million fraudulent degrees created in the past decade.
- In a report by The Star, approximately one in 20 job applicants in Malaysia enter companies using fake qualifications
- Mohamedabad in [17] adds that South Africa has shut down 42 institutes offering fake and unaccredited programs.
- As explained by Giles in [9] in the United States alone there are currently 2 million fake degree certificates and 300 fraudulent universities.
- As explained by Lam et. al in [14] in the US, due to bad reputation created by Degree Mills, only less than one-third of universities accept the legitimacy of online education. This is due to the lack of Permissioned Access Control

The key requirement in current Record Keeping is the creation of decentralized immutable credentials that are verified once by the University / Issuing authority and are in the control of the student / learner to share with various parties in the future (employers, higher education institutions etc).

Managing Intellectual Property: As explained by Wahid et. al in [25] since MOOC's emergence in 2012, it has created a new trend in online learning. MOOCs have complex copyright barriers that are linked to the relationship between education institute, its faculty, students and MOOC providers. Mostly, the course content creator, the author holds the primary right while the secondary rights belong to the person or company who created the IPR originally. As explained by Mohammed et al in [18] Trust significantly influences the employees' behaviour to share information. Further, as explained by Mingaleva et al in [16] a key problem in educational information sharing is the absence of copyright protection of course material created by educators including educational courses, lectures and presentations. Another important factor in Information Sharing as explained by Bock et al in [4] is expected rewards which is most likely to affect the participants.

As explained by Mok et al in [20] as part of the learning maturity process intellectual property rights (IPR) and its protection has become a key objective for educational institutes. European ETAN expert working group has emphasized the need for training in IPRs and inculcation of an IP culture in Education. As per UCISA, 2016, 71% of institutions have started adopting lecture

recording processes, which is a key asset for IPR. The key requirement for IP in education is for content to be created and linked to the owner through digital identity and maintain an immutable record. The critical factor of success will be:

- The creation of an interoperable network that is used for validating Content Access
- Automated Business processes to enable micro-payments for access of Edu-cation Literature and Revenue Sharing with Content Creators

Identity Management: As per ISO/IEC 24760-1 identity is defined as a set of linked attributes that associate with an entity. Digital identity is information used by computers in order to identify a specific subject. Further, SSI is an identity solution which uses credentials provided by a central organization which in turn can then be verified by 3rd party to verify the holder's identity. The prime barrier with Digital Identity Management for Education Sector is that it is primarily by an institute, or in some cases a country and is not globally acceptable and recognized. Known barriers with current centralized SSI Platforms for Education currently which are the cause of decreased Trust are:

- Low Security in Devices and Browser leading to lack of Privacy
- Weak Authentication Protocols leading to Identity Hack by network hackers
- Owned by Central Authority and not Interoperable Globally
- Not Immutable and easy to fraud the Identity information by Companies

The Researcher has analysed a total of 90 Key Node Items and aggregated them into six key themes across the three Use Cases. These key themes shall form the basis of further research:

Table 1. Matrix Coding for Conceptual Lens - Axial Code Generation

Theme	Managing Intellectual Property	Record Keeping	Identity Management
Access Control	6	8	8
Business Rules	6	2	4
Decentralization	5	2	2
Immutability	9	9	7
Interoperability	2	3	2
Technology Use Barrier	5	5	5

Industry Standard Blockchain Types

There have emerged three distinct Types of Blockchain - Public, Private, and Permissioned.

- **Public Blockchain is a Permission less blockchain**. Anyone can join the Public blockchain It is open for read, write and participation to all. Public blockchains are decentralised with no owners. Data is immutable and cannot be changed once validated on the blockchain. The Record Owner loses some level of custody and control of the Data and ZKP is used to bring Privacy.
- **Private Blockchain**. Private networks place restrictions on who is allowed to participate, read and write in the network. Business Rules and Data stored can be modified upon getting approvals from

Owner Organization. In addition, another layer of Data Security can be maintained by storing Data in Off Chain Databases like Mongo DB, Couchbase or Elastic.

- **Permissioned** blockchain fills the gap between the Public-Permissionless networks (like Bitcoin or Ethereum) and the Private Consortium networks. A Permissioned blockchain follows the permissioning from private consortiums and a decentralized governance model from Public Blockchain. As explained by Arndt in [2] Immutability and TPS are similar to private blockchain, In terms of centralization it is intermediate between the truly decentralized public blockchain and centralized private blockchain. As explained by Lemieux et al in [15] Permissioned Blockchains, the consortium members have control over the Blockchain which is managed by policies and regulations. However, custody of records is shared by all participants of the Blockchain and data is visible to all.

Insights of Blockchain Type for Education Sector

Lorem As explained by Garcia in [7] and E.Garc et. al [6] blockchains have multiple applications in Education to overcome the barrier of Federated Identity and lack of Trust in intermediary. The key strength of Blockchain for the Education Sector are:

- Transparency & Immutability: Blockchain Data is immutable and any changes to information, be it On Chain or Off Chain it is traceable and visible to all. Hence Blockchain will ensure that Information shared across Organizations is transparent and visible to all.
- Decentralization: Through Decentralized Access Control it ensures that no Central Authority controls the Enabling a Student and Institute information. There will be global access to information since there is no single owner of the Blockchain.

Below is an analysis of existing Blockchain applications in Education Sector across key Use Cases identified based on Conceptual Lens created from Literature Survey.

Record Keeping

Blockcerts

Blockcert is a digital file (JSON) that is both human and machine readable. This file can visually represent any time of record, like a diploma or a transcript, and can be enriched with metadata for greater clarity. The blockchain is used like a global notary to verify that a record is authentic and has not been altered since it was first issued. A decentralized global network can instantly verify any Blockcert without an intermediary. Blockcerts is Open Badges compliant which is based on Linked Data. Linked Data publishes data in formats which makes it understood in many contexts. Blockcerts is designed to verify records using any decentralized network including Bitcoin, Ethereum, Hyperledger, and more.

- The Massachusetts Institute of Technology offers digital diplomas to all of their graduates using Blockcerts
- As explained by Alessie [1] the Maltese project an access control layer owned by the Consortium Partners is built on top of the Public Bitcoin network. This ensures that access control is managed by the Owners in a Public Blockchain

OpenCerts

As explained by Asiri in [3] is a platform based on Ethereum Blockchain and was created by the Government Technology Agency, Ministry of Education, Ngee Ann Poly-technic and Skills Future Singapore. Since 2019, OpenCerts started to issue students' academic records for 18 universities in Singapore. Their project depends on signing document hashes in the Blockchain

without requiring any personal information from the students. When an OpenCerts certificate is created, a unique digital code is tagged to it. The digital code, along with hashed information from the certificate, is stored on the blockchain. When the opencert file on this site is opened, its contents are compared to the original value stored on the Blockchain for verification. OpenCerts is powered by Ethereum.

Sony Fujitsu

As explained by Sun et. al in [23] Sony Fujitsu is creating a Blockchain enabled Plat-form in collaboration with Hyperledger Fabric to enable

- education and training institutes to easily contribute data to the Blockchain
- Collate individual data and store in verifiable format
- Allow authorized Organizations to analyse the data for training requirements

As explained by Don Tapascott et al in [24] Sony Global Education is the first consumer of this technology to allow two parties to share official academic records securely with-out prior relationship. Further as explained in [12], Sony Global Education will verify the platform by using it to store transactional data generated by 250,000 participants in its world-wide maths competition namely Global Math Barrier.

Managing Intellectual Property- Binded

As explained by Grech in [8] Binded (previously known as BlockAI) is a copyright registration service used to store digital images on the blockchain. When the author uploads an image, it is stored along with its hash, author identity and upload timestamp. This ensures an immutable proof of publication which can be used for enforcing copy-right claims.

Identity Management - Sovrn

A decentralized identifier (DID) is an online identity that you can create that is truly owned by the owner In British Columbia in [13] Canadian companies waste C$10 Billion per year in the “red tape” process due to lack of decentralized identity. This has been optimized by using Hyperledger Indy based solution which supports SSI con-trolled by the individual. Wallet details are stored in Postgres SQL and the system sup-ports up to 2600 verifications per minute. Sovrn provide this is in permissioned plat-forms by the propagation of trust amongst entities. As per the Sovrn White Paper [22] –the “Internet of Identify” solution based on Hyperledger Indy implements a pairwise-pseudonymous identifiers which is a separate DID for every relationship to ensure complete privacy of identity information.

Summary of Applications and Barriers of Industry Blockchain Types for Education Sector based on Literature Survey

Based on the above analysis we summarize per Blockchain Type the attributes of the key themes which have been analyzed based on Literature Survey:

Table 2. Attribute Analysis of Key Themes per Blockchain Type

Blockchain Framework	Decentralization	Immutability	Business Rules	Permissioned Write/Read	Interoperability	Technology Barriers/Data Entry
Public	High	High	Medium	All	High	Low
Private	Low	Medium	High	Can Control Write Access based on User	Low	High

				Roles		
Public Permissioned	Medium	Medium	High	Control Write Access based on User Roles	Medium	Medium

Table 3. Application and Barriers of Industry Blockchain Types

Blockchain Type	**Blockchain Provider**	**Use Case**	**Applications**	**Access Control**	**Volumetric**	**Barriers**
Public Permissioned	OpenCerts on Ethereum	Issuing and validating academic certificates that are tamper-resistant and permanent	Educational institutions will substantially reduce the time spent on re- issuing certificates and vouching for their authenticity.	Per missioned Reads	Stores records of 18+ Universities in SG	Degree mills could also (Saleh, Ghazali, and Rana 2020 [21]) make use of OpenCerts to publish certifications onto the public blockchain Interoperability
Public Permissioned						
	BlockCerts on a wide variety of blockchains including Bitcoin, Ethereum, and Hyperledger	Used like a global notary to verify that a record is authentic and hasn't been altered since it was first issued	Enabling recipient control of their claims through easy-to-use tools such as the certificate wallet (mobile app)	Permissioned Read	Depends on underlying Platform	Enhanced integration with Decentralized Identifiers
Public Permissioned	Sovrin on Hyperledger Indy	Internet for Identity - create a decentralized system of student profiles that contain both profile data as well as learning records	ZKP	Permissioned Read	High due to separate Validator and Observer Nodes	Interoperable in Permissioned Group

Private	Sony Fujitsu on Hyperledger Fabric	Digital Record Keeping	It allows for more flexible data models and business logic	Permissioned Read & Write	250,000 Student Data is stored	Interoperability with other Blockchains
Public	Binded on Bitcoin	Copyright platform" for blockchain, creating "a unique Immutable fingerprint (cryptographic hash) for each copyright record"	Democratize Copyright due to a Truly decentralized Platform	Public Access	Imposed by Bitcoin	Initial authentication in the uploads. That is, how to prove ownership when a user uploads an image?

Framework Analysis of Blockchain Models for Education Sector

To verify the Literature Findings a Qualitative Research based Stratified Random Survey was conducted From Apr- Jun-2020 for gathering barriers faced by 100+ experts in the Education Sector for Information Publishing, Sharing, IP Protection and Credit Sharing and applicability of Blockchain using Closed Questions verified by Education and Blockchain domain experts. The respondent profile was a combination of Academic Teachers, Directors and Administration Staff to ensure we provide sufficient coverage across all departments.

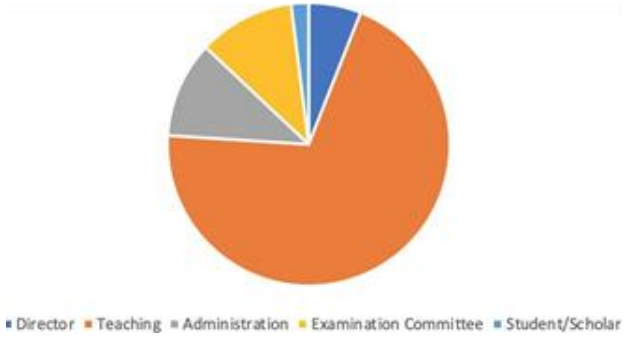

Figure 2. Information Sharing in Education - Survey Respondent Profile

Based on the above Survey Response from a Stratified sample of 100+ respondents we can say with 75% confidence that below is a summary of Blockchain requirements for Education Sector Barriers per Use Case:

Framework Analysis - Blockchain Models

To verify the Blockchain applications we have shared our observations with Industry experts including Mr. Rajesh Dudhu (Tech Mahindra, Blockchain Head), Ms. Zainon Mustaffa (Registrar, Asia School of Business, Malaysia), Nizar Jamal (Transformation and Cyber Security Expert, Florida), Dr Manohar Menon (Head of Innovation, Celcom, Malaysia), Mr. Subramonia Sarma (Senior Director of Action Learning, ASB, Malaysia) and Zheng Wei QUAH (Accredify Cofounder & CEO).

Detailed Analysis of Barriers in existing Blockchain Types

This paper has analyzed Six Key Barriers for existing Education Sector Information Sharing across three Industry Models for Blockchain Based Content. Below is a summary of identified gaps and proposed Framework.

It is critical for Education Sector to share Information across diverse institutes. However, current Blockchain Platforms work in siloes and have Interoperability limitations on:

- **Proprietary Formats:** Data storage formats are specific to every application and are not Interoperable. For e.g. if one college wishes to transfer, access or duplicate Information from one Blockchain application to the other, it is currently not supported since each application has their own proprietary formats
- **Application Based ACL's**: Smart Contracts are executed based on Signatures which are addressable by the Blockchain applications Users only. Existing frameworks do not provide a mechanism to produce signatures which can be verified by other Blockchain applications.
- **Regulatory Standards**: to be addressed at National as well as International level to help improve Interoperability across Education Institutes

Table 4. Information Sharing in Education – Survey Response

Survey Question/Theme	Significance	Observation
IS-RQ1 What are the Primary Objectives of the Respondents in Information Sharing	To understand significant Use Cases and barriers in Education	• Verification of Records due to lack of Trust is one of the major problem faced by 76% respondent leading to time delays and Operational Overheads
IS-RQ2: TECHNOLOGY BARRIER: Existing Barriers for Information Sharing across Organizations	Research questions were focused to understand the Barriers faced by Organizations due to lack of infrastructure, , process of information sharing, Govt or Organization Regulation or Technology issues.	• Cost of Digitization is the highest Barrier faced by 48% of respondents due to Technology, Resource Availability and lack of Infrastructure • Lack for common formats for Inter- Operability across Organizations
IS-RQ3: IMMUTABLE: Need for Immutable Information Share in Inter Organization and External Organization Information Sharing	Research questions were focused to understand if Data Immutability is critical and relevant for the Organization since this is a key characteristic of Blockchain Data.	• 83% of the people strongly believe that data entered in the organization should be immutable and this will help increase Trust in Information Sharing
IS-RQ4: INTEROPERABLE: Average number of times Information is shared in Inter Organization and External Organization Information Sharing	Research questions were focused to understand how frequent the information is being shared within or outside the organization. This will help to determine the Data Volumes required for Blockchain	• 62% of the people share the Information about 1-1000 times in a month 25% up to 5000 times in a month, 4.1% up to 10,000 times in a months and 8.33& share information 10,000+ Per Month
IS-RQ5: RBAC (Role Based Access Control) for Information Sharing across Organizations	Research questions were focused to understand need for security and Trust depending on what organization policy. It is commonly believed that Trust is higher within the Organization compared to external organizations. This will help to determine if we need different levels of Security and Privacy Implementation for different types of organization.	• 61% of the people say that data can be shared with trusted Organizations whereas the remaining do not share the data with 3rd Party Organizations digitally due to lack of Trust. • 48% see a strong need for Role Based Access Control with Audit logs for Read and Access Control
IS-RQ6 ACCESS PERMISSION: How is data secured in a university?	Research questions were focused to understand how data is secured in current system in the organization and depending upon that we can see what is need for security depending on what organization policy is which vary from organization to organization.	• 66% of Organizations still depend on Passwords Only for data exchange, which is not a very secure means of Data protection. Hence there is a requirement for advance data protection protocols in Organizations like Encryption and Firewalls
BC-RQ1: DECENTRALIZED: Applicability of Decentralized Blockchain to Information Sharing in Education Sector	We wanted to confirm with respondents that with the technological advancement of Blockchain do they see a application in their domain.	• 52% Respondents see an application of Block chain in cost saving for students and Organizations • 30% people see operational savings can be brought by introducing block chain.
BC-RQ2 BUSINESS RULES: What are the Key Use Cases where they see applications of Blockchain	Research questions were focused to understand the key use cases where the respondents see applications of Blockchain to their domain • Intellectual property protection • Storing student credentials • Identity verification • Innovation learning platform	• Sharing Degree Certificates (Storing student credentials) is the primary Use Case • Identity verification by the use of block chain as there is no Single Central identity currently for the students • Automated Payments for Record Sharing and Information Material Revenue sharing

Table 5. Information Sharing Barriers for Education Sector Per Use Case

Use Case	Decentralization	Immutability	Business Rules	Permission Read/Write	Inter-Operability	Technology Barrier
Record Keeping	High	High	High	High	High	High
Managing Intellectual Property	High	Medium	Medium	High	High	Medium
Identity Mgmt	Medium	High	Low	Low	High	Low

Table 6. Interview Response of Blockchain Models

Question	Significance/Themes	Observation
IS-RQ1: What are the Key Barriers in Information Sharing	• ACCESS CONTROL: Understand Need for Security in Education • TECHNOLOGY BARRIER: Understand IT Maturity Level in Organization	• There is lack of Trust with Information Partners that content will be altered without permission • No IPR Rules are in place to verify that content is not illegally shared • Technology is a serious barrier since some staff is not familiar with IT • Implementation of Access Control at Read and Write Level for Data
IS-RQ2: How is Degree Record Verification done for Uni currently	• BUSINESS RULES: The cost involved in information sharing currently will help justify Blockchain investments • Time required for Degree Verification process	• For a Small Size University, currently there is a Manual process for Degree record Verification • The process takes 2-3 Days and cost per Degree Certificate Verification varies from 8- 15 Dollars
IS-RQ3: What is the confidence level that Information shared with Organizations is Secure	• DECENTRALIZATION: Understand the key barriers faced in Information Sharing • ACCESS CONTROL: Maturity level of existing Data Security Tools. To help determine the different levels of Security and Privacy required in the Blockchain Models	• There is no Regulatory process in place for Information Sharing • There is no Audit Log or Traceability of changes, Modifications done by Partner Organizations • Content Plagiarism is a serious issue and Revenue Sharing mechanisms are not in place for IP content
BC-RQ1: What are the key Use Cases where Blockchain has applicability in Education	• INTEROPERABLE: Understand the key use cases where the respondents see applications of Blockchain to their domain:	• Organizations believe that they do not have a mechanism to verify the Degree Records of new Employees and they trust the certificates shared by Employee • Verification of Health Records of students • Interoperable Blockchain to ensure Data Trust amongst Organizations
BC-RQ2: What is the Cost of Investment from	• TCO: Understand the Investment cost and appetite for the Industry	• Blockchain is coming up as Blockchain as a Service provided by Cloud Providers like AWS, Azure and Alibaba. With minimal license cost this is available to Organizations and hence Cost of Operational Blockchain is not prohibitive
BC-RQ3: What are the key barriers in Blockchain Implementation in Industry	• IMMUTABLE: Understand the barriers cases where the respondents see issues of Blockchain to their domains	• Availability of Blockchain trained resources is an inhibitor for implementation of Projects • There is lack of direction at a National Level for implementation of Blockchain in Education in India • Interoperability of Data Across Blockchains and Institutes • No way to verify the Data uploaded by the Institutes in the Blockchain

Fine grained Access Control Policies

Current systems implement Coarse grained Policies e.g. Access rights based on User Role on content. However, Fine grained policies based on User Identity, User attributes or Multiuser approvals such as below are not supported:

- Time Based: If the user has edited more than "X" Records in the last 1 Hour then do not allow Record editing
- Provenance Based: Edit rights are declined if the User does not meet the requisite provenance predicates. For e.g. if the User has transacted has not been associated with the Record for more than "Y" Months then access is not granted
- Aggregate policies: if the Degree Record is More than a Qualification e.g. PhD then record edit is not permitted unless approved a minimum of "Z" Owners.
- Hierarchy Based Access: User access roles can be defined based on Hierarchies and a child can inherit all the Access Control rights assigned to the parent

Data Loading Verification

Blockchain Models can be used by Fraudulent Organizations like Degree Mills for Record Keeping. There is no Business Process to verify the Data Published into the Blockchain for either Record Keeping or Copyright purposes. This is a Business Process limitation. The certificates stored in the blockchain are tamper proof, but current Blockchain Models do not have a separate verification service for verifying its validity. Hence, there is a possibility to spoof the certificate.

Conclusion and Future Scope

This paper has analyzed three Blockchain Industry Models with the conceptual lens of six known Barriers in Education Sector for Information sharing across three key Use Cases. All three Blockchain Models provide varying levels of Decentralization, Immutability and Permissioned Access Control. Public Permissioned Blockchain Model provide support for Identity Management and hence are suitable for Identity Management Solutions. Public and Permissioned Models provide higher level of Decentralization and hence are suitable for Intellectual Property Protection. Record Keeping use case are applicable for all types of Blockchain Models. Future research can focus on Blockchain Models to ensure a solution which provides Fine Grained Access Control and Interoperability across Blockchain Models.

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