CONNECTED IMPACT

Unlocking Education and Workforce Opportunity Through Blockchain

American Council on Education®

OFFICE OF Educational Technology

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Through Blockchain

by Kerri Lemoie and Louis Soares

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Louis Soares

Soares is ACE's chief learning and innovation officer. In this role, Soares incubates and scales ACE's executive leadership networks, as well as catalyzes compelling research and innovation initiatives across the Council. Working with colleagues, Soares integrates the work of ACE's leadership, research, and innovation teams to optimize membership value for colleges and universities by developing programs and services to advance the success of campus leaders, diversify the executive talent pipeline, and facilitate partnerships to enhance institutional performance. Prior to ACE, Soares was the director of the postsecondary education program and fellow at the Center for American Progress, director of business/workforce development under Rhode Island Governor Donald L. Carcieri, and director of education partnerships for the Rhode Island Technology Council.

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Interviewees:

American Public University System (IJOER)
Arizona State University and Trusted Learner Network (TLN)
BCDiploma
BitDegree
Central New Mexico Community College
Concentric Sky
Consensys
Credly
Digital Credentials
Consortium Digitary
Ellucian
Elon University
Ethos Vet
Evernym
Fluree
Georgia Tech (C21U)
Government of Canada (Talent Cloud)
Government of Canada (Pan-Canadian Trust Framework)
GreenLight
Hyland Credentials (formerly Learning Machine)
IBM
iDatafy
Learning Economy
National Student Clearinghouse
The New School
ODEM
Oral Roberts University
Parchment
Pistis.io
RANDA
Registree
Salesforce
Santa Fe Public Schools
Southern New Hampshire University
The State University of New York
Union Public Schools
University of Texas
University of Washington Continuum College
VetBloom
Workday

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FOREWORD

This report comes at a moment of unprecedented uncertainty for higher education. In a matter of weeks, colleges and universities across the country halted face-to-face classes and moved instruction online. Students displaced from dorms are now grappling with the reality of food insecurity and even homelessness as the broader economy has stalled and jobless claims have soared. Dreams of economic mobility have been deferred for millions of learners who were pursuing new careers and credentials.

In periods of economic crisis, higher education typically serves as both a backstop for displaced workers and an engine for economic recovery. But today's crisis is exposing widening fault lines between educational institutions and the demands of an increasingly dynamic labor market.

At the core of that challenge is a communications gap rooted in a disconnect between how higher education and the labor market talk about, measure, and signal individuals' skills.

This issue is not new. Just months ago, when we were in the midst of the tightest labor market on record, education and business leaders were already concerned about the mismatch between educational outputs and labor market demand.

As of December 2019, four in 10 recent college graduates were underemployed (Federal Reserve Bank of New York 2020), and Black and female graduates were each nearly 10 percentage points more likely to be underemployed than their White and male peers (Williams and Wilson 2019; Burning Glass Technologies and Strada Institute for the Future of Work 2018). Employers were looking beyond the degree to assessments or even college alternatives in order to identify workers with in-demand skills (Connley 2018).

Now, as the implications of mass unemployment loom large, the imperative of making good on our collective educational investments takes on new urgency. Addressing issues of interoperability between education and employment is more important than ever.

As we make our way through the crisis and into recovery, that imperative should encourage experimentation with approaches to credentialing (and hiring) that leverage the potential of new technologies to provide more granular descriptions of skills and improved communication among education and training organizations, individuals, and employers.

Blockchain, in particular, holds promise to create more efficient, durable connections between education and work. It can provide the technological fabric to help displaced workers translate their skills for new education opportunities and employers, and may hold particular value for those currently underserved by the existing education-to-employment paradigm.

This report reflects the culmination of the first phase of a two-year initiative focused on exploring both the opportunities and the risks of utilizing blockchain to translate skills and educational experiences into a language that individuals—and employers—can use.

That exploration began before the COVID-19 crisis, in recognition that higher education needed a new way to codify and communicate the outcomes of both formal and informal learning. It reflected a belief that providing learners, including those most at risk, with control over their data could enable more seamless transitions from education to employment (and back).

In the wake of the COVID-19 crisis, learners will be more mobile, moving in and out of formal education as their job, health, and family situations change. This mobility will be true both for students already in the educational pipeline and for the working adults who will turn to higher education to retool and reenter the job market. They will need consistent ways to document their learning and bring their records with them.

Our institutions will, likewise, struggle to find their footing in ways that are distinct from previous recessions. More than a handful may close during this period. It is an extreme possibility, but one we must prepare for—and it will force us to reconsider our role as the sole owners of student records. We must be more willing than ever to test innovations that could equitably help people better develop and share their skills. Creativity and experimentation will be essential for higher education to continue to open the doors to opportunity.

Ted Mitchell
President
American Council on Education

INTRODUCTION

This report is the first phase of the Education Blockchain Initiative, funded by the U.S. Department of Education and managed by the American Council on Education (ACE). It summarizes an intensive research project to better understand the application of blockchain, a form of distributed ledger technology, to education. Its content is intended to inform policymakers, technology developers, education practitioners, and workforce entities about the state of and potential of interoperable digital credentials anchored on blockchains. This report also provides guidance to these stakeholders on the effective implementation of blockchain-based digital credentials infrastructure.

This report provides an introduction to blockchain technology and adds context for why blockchain's attributes may prove useful and effective in a global, technology-driven economy that is dependent on documenting, verifying, and sharing data on individual learning. It summarizes the findings of an intensive research project, particularly focusing on themes of personal data agency and privacy, lifelong learning, and the power of stakeholder ecosystems. Delving deeper into DLT itself, the report describes specific applications, protocols, and networks and infrastructure. It elaborates on challenges and considerations at this early stage of DLT application to education and offers concluding remarks for the future of blockchain in education.

What Is Blockchain?

Blockchain is a technology best known as the underpinning of the first cryptocurrency, Bitcoin. It is a type of shared, distributed ledger technology (DLT) that uses an agreed upon and encrypted process to ensure that the information on the ledger is tamper proof and that the data on the blockchain can be trusted even without centralized, third-party validation. DLT consists of three layers:

- **Applications:** This layer is how end users interact with DLT. As such, it might take the form of digital wallets, mobile interfaces, analytics tools, and the like.
- **Protocol and Network:** This layer encompasses the software and processes that govern a distributed ledger, such as consensus mechanisms and issuance of tokens.
- **Infrastructure:** This layer encompasses the computers, servers, and systems that make up the peer-to-peer network running the distributed ledger (Nelson 2018).

The concept of a ledger is common in business settings, where different parties record revenues and expenses. Today, a shared and distributed blockchain ledger enables the transaction record to be seen

BLOCKCHAIN

Blockchains are distributed digital ledgers of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one (making it tamper evident) after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify (creating tamper resistance). New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules (Yaga et al. 2018, 49).

by all participants. Because the process of recording transactions to the ledger is agreed upon by users (i.e., "consensus based") and encrypted, the ledger can be trusted by all who transact on the blockchain. Since Bitcoin, thousands of other distributed ledger technologies, including more blockchains, decentralized applications, and software frameworks, have come into existence.

This expansion of DLTs is not surprising. In a global, technology-driven economy that generates trillions of online transactions a day in banking, ecommerce, health care, and the Internet of Things, a shared, distributed ledger that is used and trusted by all participants of a transaction can reduce costs and inefficiency and thus expand economic growth.

At its core, a DLT is about managing data, transactions, and relationships differently, particularly by avoiding reliance on a centralized authority to ensure that all participants on the blockchain, and their data, can be trusted. This lack of a centralized authority could usher in a time when individuals can have more control of their own data, enhancing their ability to make transactions of all kinds and allowing select people to see and use their ledger. While DLT gained attention as a mechanism for conducting transactions for digital currencies like Bitcoin, the underlying applications, protocols, and networks and infrastructure can be used to document, verify, and share data about many things, including learning, knowledge, skills, and abilities and the credentials that represent them.

Why DLT for Education?

Joseph Stiglitz, Nobel laureate economist, and Bruce C. Greenwald, in their 2014 book *Creating a Learning Society: A New Approach to Growth, Development, and Social Progress*, wrote that "the most important endowment (for economic growth) is a society's learning capacities, which in turn are affected by the knowledge that it has; its knowledge about learning itself; and its knowledge about its own learning capacities" (Stiglitz and Greenwald 2014, 26). Stiglitz and Greenwald bring a macroeconomic perspective to an issue: how a society knows what it knows.

This issue is increasingly relevant to public policymakers, educators, and employer stakeholders with regard to transactions around education, skills, and competencies. Indeed, the stakes may be highest for individual students, workers, and citizens that have to learn and document what they can do while, at the same time, the skills most in demand by employers are rapidly changing. Recent research by the World Economic Forum (2017) indicates that the half-life of skills learned in college is now just five years, while according to the U.S. Bureau of Labor statistics, average time in a single job is shrinking and is now only 4.2 years (U.S. Department of Labor, Bureau of Labor Statistics 2018). This speed of transition in labor markets suggests both a growing number of and increased intensity in learning and employment transactions for the foreseeable future.

But historical conventions, policies, and technologies limit their access to human capital data, and learners, therefore, lack agency over the record of their own learning. Moreover, in a fast-changing world, the ability of individuals to document, verify, and share data about what they know and are able to do may be the essential component that enables personal career paths for a future of opportunity, economic competitiveness, and social mobility.

This ability to give individuals agency over their data is not as easy as to foster as it may seem. A modern economy keeps information about what people know in many different types of credentials, including resumes, CVs, high school diplomas, college transcripts and degrees, human resource records, job applications, licenses, certificates, and increasingly, digital badges. Education, employer, and workforce stakeholders then use these credentials to conduct transactions such as college admissions or transfer, recruiting, hiring, and promoting employees. Conducting knowledge, skills, and abilities transactions with this variety of credentials across multiple stakeholders with different ways of verifying that learning has taken place is a challenge. Technologies such as blockchain help solve this challenge by shifting control over human capital data from education, workforce, and employer stakeholders to the individual learner, worker, and citizen.

Controlling your own credentials is increasingly important. Today, 65 percent of all jobs require a post-secondary credential (Carnevale, Smith, and Strohl 2013), so, not surprisingly, we are experiencing an explosion in the number of credentials that document learning. A 2019 analysis of the U.S. education and workforce-training landscape conducted by the Center for Regional Economic Competitiveness and the George Washington University Institute for Public Policy identified 738,428 unique credentials produced for documenting learning and used in labor market decision-making (Credential Engine 2019). The count includes credit-bearing degrees and certificates, as well as non-credit-bearing offerings such as digital badges and apprenticeships. Fueled by certificate and badge growth, the number is projected to grow quickly in the coming decades. This phenomenal growth requires near real-time capability to document, verify, and share what an individual knows and is able to do.

The data on college transfer provide a different perspective on what happens to what students have learned and whether they can keep it when they move across institutions. According to a 2018 National Student Clearinghouse report on transfer, of the one million first-time undergraduate students who enrolled in fall 2011 and who transferred within six years, 53 percent transferred once, 27 percent transferred twice, and 20 percent transferred three times or more (Shapiro et al. 2018). Yet, a 2017 Government Accountability Office analysis indicated that students on average lose 43 percent of their credits when they transfer (U.S. Government Accountability Office 2017). All of what students have learned is not necessarily captured in the credit transfer transaction when they cross institutional boundaries.

In addition, education and labor market data suggest that individuals need to be lifelong learners in order to be successful. Moreover, the number of post-traditional learners has increased in recent years (Barrett 2018) and may be reaching a total of 60 percent of all students (Soares, Gagliardi, and Nellum 2017). These students may defer post-secondary enrollment after high school or enrolled after earning their GED®. They may be older adults, starting college or returning after working or serving in the military, or they may be first-generation students, single parents, or adults attending part time. Post-traditional students tend to have longer, episodic education pathways while combining life, work, and education, and they face challenges completing quality postsecondary credential programs. Also, minorities are overrepresented among lower income, post-traditional learners who are at risk of not completing credential programs, thus further widening equity gaps and attendant social mobility challenges (Carnevale and Smith 2018). Documenting and sharing what they know and are able to do spans across colleges and universities, employers, and other venues, and requires translation of sector-specific learning and skills taxonomies. In other words, the lack of a common language is also a complicating factor.

With so many students, workers, colleges and universities, employers, and other stakeholders seeking to document, verify, and share evidence of learning, it is easy to see how blockchain's unique attributes of a tamper proof, shared ledger could optimize human capital and promote competitiveness and social mobility. College registrars, hiring managers, students, and workers all could share a distributed ledger in near real time, making education and labor market transactions to mutual benefit. Importantly, blockchain would enable more individual student and employee agency, giving them more control over their own human capital record.

Still, these are early days. In 2017, a European Commission report (Grech and Camilleri 2017) noted that blockchain applications in education were still in their infancy. It acknowledged that some organizations used DLT for the sake of using it, not because they assessed it to be the appropriate technology for the problems they sought to solve. It also suggested that while it could be a decade before the technology proves itself, it could have an impact on education, just as the Internet has.

Three years later, this potential still appears to be true. There are more organizations registering credentials on blockchains, but many of these credentials are not yet claimed or used. That said, there are now bigger ecosystem initiatives that are investigating how their networks connect and utilizing the technology for transparency and efficiency. There is a wider understanding of what the technology is capable of beyond securing credentials, especially in terms of control of personal data. The technology and related standards are a work in progress, but this is the critical stage where participation is what establishes the criteria and use cases to move it forward.

RESEARCH AND FINDINGS

The research for this report was conducted November 2019 through February 2020. It sought to conduct a landscape analysis of blockchain efforts related to education using a framework first developed by Risius and Spohrer (2017). Their framework was modified to fit this research, using the framework's activities (design and features, measurement and value, management and organization) and applying them to relevant stakeholders (individuals and society, institutions and workforce, initiatives and efforts). It asked questions such as:

- What problems does this solve? (design and features)
- How does blockchain change current systems and technology? (measurement and value)
- What are the legal and privacy issues? (management and organization)

The approach included online research, literature review, and industry interviews, including interviews with institutions, implementers, and experts in education and education technology. Because most initiatives and efforts are at the proof of concept, pilot, or planning stages, there was limited access to students and employers actually participating in these efforts. For this reason, the research was limited primarily to institutions and implementers. In total, 40 institutions, implementers, and experts in blockchain and in education were interviewed. The findings reflect an analysis of their aspirations, attitudes, and perspectives.

Summary of Findings

The research found 71 active efforts internationally in various stages of development, research, and planning regarding blockchain and distributed ledger technologies in education. It is an exciting time for the emergence of this technology in education, but it is early. Many efforts are at the proof of concept or pilot stages of testing and iterating. Some efforts are adding blockchain-related functionality to existing platforms or are in the ideation and start-up stages.

Several of the interviewees expressed trepidation and an inclination to wait and see. Primary concerns were the

SELF-SOVEREIGN IDENTITY

An identity system architecture based on the core principle that Identity Owners have the right to permanently control one or more Identifiers together with the usage of the associated Identity Data Privacy by Design - A set of seven foundational principles for taking privacy into account throughout the entire design and engineering of a system, product, or service (Sovrin 2019, 23).

costs of adding and shifting to new systems, and how legal and operational questions surrounding data ownership and control will be addressed. Also, distributed ledger technologies are not widely understood, are still nascent, and have not proved their value in this context yet.

There is anticipation surrounding the development and refinement of educational data standards and self-sovereign identity-related standards. These standards are critical elements that will contribute to how records are understood and verified. The education data standards aim to clarify how education and workforce records are understood. Self-sovereign identity-related standards provide the vocabulary and protocols to verify personal data. The work on these standards is accelerating, but at the time of this writing, they are not likely to be production-ready for another year or more.

Most of the efforts are in some way related to higher education and the workforce, with a couple of initiatives aimed at students in high school. Further, many of these efforts are in some way related to the issuing and verification of academic and work records. Blockchain-based CVs and portfolios expand upon this concept by providing management and display of aggregated records. Small and localized ecosystems comprised of learners, educators, institutions, and employers support and encourage education and job-seeking efforts by leveraging blockchains to secure and communicate evidence of learning, recommendations, and work experience. Online courseware applications are offering innovative education models intended to make learning and training more accessible, affordable, and applicable to available employment opportunities. Other pilots are using self-sovereign identity-related standards with the potential to give individuals more control over their personal information.

INITIAL COIN OFFERING (ICO)

The first sale of a cryptocurrency to the public conducted for the purpose of raising funds (as to support a start-up) (Merriam-Webster, n.d.-a).

TOKEN

A unit of cryptocurrency (Merriam-Webster, n.d.-b).

DECENTRALIZED NETWORK

A network configuration where there are multiple authorities that serve as a centralized hub for a subsection of participants. Since some participants are behind a centralized hub, the loss of that hub will prevent those participants from communicating (Yaga et al. 2018, 51).

DISTRIBUTED NETWORK (PEER-TO-PEER NETWORK)

A network configuration where every participant can communicate with one another without going through a centralized point. Since there are multiple pathways for communication, the loss of any participant will not prevent communication (Yaga et al. 2018, 51).

DISTRIBUTED LEDGER TECHNOLOGY (DLT)

A system, most commonly a blockchain, for creating a shared, cryptographically secured database (MIT Technology Review 2018).

Several of the efforts have used initial coin offerings (ICOs) to raise funding and add functionality to their systems. Tokens, units of cryptocurrency, are purchased during ICOs or offered while participating in systems. They are being used to incentivize behavior, motivate participants, and pay for services or tuition.

A variety of distributed ledger technologies are being used and often combined. The public Bitcoin[1] blockchain is the largest, most mature network with, at this writing, over 10,000 nodes. Although initially conceived to store a ledger of cryptocurrency transactions, it is also used to record other types of transactions, and it is the DLT currently most frequently used in education. This is likely the case since Blockcerts,[2] a technology standard and code library for registering and verifying certificates on blockchain, has been in existence the longest and started with the Bitcoin blockchain. Blockcerts expanded to use Ethereum,[3] another public blockchain that was created from Bitcoin.

In addition to storing transactions, Ethereum runs tiny, decentralized programs, also referred to as smart contracts. Many of the projects are using smart contracts to process logic, such as completions of tasks and numeric calculations for grading. Ethereum is a popular choice, but there are several implementations of Hyperledger Fabric or Hyperledger Sawtooth, which have the capability to run smart contracts as well.

Hyperledger[4] is a collection of community-driven frameworks and code libraries for blockchains supported by the Linux Foundation. Hyperledger frameworks can be used to build public, private, hybrid, and consortium blockchain systems. At this early stage, projects using Hyperledger are piloting private permissioned and hybrid systems.

LEDGER

A record of transactions (Yaga et al. 2018, 52).

TRANSACTION

A recording of an event, such as the transfer of assets (digital currency, units of inventory, etc.) between parties, or the creation of new assets (Yaga et al. 2018, 54).

SMART CONTRACT

A collection of code and data (sometimes referred to as functions and state) that is deployed using cryptographically signed transactions on the blockchain network. The smart contract is executed by nodes within the blockchain network; all nodes must derive the same results for the execution, and the results of execution are recorded on the blockchain (Lesavre et al. 2020, 55).

PERMISSIONED (PRIVATE)

A system where every node, and every user must be granted permissions to utilize the system (generally assigned by an administrator or consortium) (Yaga et al. 2018, 53).

PERMISSIONLESS (PUBLIC)

A system where all users' permissions are equal and not set by any administrator or consortium (Yaga et al. 2018, 53).

	PUBLIC BLOCKCHAIN	PRIVATE BLOCKCHAIN	BLOCKCHAIN CONSORTIUM
Openness	completely open	open to specific organizations/groups	open to an individual entity
Write access	anybody	specified multiple nodes	completely internal control
Read access	anybody	anybody	open to the public/be restricted by any degree
Anonymity	high	low	low
Transaction	slow	fast	extremely fast
Decentralization	fully distributed	partial decentralization	partial decentralization

Adapted from: Wu, Jiani, and Nguyen Tran. 2018. "Application of Blockchain Technology in Sustainable Energy Systems: An Overview." *Sustainability* 10 (9): 3067. 10.3390/su10093067.

Across these different technologies and initiatives, assets and data files are commonly being stored using the InterPlanetary File System (IPFS), particularly for efforts related to digital credentials and transcripts that store data about the records themselves, including PDFs, images, and other related documents. IPFS is a peer-to-peer file sharing network that can run on computers and mobile devices. IPFS also tracks changes, making it possible to view any updates to files, and because it is a distributed network, files are more readily accessible.

Proof of concept implementations, use case development, cost of investment, evolving data and identity standards, and the emergence of open source and proprietary solutions are portraits of early stage technologies. Blockchain in education pioneers are experimenting and learning fast about systems and markets for documenting, verifying, and sharing evidence of learning and competence. In time, the unique attributes of blockchain—transparency, trust, and tamper resistance—may improve upon how these systems and markets operate.

Themes

Three major themes emerged from the research that reflect opportunities to use DLT to advance social equity: personal data agency, lifelong learning, and the power of connected ecosystems.

PERSONAL DATA AGENCY

The interviews and literature review for this report uncovered a prevailing theme: distributed ledger technologies can "democratize" data and empower individuals with agency over their personal information. This personal data agency theme has an almost movement-like feel to it. Currently, when individuals need to prove their education and work history, they rely on institutions and past employers to verify education and workforce records. However, the institutions or employers may not be available, the records could have been lost or destroyed, or in the case of higher education, individuals may be required to pay fees. The inability to access or control their records can inhibit opportunities and keep them in the dark about what information is actually in their records.

Data stored on centralized systems is managed by those who control the servers that host the data. Data can be changed, deleted, and shared without consent or knowledge of the individuals who created that data. For example, Open Badges, a type of digital credential containing data about achievements, are typically hosted on web servers. If the badge data is changed, there is no inherent process to track that change. If data is deleted, the server goes down, or the issuer no longer exists, the badge is no longer verifiable.

In comparison to centralized systems, distributed ledger technologies are inherently more transparent, persistent, immutable, and secured by encryption. These characteristics have inspired new approaches to digital credentials and identifiers that intend to provide individuals immediate access to their digital data, the ability to control who can view it, and a way for their data to be verified without contacting the issuing parties.

LIFELONG LEARNING

The concept of lifelong learning—the need to continue learning and documenting skills gained over one's working life—emerged as a key driver of most of the examined blockchain projects in the research interviews. There is an intuitive connection to be made between blockchain's value at documenting, verifying, and sharing data across diverse stakeholders and a fast-moving economy driven by learning and credentialing.

The Brookings Institution documented the speed of change in the economy and, in particular, the labor market in a 2019 report on automation in the economy. The report found that information technology and artificial intelligence are likely to continue to change the nature of work and jobs, with as many as 46 percent of all jobs being at risk of transformation in the near to mid-term (Muro et al. 2019). Not surprisingly, this significant labor market change is putting pressure on traditional and new education providers to produce and document learning faster. The provider ecosystem consists of K–12 school systems (particularly high school), colleges and universities, public workforce development programs, employers, and nonprofit and for-profit education/training providers, in addition to an emergent cadre of edtech credential solution firms. One reference point for the dynamism of this learning and credentialing ecosystem is the growth in the number of credentials in recent years documented by the nonprofit clearinghouse Credential Engine. Its research documents over 730,000 unique credentials in the United States alone, inclusive of:

- 370,020 credentials issued by postsecondary educational institutions, including both those that participate in Title IV and those that do not;
- 7,132 credentials from MOOC providers, the vast majority of them being course completion certificates;
- 315,067 credentials from non-academic organizations, with the largest categories being digital badges and online course completion certificates; and
- 46,209 credentials from public and private secondary schools (Credential Engine 2019).

The growth in credentials across all providers, but especially those from new and shorter-term education/training programs, is creating a challenge for documenting, verifying, and sharing data about whether learning has occurred between stakeholders. For individual students and workers, this rapid growth can lead to challenges in organizing their learning into a verified and shareable human capital profile that is optimized for life and economic success.

Thus, experimenting with blockchain in credentialing can benefit all stakeholders. Verifiable transcripts and CVs can make it possible to display life experiences that can match the increasing complexities of employer and worker needs. Individuals can use digital wallets and web applications to control how their histories display with substantial data-backed proof that paper credentials, online resumes, and LinkedIn profiles do not provide.

Workday Credentials[5] is an example of a general-purpose digital credentialing platform that issues and verifies blockchain-backed verifiable credentials, as well as accommodating credentials earned on different platforms. Credentials are stored directly in a digital wallet, WayTo,[6] where recipients can control and manage who has access to their data and use the wallet as a portable profile. Another example, Pistis,[7] provides a shareable "Lifelong Learning Profile" where each credential is viewable along with learning artifacts. Users have full control over their records and may access them using mobile devices and web browsers.

THE VALUE OF CONNECTED ECOSYSTEMS

Technology can supplant some processes, but it does not entirely replace the value of human connections and trusted relationships. These connections and relationships can lead to networks of students, educators, community members, institutions, employers, nonprofits, and government, creating an ecosystem of trust.

Human ecosystems supported by blockchain infrastructure can provide members with access to more functionality, opportunity, and control. For example, SSI ecosystems are standards-based, using protocols and blockchain technologies, but need trust frameworks and registries that are created and maintained by humans. The research showed that in education, leaning on human trust and private blockchains, especially while the technology and standards mature, gives the members of networks and their technology partners breathing room to innovate.

The Dallas Independent School District, the Dallas Community College District, the University of North Texas Dallas, the Mesquite Independent School District, the Garland Independent School District, and the Grand Prairie School District make up a network built upon existing relationships and agreements. They use GreenLight,[8] a private, permissioned Hyperledger Fabric blockchain, to remove barriers for students to get into college and employment by giving them access and complete control of their verified academic records, including transcripts, badges, certifications, references, recommendation letters, and licensures. This community is particularly focused on first generation and low-income students who are struggling with college enrollment. With GreenLight, students can apply to many colleges and for many scholarships at once, making the process easier to complete and more efficient.

In Arizona, an ecosystem comprised of Arizona State University[9] (ASU) and the Maricopa County Community College District is piloting the Trusted Learner Network using a private, permissioned Hyperledger Sawtooth blockchain provided by Salesforce.[10] The pilot is focused on reverse transfer, a process in which ASU sends learner course completion records from enrolled ASU students to the community college(s) where the student was previously enrolled. Many transfer students have not completed their associate degrees when they transfer from two-year to four-year institutions. Reverse transfer credits make it possible for students to be awarded an associate degree from their previous community college while actively attending their four-year institution, granting the benefit of a recognized, career-boosting associate degree.

Ecosystems are also an ideal setting for educators, students, and employers to connect. Two efforts found through the research have built ecosystems that provide the settings for job seekers to learn and connect to employers. ODEM[11] has developed a matchmaking system based on the multilingual classifications of European Skills/Competences, Qualifications and Occupations,[12] connecting job

DIGITAL WALLET

A software module, and optionally an associated hardware module, for securely storing and accessing Private Keys, Link Secrets, other sensitive cryptographic key material, and other Private Data used by an Entity (Sovrin 2019, 35).

PRIVATE KEY

The half of a cryptographic key pair designed to be kept as the Private Data of an Entity (Sovrin 2019, 19).

PUBLIC KEY

The half of a cryptographic key pair designed to be shared with other parties in order to decrypt or verify encrypted communications from an Entity. In digital signature schemes, a Public Key is also called a verification key (Sovrin 2019, 20).

seekers to employers who use it to find potential employees and train and hire them.

BitDegree[13] provides training designed by employers for hard-to-fill occupations with the intention to mentor potential employees and fill positions aligned to the skills taught in the course. Students pay a small fee to take the course or apply for scholarships to cover their fee. Their efforts are verified with tests, assignments, and problem solving. Employers may track student enrollment and progress. Upon completion, students are paid with BitDegree tokens that can be used toward future courses on the BitDegree platform or exchanged for traditional money.

These ecosystem examples help us to return to the question of how DLT might be helpful in addressing social equity issues with regard to education and employment outcomes. The Dallas Community College District blockchain implementation stands out in this regard, as it was developed inside a much larger social commitment by community stakeholders to increase educational and employment outcomes of low-income and marginalized learners and workers. This focus on improving outcomes for undersupported populations provides social commitment and attendant implementation guardrails to ensure learners and workers are the primary beneficiaries of the DLT.

In this social good context, the themes of personal data agency, lifelong learning, and connected ecosystems hold promise as drivers to close equity gaps using blockchain in education. The promise is to provide under-supported learners and workers with more control over how to benefit from their human capital and improved engagement with the stakeholders seeking to access their talent. Extant experiments will help us understand if this promise can be realized. Not surprisingly, social impact organizations such as New America[14] and The Beeck Center for Social Impact and Innovation[15] are also working on tools to help ensure that blockchain is used to serve the public good.

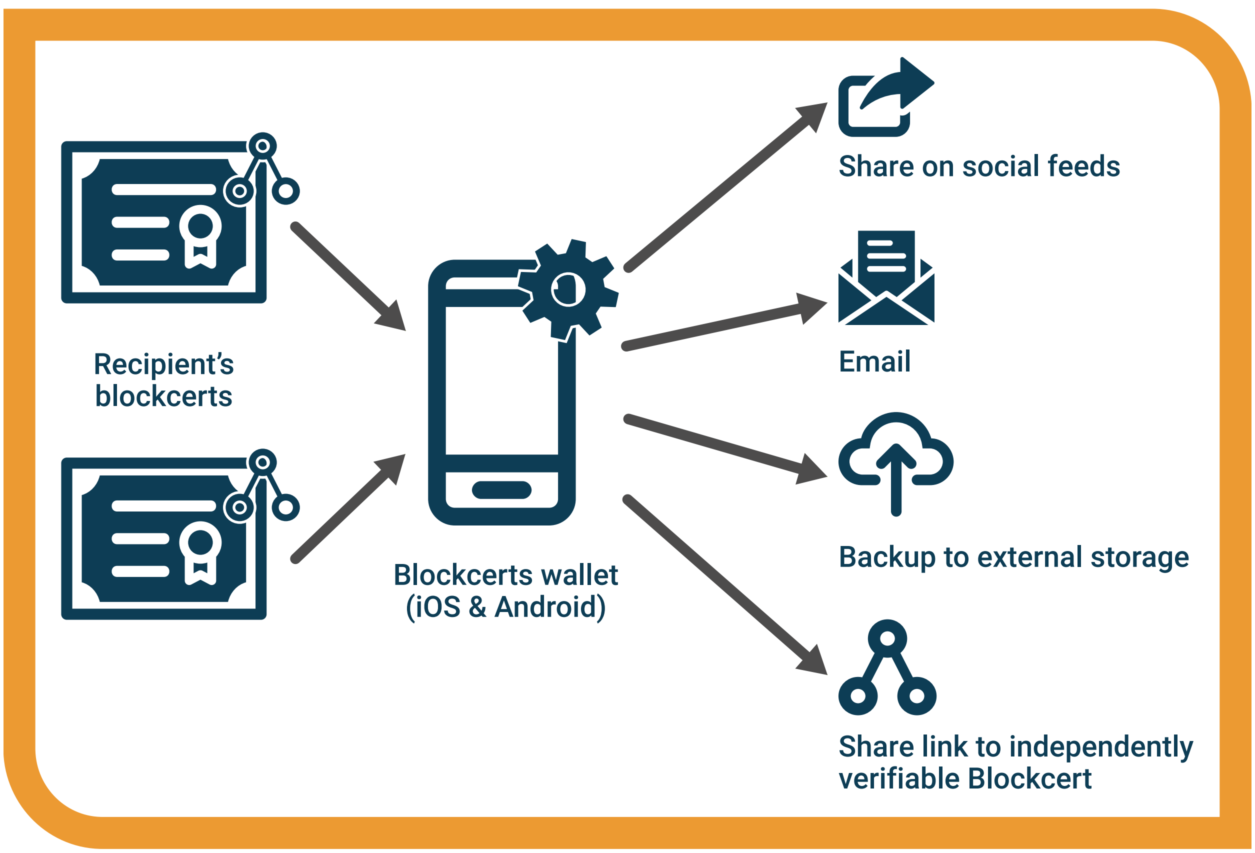
DLT IN PRACTICE

Several concepts and entities contribute to the efforts to bring blockchain technology to higher education. The following surfaced most often during the research.

BLOCKCERTS

Blockcerts[16] is one of the first frameworks to issue a verifiable type of credential to blockchain. It was initially prototyped by Learning Machine (now Hyland) and MIT Media Lab[17] in 2016 to be "an open standard for creating, issuing, viewing, and verifying blockchain-based certificates" that are cryptographically signed, tamper-proof, and shareable. The Open Badges-compliant[18] certificates are registered on the Bitcoin or Ethereum blockchains for verification. The Blockcerts code library[19] provides resources to issue and verify Blockcerts, as well as for digital wallet applications on IOS and Android.

Issuers of Blockcerts credentials send invitation emails for credentials to the recipients. Recipients are instructed to download the Blockcerts digital wallet where they can accept the invitation, generate a public/private key pair, and send the public key to the issuer. The issuer then registers the certificate on a public blockchain using the recipients' public key as the transaction recipient address. Once the transaction is processed, the blockchain credential is available to the recipients in their mobile wallet application where they have the agency to share it on social media, send via email, backup to cloud providers, and share a link or QR code that can be used to verify the credential without reliance on the issuing organization.



Adapted from: https://www.blockcerts.org/guide/recipient_experience.html

The verifiability is confirmed by cryptographically matching the certificate data to the one registered on the blockchain. As long as the data matches, the certificate is verified. If a single character or space is missing, changed, or added to the certificate that is being compared, the match will fail, and the certificate will be considered unverified.

Some implementers of Blockcerts use only part of this solution, diminishing the privacy of the recipient. Some platforms issue Blockcerts to take advantage of the verifiability that blockchains can provide but do so in addition to hosting the Open Badges data on a web server. In these instances, recipients typically do not have the same privacy options because the sharing of their badges continues to be tracked on the web server, and the issuing organization can retrieve this information from the platform.

Hyland Credentials (formerly Learning Machine) develops, supports, and shepherds Blockcerts. It also provides institutional and enterprise Blockcerts solutions. Massachusetts Institute of Technology, Southern New Hampshire University, Union Public Schools in Tulsa, Oklahoma, ECPI University, Maryville University, and Central New Mexico Community College are examples of institutions using Hyland Credentials' services to issue digital diplomas and transcripts. The government of Canada's Talent Cloud initiative[20] used Hyland Credentials to issue credentials demonstrating assessed skills related to recipients' acceptance into the government's Free Agent program (Greenspoon 2018).

Verifiable Credentials

Verifiable Credentials[21] (VCs) are methods to describe claims about qualifications, experience, health records, financial information, or any other type of information "on the Web in a way that is cryptographically secure, privacy-respecting, and machine-verifiable" (Sporny, Longley, and Chadwick 2019). This W3C-recommended standard is considered to be part of the suite of self-sovereign identity (SSI) technologies based on the principles authored by Christopher Allen (2016) that include user control and consent, interoperability, protection, portability, and persistence. VCs can be used to describe educational credentials as well as identifying documents like driver's licenses, passports, and library accounts.

VCs contain metadata properties that reference the recipient (also called subject or holder), the issuer, the issue date, the expiration date (if applicable),

DECENTRALIZED IDENTIFIERS (DIDS)

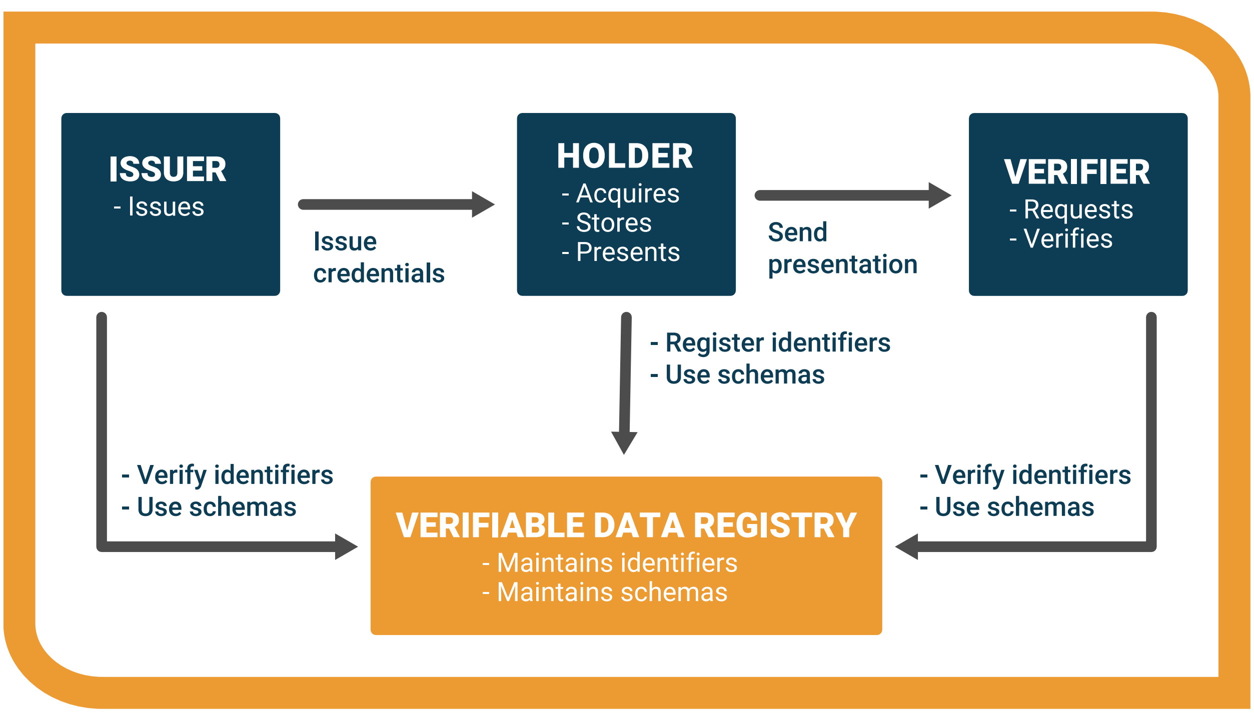
A globally unique identifier developed specifically for decentralized systems as defined by the W3C DID specification. DIDs enable interoperable decentralized Self-Sovereign Identity management (Sovrin 2019, 7).

ZERO-KNOWLEDGE PROOF

A cryptographic scheme where a prover is able to convince a verifier that a statement is true, without providing any more information than that single bit (that is, that the statement is true rather than false) (Lesavre et al. 2020, 56).

and how to verify the credentials. The recipient and issuer properties can be populated by Decentralized Identifiers[22] (DIDs), a digital identity represented by a unique alphanumeric string that works like a web address by pointing to data that can prove control of the identity being represented. How DIDs are formatted, created, read, updated, and deleted are specified by instructions in DID methods. Just as VCs provide instructions on how to verify the credential, DIDs contain references to their methods so that verifying machines know what instructions to follow. DIDs can also make it possible for individuals to have more control over their data by being able to convey verifiable information without disclosing unnecessary sensitive and personal information. A cryptographic protocol called zero-knowledge proof (ZKP) can prove one aspect of data without revealing any additional data. For example, ZKP can make it possible for people to prove they are a certain age without disclosing an actual birthdate.

VCs are issued and verified as part of an ecosystem containing multiple roles. The issuer publishes and sends a credential that references the recipient (or subject or holder). The recipient stores the credential in a wallet application and can then share the credential with a verifier, such as a school or an employer. The verification process includes confirming the issuer is credible by comparing the digital signature of the issuer in the credential to the digital signature provided in the Verifiable Data Registry. This registry also contains a list of revoked credentials so that the verifier can check that the credential is still in good standing. This type of SSI ecosystem is typically enabled using distributed ledgers to increase the likelihood that the data will be available.



Adapted from: https://www.w3.org/TR/vc-data-model/

DIGITAL SIGNATURE

A cryptographic technique that utilizes asymmetric-keys to determine authenticity (i.e., users can verify that the message was signed with a private key corresponding to the specified public key), non-repudiation (a user cannot deny having sent a message), and integrity (that the message was not altered during transmission) (Yaga et al. 2018, 51).

VCs can be used to describe student enrollment, academic credentials, membership, and roles in groups. A recent use case in education illustrates how VCs can be used to represent digital forms of students' physical IDs. Evernym[23] is implementing an early access plan[24] for higher education that enables universities to issue and accept verifiable digital credentials. Students can manage and share their digital credentials by using Evernym's digital wallet, Connect.Me,[25] to access services on campus and log in to university systems. They may also use them to apply for jobs or loans and get student discounts. Just as if students were using their physical student IDs, the university's system will not be notified when they use them. Evernym plans to expand this program to other types of verifiable credentials issued for coursework and achievements in higher education that students can use to prove their experiences and qualifications.

VCs can also be used in public libraries, which in addition to lending materials in person, often have extensive and free online experiences available. Libraries are typically available in every community, provide resources such as public computers and meeting rooms, and commonly host activities such as ESL classes and maker labs. There is often a low barrier to getting library cards, since many libraries do not require photo ID. Some libraries have notaries, making it possible to consider how libraries could play a role in issuing legally accepted IDs.

The San Jose State University School of Information[26] used an IMLS grant to explore uses of blockchain technologies in libraries. It hosted a national forum,[27] delivered a Library 2.0 virtual conference, "Blockchain Applied: Impact on the Information Profession,"[28] sponsored a MOOC[29] on blockchain and decentralization for information industries, and published a book[30] outlining opportunities and challenges for blockchains in libraries. The researchers are currently seeking funding to experiment with an SSI universal resolver that will enable individuals with verifiable digital credentials to gain access to resources at all participating libraries.

Trust Frameworks

Trust frameworks (also called governance frameworks) provide the rules and policies that govern how data is managed, stored, and verified. A trust framework can be described as "a legally enforceable set of specifications, rules, and agreements that govern a multi-party system established for a common purpose, designed for conducting specific types of transactions among a community of participants, and bound by a common set of requirements" (Makaay, Smedinghoff, and Thibeau, 2017, 3). Trust framework policies can determine what members have the authority to issue or revoke credentials.

With frameworks like this in place, verifiers of credentials trust the governance of the community to have vetted their members.

Communities could be at the federal, state, or district level. Universities may form trust frameworks; trust frameworks could be based on existing association memberships. An example of a trust framework is OrgBook BC,[31] in British Columbia. As of this writing, it has 1.3 million active legal entities and is managing over 2.4 million VCs for businesses that are legally registered as corporations in BC.

Education Technology Standards and Related Initiatives

The Verifiable Credentials (VCs) standard provides metadata properties and instructions on how to perform the verification, but it is not specific to education and does not provide descriptions of the credentials, explain what they mean, or demonstrate evidence of achievement. To accomplish this, educational data standards describe various types of initiatives and alignments to competencies. EdMatrix[32] is a comprehensive, up-to-date list with explanations of the learning standards.

The Open Badges standard[33] describes how information about skills and accomplishments, the earner, the issuer, and evidence can be embedded into portable image files and validated. It was originally incubated as an open community project at the Mozilla Foundation with support from The MacArthur Foundation. In 2015, Concentric Sky was hired to lead the community in drafting the 2.0 version of the specification, and in 2017 it was transferred to IMS Global[34] to support and shepherd advancements. The Open Recognition Alliance[35] and Badge Summit[36] provide support and innovation in the open community.

The objective of the Comprehensive Learner Record (CLR) standard[37] is to describe how all learning experiences (formal, informal, employment-related, co-curricular activities, etc.) can be expressed

GUARDIANSHIP

There are circumstances in which individuals may not have the capability or access to control their identity-related data. Examples may include children assigned a legal guardian, refugees who have lost either their identification documents, or whose documents are no longer available, and some individuals among the homeless. The Sovrin Foundation's (https://sovrin.org) Governance Framework is currently exploring the concept of Guardianship, which "relies on formally vetted legal constructs and encompasses situations with little or no legal foundation where social norms or organizational rules underpin roles. It captures the actual transfer of control of private data and keys from an individual (the dependent) to a guardian (an independent identity owner)" (Abdullah et al. 2019, 9).

GOVERNANCE FRAMEWORK (TRUST FRAMEWORK)

The set of business, legal, and technical definitions, policies, specifications, and contracts by which the members of a Trust Community agree to be governed in order to achieve their desired Levels of Assurance (Sovrin 2019, 11).

digitally. This includes degrees, certificates, licenses, competencies, courses, and Open Badges. Applications can use this standard to render their clients' records. This standard is an offering at IMS Global that launched in August 2019.

The Common Education Data Standards (CEDS)[38] facilitates the sharing of student data when students transfer between entities such as programs, institutions, districts, and states. The vocabulary and data model describes organizations, accreditations, credentials, and competencies. It is supported by the National Center for Education Statistics (NCES) and maintained by an open community.

The Ed 3.0 Research Network (E3RN) brings together "labs" of innovators committed to collaboration in support of lifelong, personalized, competency-based learning and to publish recommended practices at the IEEE.[39] This includes finding the common denominators between the existing education data standards and how they translate and transfer between each other. Some primary focuses are decentralized identifiers, credential descriptions, and verifiable credentials, as well as the architecture to build trustful technology.

The T3 Innovation Network[40] is working with more than 450 public and private organizations representing business, government, education, and technology to build an open, public-private data and technology infrastructure for a more equitable future. The free and open network is created and managed by the U.S. Chamber of Commerce Foundation to explore emerging technologies like AI and blockchain, as well as data standards to better align education, workforce, and credentialing data with the needs of the new economy. Their four areas of focus include open data standards; open shared competency infrastructure; linked, individual-level data; and comprehensive learner and worker records. These efforts align with and support the American Workforce Policy Advisory Board's Interoperable Learning Record[41] initiative.

Blockchain in Education-Related Initiatives

The Digital Credentials Consortium (DCC)[42] is a multi-university-led effort focused on creating a trusted, distributed, and shared infrastructure for issuing, storing, displaying, and verifying digital academic credentials. Their objective is to develop a universal standard with a transparent, learner-centered design and governance model. Much of the work is being incubated at the W3C Verifiable Credentials for Education Task Force community group,[43] where collaboration is open and public. Founding members include Delft University of Technology, Georgia Institute of Technology, Harvard University, Hasso Plattner Institute, University of Potsdam, Massachusetts Institute of Technology, McMaster University, Tecnologico De Monterrey, TU Munich, UC Berkeley, UC Irvine, University of Milano-Bicocca, and the University of Toronto.

The Learning Economy Foundation[44] (LEF) is a DC-based nonprofit with a mission to steward the global Internet of Education (IoE) and launch a sustainable, multi-system, multi-agent, learning GPS ecosystem by 2025. LEF supports the development of co-labs across districts, states, nations, and regions, each providing the expertise, education, and technical infrastructure needed to localize a public-good marketplace that provides utilities such as digital wallets, skill libraries, and learning pathways.

The European Blockchain Services Infrastructure[45] is a "joint initiative from the European Commission and the European Blockchain Partnership (EBP) to deliver EU-wide cross-border public services using blockchain technology." It is a peer-to-peer network with nodes supported by the European Commission and Member States. There are four use cases, including notarization, EU identity, and data sharing. The fourth use case, diplomas, will be used by higher education and include lifelong learning recognition and accommodate needs for communities such as refugees by providing tamper-proof, persistent credentials to prove education and work qualifications. Beyond blockchain, diplomas will also use SSI and verifiable credentials with the aim to empower EU citizens with control of their data and their identity.

C21U[46] is an applied research laboratory at Georgia Tech developing, testing, and evaluating new technologies that are currently playing a role or that could play a role in higher education practices. One of its research studies[47] evaluated students' perceptions of Blockcerts. C21U is one of the founding members of the Digital Credentials Consortium.

OpenBlockchain[48] is an initiative from The Open University's[49] technology research and innovation lab, Knowledge Media Institute.[50] Across a range of projects, it has conducted experiments and pilots in education with Ethereum, Open Badges, and Blockcerts. Recent projects include QualiChain,[51] https://instituteofcoding.open.ac.uk/badges/,[52] PeerMiles,[53] and LinkChain, which explores the decentralization of data using blockchains and linked data using the Solid project.

DEEPER DIVE INTO THE TECHNOLOGY

Blockchains

Blockchain technology originated as the underpinning architecture of the first cryptocurrency, Bitcoin, which is "an electronic payment system based on cryptographic trust instead of human trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party" (Nakamoto 2008, 1). Blockchains are a type of distributed ledger that saves transactions in blocks of data that are in chronological order and mathematically reliant on each other.

Each transaction in a blockchain is timestamped and contains data referencing only the participating parties' wallet addresses, how much is being transferred, and information verifying that the transaction succeeded. At regular timed intervals, processed transactions are combined into a segment of data called a block. Once all nodes on the network reach a consensus that this newest block has been accepted as the one and only version of the truth, it is mathematically linked to the previous one, and the entire ledger of data is distributed to each node. This process secures the ledger and ensures the data is immutable. A block cannot be modified, nor can one be inserted or removed without affecting every subsequent block and every node becoming aware.

Public-key cryptography is used to ensure the integrity of transactions. This system is based on public and private key pairs, which are long, mathematically related, alphanumeric strings. A person's public key can be shared safely with others so that anyone

CRYPTOGRAPHIC TRUST

Trust bestowed in a set of machines (Man-Made Things) that are operating a set of cryptographic algorithms will behave as expected. This form of trust is based in mathematics and computer hardware/software engineering (Sovrin 2019, 7).

NODE

A computer network server running an instance of the code necessary to operate a distributed ledger or blockchain (Sovrin 2019, 16).

CONSENSUS

A process to achieve agreement within a distributed system (Lesavre et al. 2020, 53).

IMMUTABLE

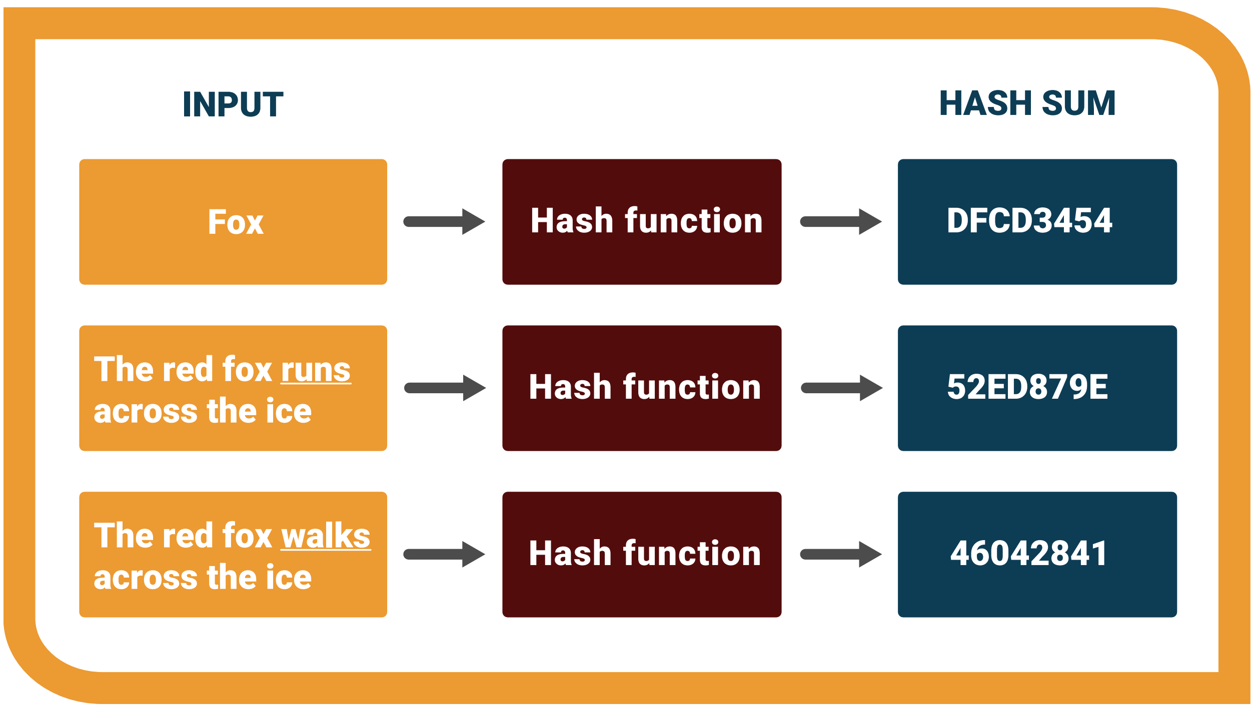
Data that can only be written, not modified or deleted (Yaga et al. 2018, 52).

can use it to encrypt a message to that person. That same person's private key should always be kept private and hidden because it is the only key that can decrypt that message. Also, the private key is what proves the assignment of anything associated with the public key, such as cryptocurrency and education credentials.

HASHING

A method of calculating a relatively unique output (called a hash digest) for an input of nearly any size (a file, text, image, etc.) by applying a cryptographic hash function to the input data (Yaga et al. 2018, 52).

Key pairs can be generated on most computers, but the most common scenario is for a wallet application to generate the key pair. Although wallets were originally created to receive and send cryptocurrency, they can also be used to manage personal data like academic credentials and digital identities. The wallet creates a key pair, and then the public key is transmuted and shortened using a function called hashing, a mathematical algorithm that converts one value to another.



Adapted from: https://commons.wikimedia.org/wiki/File:Hash_function.svg

When a public key is hashed, its shorter value can be used as a public address of the wallet from which transactions can be sent and received. In the case of educational credentials, the received credential is assigned to the wallet address, and the private key associated with that wallet address can provide proof of being the recipient.

Key owners are responsible for their secure storage because if a private key is lost, access to the data associated with it is lost too. If a private key is stolen, the data is possibly accessible by the entity that has control of it. For this reason, many wallet providers have backup recovery methods, but in many cases, recipients of academic credentials or professional certifications referenced or stored on blockchains must request a reissue when they have lost their keys.

Hybrid Blockchains

Hybrid blockchains combine both public and private blockchains, with many variations. One scenario may have a public blockchain that can be accessible to be read by anyone and also have a private blockchain controlling the access to write to the public chain. A hybrid blockchain could also contain both public and private transactions. Another configuration could be a fully decentralized permissionless blockchain paired up with one or more private blockchains. An educational ecosystem hybrid blockchain may wish to reference digital credentials on a public blockchain but track and manage tuition payments on a private blockchain.

Smart Contracts

Smart contracts are tiny programs that self-execute when anticipated conditions are met. Smart contracts are beneficial because they aren't controlled by a central authority, so they cannot be censored or shut down. Smart contracts are accessible globally, and unless the entire blockchain is down, they will never stop running. In education, smart contracts could be used to audit transcripts, or by learning management systems to trigger when assignments are submitted, or by administrative systems to automate supply management.

Blockchain Frameworks and Libraries

There are numerous open-source blockchain frameworks and libraries, but Hyperledger's offerings are being used most frequently by proofs of concept and pilots in education. Hyperledger[54] launched in 2016 as an open-source, collaborative project hosted at the Linux Foundation. The goals of Hyperledger are to create and support community-driven frameworks and code libraries for blockchains. It provides toolkits and engages open, public, community special interest groups such as the Education Architecture Special Interest Group (EASIG),[55] which launched in October 2019.

RECOVERY KEY

A special private key used for purposes of recovering a Wallet after loss or compromise Privacy by Design. A set of seven foundational principles for taking privacy into account throughout the entire design and engineering of a system, product, or service (Sovrin 2019, 21).

The first two blockchain frameworks released were Hyperledger Fabric, a configurable blockchain framework intended for private permissioned networks, and Hyperledger Sawtooth, able to be configured as public or private networks. In 2017, the Sovrin Foundation contributed the code base for Hyperledger Indy, a ledger to create and manage decentralized, self-sovereign digital identity. Cloud providers such as AWS, Azure, IBM, and Google Cloud offer hosting options for Hyperledger blockchains.

Distributed Ledger Databases

Blockchain is a distributed ledger technology, but not all distributed ledgers are blockchains. Fluree[56] is an RDF-based graph database that has blockchain characteristics such as decentralized, tamper-proof data storage and is also queryable. It can be deployed as a centralized database or as a decentralized database network as part of traditional centralized technology stacks or blockchain stacks. Fluree will be available as open source in 2020 and is currently available as a free community edition for download and as a hosted on-demand service.

Decentralized File and Data Storage

The InterPlanetary File System[57] (IPFS) is a distributed, peer-to-peer file-sharing system. IPFS can be used to share files across computers and mobile devices locally on a network without Internet access and globally when the Internet is available. An IPFS user can save a file or media to a device, and it will be assigned an address that will be accessible to others. Any edits made to files on IPFS are tracked. It is possible to configure domain names so that websites can be hosted on IPFS. Hosting files and websites on multiple computers makes them less likely to have downtime and less vulnerable to censorship. In classroom settings with local networks but no Internet, access files can be shared and collaboratively edited. Documents containing credential data and evidence of learning or achievements (as with Open Badges) can be stored and verified on IPFS.

Solid[58] (for Social Linked Data) is an initiative started at MIT by Tim Berners-Lee, the inventor of the web. It is a decentralized, peer-to-peer network where users have full control over their data, which is stored in one or many pods (or personal online data stores) hosted anywhere the users want. Users give permission to access their data to applications that are authenticated by Solid. Every piece of data is linked using an HTTP URL, which establishes the instructions for data access and usage.

RESOURCE DESCRIPTION FRAMEWORK (RDF)

A special private key used for purposes of recovering a Wallet after loss or compromise Privacy by Design - A set of seven foundational principles for taking privacy into account throughout the entire design and engineering of a system, product, or service (Sovrin 2019, 21).

In education, Open Badge earners could store their evidence in pods. Comments and endorsements about the badge earners' evidence may also be stored in pods belonging to other users. Then linked data makes the connections between the relevant pods and data so that applications with permission to access this evidence-related data may display it. In late 2019, discussions began to incorporate Decentralized Identifiers (DIDs),[59] a self-sovereign identity-related standard, into Solid.

CHALLENGES AND CONSIDERATIONS

Challenges

As noted at the top of this report, implementations of distributed ledger technologies are still in the early stages. Most efforts are accelerating, but proofs of concept, pilots, and planning are the majority of efforts. These experiments have and will continue to hit bumps in the road. Some of these challenges can only be resolved by humans, and others may just take time and cycles of development.

UNDERUSE OF DIGITAL CREDENTIALS

Although digital credentials are being registered on blockchains, they are not being claimed or used very often. The analogy of paper credentials to digitized ones is easy to understand and relatable, but there are currently few situations in which digital credentials are useful. Hiring managers and registrars do not trust them yet or do not understand how to evaluate them.

The technology is not widely understood or trusted, and it has not proven to be more efficient and purposeful than current processes and systems, so the perceived benefits do not yet outweigh the costs. The self-sovereign identity standards, Verifiable Credentials and Decentralized Identifiers, show substantial promise but are nascent and still have many issues and concerns to address. The technical standards work is accelerating, and education data standards are being evaluated so that the data that will be verifiable and also have contextual significance, but it could be another year before this work has progressed through the levels of acceptance at the standards bodies for early adoption to begin.

OFFCHAIN

Refers to data that is stored, or a process that is implemented and executed, outside of any blockchain system (Lesavre et al. 2020, 55).

ONCHAIN

Refers to data that is stored, or a process that is implemented and executed, within a blockchain system (Lesavre et al. 2020, 55).

PRIVACY BY DESIGN

A set of seven foundational principles for taking privacy into account throughout the entire design and engineering of a system, product, or service (Sovrin 2019, 19).

CONCERNS AND QUESTIONS ABOUT DATA OWNERSHIP AND CONTROL

Data ownership can be muddy, especially considering legislation such as General Data Protection Regulation (GDPR) and Family Education Rights and Privacy Act (FERPA). When it comes to learner records, control of data is not synonymous with ownership, and ownership of data in decentralized systems is not the same as in centralized systems. In centralized systems, data is owned and controlled by the owner of the server(s) hosting the data. In decentralized systems, having the private key associated with a transaction proves control but not necessarily ownership. If learners are issued a Verifiable Credential (VC) using their public key, they have control, but they do not necessarily own the data unless they self-issued the credential. If they lose the key, they lose control of the data. This challenge is pertinent cross-industry when it comes to blockchain and cryptocurrency. Recovery systems for keys are improving, as are digital wallets.

THE DIGITAL DIVIDE

It is critical to remember that not all Americans have access to the Internet or technology. According to the Pew Research Center, 29 percent of Americans do not own smartphones. Forty-four percent do not have broadband services, and 46 percent do not have a computer (Anderson and Kumar 2019). Before distributed ledger technologies have the potential to advance social equity, everyone needs to be online or have access to the tools they need to participate.

IMPLEMENTATION COSTS

There are substantial costs for institutions to invest in new technologies. Replacing existing processes with new ones takes time, staff, and materials. Institutions with more resources will likely be able to pursue implementation first, but smaller and less-funded institutions may wish to consider how blockchain technology could enhance their current systems instead of replacing them. In higher education, enhancing could mean issuing self-sovereign identity digital IDs to their faculty, students, and staff. Leaning on existing processes that determine eligibility and roles will reduce the time, effort, and costs associated with creating new processes.

PERMANENCE ISN'T ALWAYS A GOOD THING

Immutability is one of the most useful characteristics of blockchain, but it could have unintended consequences. For example, it may be unsafe for transgender people and victims of abuse to have tamper-proof data referenced on a blockchain, even if it is encrypted. Personal data and education records that can establish a location or reference an identity can be dangerous to those who need to be completely disassociated with prior identities. For this reason, it is advisable to never store any data on a blockchain even if it is encrypted which someday could be broken. Instead, it is recommended to store off-chain so that individuals may control all aspects of privacy. Overall, taking a Privacy by Design approach is advisable for all data-related efforts.

Considerations

THE DECENTRALIZED WEB

Smart Contracts, IPFS, and Solid provide tools to build decentralized web and mobile applications. A peer-to-peer model serves websites and applications without a central authority, giving participants full control of their data. From a practical perspective, this scenario improves uptime or at least reduces the chance for a single point of failure since the web application is not reliant on a single entity to keep it running. Without decentralization, this issue is solved by distributing servers, but the servers are still controlled by a single entity. If that entity goes away, so does the website and its data.

AFFORDABILITY IN EDUCATION

Distributed ledgers can help education be more affordable and therefore more accessible. This opportunity has been explored by a few efforts that are using their own tokens, experimenting with pay-as-you-go courses that use cryptocurrency and a combination of cryptocurrency and fiat traditional money. For example, students earn BitDegree tokens when they complete their courses. But there have not been as many efforts exploring this as could be imagined with a technology literally generated because of a cryptocurrency.

Given that more than $1.5 trillion in federal student loan debt exists in the United States (Miller et al. 2019), millions of students may be interested in new options that make college more affordable. It would be interesting to see how cryptocurrency could be applied to "earn as you learn" models like BitDegree or paid internships or on-the-job-training. How could cryptocurrency apply to student loans? Could students save up for college with cryptocurrency? Could universities create their own currency exchanges?

ECOSYSTEMS FIRST

Interestingly, the interviews and research for the paper made very clear that cross-sectoral, interorganizational human relationships are important precursors to many blockchain initiatives in education. In other words, ecosystems matter. The word ecosystem—a community of interconnected actors who need each other to solve a common challenge and who derive unique value when the challenge is resolved—is often overused but is well-suited here. For example, the Dallas Community College

District/Greenlight Credentials project includes K–12 public schools, employers, area four-year colleges, food banks, and workforce development and public transportation agencies, to name only some of its collaborators. This complex web of actors, all focused on student and worker success from different angles, sharing complementary data points that together compile a learning record—they comprise an ecosystem if there ever was one. Early blockchain in education pioneers are quickly discovering that preexisting ecosystems, with stakeholders that have already agreed on problems they want to solve together with regard to student and worker success, are a critical resource for blockchain technology to take hold and add value.

Building upon existing stakeholder relationships sets a foundation of trust. For this reason, we recommend an "Ecosystems First" approach to build trust and encourage adoption. Ecosystems and trust frameworks are mutually beneficial because trust frameworks are built upon ecosystems, and ecosystems are reliant on their trust frameworks to provide evidence of trust. Taking an ecosystem or consortium approach using the existing trust as a scaffold to develop frameworks, decentralized systems, and software that meets the needs of the whole community is a path to acceptance and adoption.

Over time, the technology will improve and be easier to use. The concepts will become more familiar to stakeholders. Individuals will experience what it means to have control over their data, and the desire for this control could spread into other contexts. Blockchain was conceived as machines working together to reach consensus. It is an appropriate metaphor for collaborative networks. By building upon the scaffolding of existing trust and relationships, blockchains can spur thinking about data use, data ownership, and data control.

CONCLUSION

After the capacity to learn itself, the ability to document, verify, and share evidence of learning, at scale, in near real time, may emerge as one of the key competitive advantages in a technology-driven, global economy in the coming decades. Furthermore, given the speed and granularity of the need to document, verify, and share human capital information, empowering individuals to have control and agency over their learning record may be a determining factor that supercharges this competitive advantage. This competitive advantage can only be catalyzed by technologies that are at once resilient, secure, adaptable, and trust enabling.

The unique attributes of distributed ledger technology—sustainable, transparent and auditable, secure and private, consensus and transaction driven, and flexible and adaptable—make it an appropriate technology for this purpose. Critically, because of its distributed nature, DLT allows for individualized ownership of one's data (students, workers) while, somewhat paradoxically, assuring its trustworthiness for use by other stakeholders (K–12 schools, college and universities, employers).

As with any new technology, use cases, proofs of concept, standards, costs, and necessary change in organizational behavior are all present in the examples of blockchains in education that this report investigated. Key themes that emerged were emphases on data privacy, ownership and agency, lifelong learning, and stakeholder ecosystems. These themes are heartening each in their own right. Data privacy and ownership agency are imperative if individuals, especially vulnerable populations, are to control how they use and share their human capital data in a distributed ledger. Lifelong learning as a guiding principle suggests that documenting, verifying, and sharing evidence of learning cuts across many different types of centralizing institutions—for example, K–12 schools, colleges and universities, and employers—indicating the sensibility and strengths of distributed ledgers. Stakeholder ecosystems are the existing set of relationships between organizations that transact through the education and learning of students and workers, including school registrars, college admissions officers, hiring managers, and information technology professionals and providers. These stakeholders already interact to ensure that learning moves across institutional boundaries in ways that make sense for students, workers, educational institutions, and business. The research shows that pre-existing and robust stakeholder ecosystems are a critical foundation in early blockchain experiments and pilots. They bring trust that predates the DLT to transactions, creating a space for blockchain to develop.

This extant research challenges the education and employment stakeholder ecosystem to consider the following questions: what problems are you trying to solve and who are you trying to help? Who are your partners in this exploration? How does the blockchain change current systems and technology? Why is blockchain part of the solution, and how will you develop a system that puts your learners' needs first? Can blockchain make the documenting, verifying, and sharing of credentials more equitable, affordable, and trustworthy in this circumstance? These questions can guide a structured exploration of existing and emergent blockchain projects with a holistic (technology and human systems) lens and an eye on technology design and features, measurement and value, and governance and organization that allow us to assess the maturity of the technology.

From Blockcerts to Verifiable Credentials to self-sovereignty to privacy by design, distributed ledger technology is creating a new relationship between individuals, educational institutions, and employers and the data that documents, verifies, and shares the learning individuals gain throughout their lives. As a society and economy, we must ensure these new relationships support improved opportunity to learn for all, preserve evidence of all quality learning, ensure equitable use of learning data, and empower learners and workers to use their data to pursue a prosperous life and promote economic growth. In the consensus-driven spirit of blockchain, we can achieve these aspirations together.

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APPENDIX

Design Questions

What problems does this solve?

A fast-moving economy in which work is continuously being altered by technology yields highly variable learn, work, and career pathways for millions of student/workers. Continuous learning and variable career pathways, in turn, mean that many stakeholders, not all having a common understanding of learning and the knowledge, skills, competencies, and abilities, need to have access to an individual's learning/competency record. This disconnect creates a circumstance of imperfect trust between education and labor market ecosystem stakeholders, including students, workers, education providers, and employers. This state of imperfect trust can lead to under-recognized learning and competencies for student/workers and inefficiency in both the delivery of learning and the transfer of learning across education providers and employers. Blockchains can help carry out transactions with a learner record in a way that preserves individual data ownership and trust in the documented information.

Blockchains manage data, transactions, and relationships differently by avoiding reliance on centralized authority. A consensus-based and cryptographic-fueled process ensures that the information on the ledger is tamper proof, and the distribution of the ledger can reduce the risk of downtime. These characteristics and this transparent process can make information recorded using blockchain more trustworthy and reliable than information recorded on centralized systems, an opaquer process dependent on the trust of the entities storing the data.

How does blockchain change current systems and technology?

Technology solutions, hardware and software, embody the technical parameters, business processes, and cultural norms of a given era. Today's human capital and learning management technologies reflect this assertion. School transcripts, employer human resources records, resumes, CVs, degrees, certifications, certificates, and badges are all artifacts that society uses to document learning and competence. Since at the least the end of World War II, first human and then technology systems were developed to hold these artifacts and convey them for different education and labor market transactions. A fundamental feature of this human capital documenting approach was that it was designed by and for centralized ecosystem stakeholders like education institutions and employers. This creates a subtle and potent sense that these stakeholders own this record of competence. Students in particular have direct experience of this design feature when trying to get access to their own transcripts, which can be a laborious process. In the twentieth-century assembly-line economy, with long product cycles and lifetime careers, technology and centralization grew up together as a means of effectively tracking relatively stable human capital pathways. The twenty-first-century economy is based on dynamic product demand, flexible production, and adaptable careers paths. In such an economy, centralization and legacy technologies that support it may not be the optimal locus of ownership of a record of learning. The learner/worker as a locus of control for the data that helps society deploy both individual and scaled human capital may be the optimal solution. This solution requires decentralizing technologies.

Blockchains, along with SSI-related standards, verifiable credentials, and decentralized identifiers, can make it possible to shift primacy of control over human capital data from education, workforce, and employer stakeholders to the individual learner, worker, and citizen. This control could provide individuals with a nearly real-time capability to document, verify, and share what they know and are able to do. The relationship between decentralizing and centralizing technologies is playing out today in education and labor markets around the world. For blockchain pioneers and other stakeholders, student and worker success should be the guiding principle for balancing the two technology trajectories.

How are legal and privacy issues addressed?

As noted above, when it comes to learner records, control of data is not synonymous with ownership, and ownership of data in decentralized systems is not the same as in centralized systems. In centralized systems, data is owned and controlled by the owner of the server(s) hosting the data. In decentralized systems, having the private key associated with a transaction proves control but not necessarily ownership.

Still, the great promise of blockchain is a learning record that is both controlled by the individual and yet trusted by a diverse set of stakeholders that optimizes human capital outcomes for all parties. This outcome-optimizing potential immediately raises questions about who owns, controls, and shares learning data. Not unlike society's use of social media technology, our current implementation of blockchain is redefining notions of privacy and agency with regard to individuals' control of their human capital profile. In this instance, a humble default position for all ecosystem stakeholders should be a "first do no harm to the learner/worker" ethos, meaning that the good of the individual should be a governing principle for guiding blockchain implementation. This default position serves a social purpose, especially when solutions are being applied to challenges of marginalized groups. Further, it serves a technological purpose since a useful decentralization is intimately tied to the fate of the individual.

Additional Resources

Communities, Foundations, and Network Initiatives

- Decentralized Identity Foundation
- Digital Credentials Consortium
- Hyperledger Education Architecture Special Interest Group
- U.S. Department of Education Education Blockchain Action Network
- U.S. Chamber of Commerce Foundation T3 Innovation Network

Glossaries

- "A Glossary of Blockchain Jargon" (MIT Technology Review)
- Sovrin Glossary V2

Government

- Office of Educational Technology—Blockchain in Education

Research and Reports

- Blockchain in Education (European Commission)
- T3 Innovation Network Background & Reports
- The Blueprint for Blockchain and Social Innovation
- Understanding the Student Experience with Blockcerts (Blockchain-Powered Academic Credentials) Through Usability Testing

Self-Sovereign Identity

- On Guardianship in Self-Sovereign Identity
- The Nail Finds a Hammer (New America Foundation)
- What if I Lose My Phone?

Standards

- A Primer for Decentralized Identifiers
- Blockcerts
- Comprehensive Learner Record Implementation Guide
- EdMatrix—Directory of Learning Standards
- Open Badges
- Verifiable Credentials for Education Task Force
- Verifiable Credentials Use Cases

White Papers

- A Taxonomic Approach to Understanding Emerging Blockchain Identity Management Systems (NIST)
- Blockchain Technology Overview (NIST)
- Building the Digital Credential Infrastructure for the Future (Digital Credentials Consortium)
- Improving the Talent Marketplace Through the Application of Web 3.0 Technologies (U.S. Chamber of Commerce Foundation)
- The Blockchain Ethical Design Framework (Beeck Center for Social Impact and Innovation)
- White Paper on Interoperable Learning Records (American Workforce Policy Advisory Board)

Examples of Efforts

Below is a small sampling of the efforts found during this research. A more up-to-date directory can be found at https://usedgov.github.io/blockchain/directory.

Digital Credentials

Hyland Credentials (formerly Learning Machine) (https://www.hylandcredentials.com/)

Hyland Credentials provides software and support for institutions and enterprises to issue the Blockcerts (https://www.blockcerts.org/about.html), blockchain credentials originally prototyped by Learning Machine, and MIT Media Lab in 2016. MIT, Southern New Hampshire University, Union Public Schools in Tulsa, Oklahoma, ECPI University, Maryville University, and Central New Mexico Community College are examples of institutions using Hyland Credentials' services to issue digital diplomas and transcripts. The government of Canada's Talent Cloud initiative (https://talent.canada.ca/en) used Hyland Credentials to issue credentials demonstrating assessed skills related to recipients' acceptance into the government's Free Agent program (Greenspoon 2018). In 2019, Learning Machine was awarded $159,040 by the U.S. Department of Homeland Security for its proposal to upgrade Blockcerts to fully implement the W3C Verifiable Credentials standard.

Oklahoma Union Public Schools (https://www.unionps.org/422016_3)

Union Public Schools in Tulsa is the first K–12 instance of using Blockcerts. 3Dream Studios (https://www.3dreamstudios.com/) implemented a system in 2019 that issues diplomas and cumulative transcripts to students in 9th through 12th grades. Diplomas are issued once a year at graduation. Cumulative transcripts are issued twice a year. Future plans include issuing micro-credentials, industry certifications, and senior capstone projects.

Bestr—Italy (https://bestr.it/)

Bestr is the Open Badges issuing platform for Cineca (https://www.cineca.it/), a nonprofit interuniversity consortium of 69 Italian universities and 11 national public institutions. Bestr began offering the option of issuing Blockcerts in addition to Open Badges in 2019. Two universities listed in their public key registry (https://bestr.it/issuerspublickeyregistry/view) include Università degli Studi di Milano-Bicocca and University of Padova. The universities have future plans to allow students to track their credits earned at foreign universities.

Credly (https://credly.com)

Credly is one of the original Open Badges issuing platforms. It has implemented Blockcerts and offers publishing to blockchain as a sharing option for recipients of Open Badges if the issuers enable the feature. Lehman College (http://www.lehman.edu/) announced in May 2019 that it would enable diplomas to be published on using Credly's service.

Gujarat Forensic Sciences University (GFSU)—India (https://www.gfsu.edu.in/)

SSBI Digital (http://www.ssbdigital.in) partnered with Fluree (https://flur.ee/) to develop a proof of concept at GFSU to prove the legitimacy of academic credentials, reduce diploma and resume fraud, and reduce time and overhead in transcript verification. The application provides students with a digital interface to allow seamless sharing of credentials with potential employers. It is expected to roll out to other universities in India by Q3 2020.

OpenCerts—Singapore (https://opencerts.io/)

OpenCerts is an open-source platform that issues and verifies digital academic certificates using Ethereum. OpenCerts first piloted in 2018 and was developed by GovTech Singapore (https://www.tech.gov.sg/) in collaboration with SkillsFuture Singapore (https://www.skillsfuture.sg/AboutSkillsFuture) and Ngee Ann Polytechnic (https://www.np.edu.sg/).

CVs, Portfolios, and Professional Evaluation

Workday Credentials (https://credentials.workday.com/docs/overview/)

Workday Credentials is a general-purpose digital credentialing platform that issues and verifies standards-based blockchain-backed credentials. It is accessible through APIs and Workday's HR enterprise software. This system leverages a public permissioned Hyperledger Fabric blockchain to cryptographically anchor and universally resolve the validity of any credential. Credentials are not stored on the blockchain but instead directly in a wallet mobile app, WayTo (https://mywayto.com/), where recipients can control and manage who has access to their data. Credentials earned on different platforms can be ported to this wallet, and recipients can use the wallet as a portable profile.

RANDA Solutions (https://randasolutions.com/)

RANDA Solutions provides an Ethereum-based wallet and verifiable licensing and credential solutions for state and school systems. The platform informs continuing education and stores credentials, licenses, as well as demonstrations of curriculum development. Teachers have wallets containing their verifiable digital credentials and all individual components of their license, making it more efficient for states to onboard new teachers both in and out of state, for districts to track documentation, and for teachers to transfer to districts.

Pistis (https://pistis.io)

Pistis.io is a customizable platform that issues and displays verifiable credentials. It provides a shareable "Lifelong Learning Profile" where each credential is viewable along with learning artifacts. Users have full control over their records and may access them from mobile phones and web browsers. It is powered by both Ethereum and Hyperledger Fabric.

SmartResume (https://www.smartresume.com/)

SmartResume connects job seekers and potential employers through verified digital resumes that are created in partnership with the job seekers' academic institutions. Institutions provide academic credentials, co-curricular activities, and student honors, which are stored with unidentifiable personal information on a private, permissioned Hyperledger Fabric blockchain and verifiable. Job seekers can customize the display, add additional information, and make their SmartResumes searchable within the network of employers. Their identities are hidden until they choose to reveal them when they are contacted by a potential employer. SmartResume is currently piloting with the University of Arkansas System, the Arkansas State University System, the University of Central Arkansas, and Arkansas Tech.

Ecosystems

GreenLight (https://greenlightlocker.com/)

GreenLight removes barriers for students to get into college and employment by giving them 24x7 access and complete control of their verified academic records, including transcripts, badges, certifications, references, recommendation letters, and licensures. Participating academic institutions include the Dallas Independent School District, the Dallas Community College District, the University of North Texas Dallas, the Mesquite Independent School District, the Garland Independent School District, and the Grand Prairie School District. GreenLight is built using a private permissioned Hyperledger Fabric blockchain. All student records are encrypted and digitally signed. Users may grant and revoke access to their records at any time.

IBM Learning Credential Network (https://www.ibm.com/blogs/blockchain/2019/11/a-new-learning-credential-blockchain-to-help-bridge-the-skills-gap/)
IBM is in the early stages of developing a consortium blockchain platform using Hyperledger technologies to produce a permanent, verifiable record of learning and skills certifications and qualifications. Job applicants will have control of their data and choose how and with whom it is shared. This will enable job applicants to more seamlessly connect with companies while helping employers more easily and reliably match and verify people's skills with open jobs.

VetBloom (https://vetbloom.com/)
VetBloom, one of the founding members, provides online continuing education for veterinarians and aims to use the network to add efficiency to the talent acquisition process. Another founding member, Central New Mexico Community College (https://www.cnm.edu/), is interested in the network to provide an open marketplace where students can control their credentials and employers find candidates for their job openings. National Student Clearinghouse (https://www.studentclearinghouse.org/), also a founding member, is evaluating blockchain's benefits for learners, education, and workforce communities.

ODEM—Switzerland, United States (https://odem.io/)
ODEM provides a marketplace for students to connect with verified educators and subject matter experts, providing competency-based education. When students' skills are verified, they are issued a certificate that is stored on IPFS and hashed for verification on Ethereum. ODEM's matchmaking system based on European Skills/Competences, Qualifications and Occupations (ESCO) (https://ec.europa.eu/social/main.jsp?catId=1326&langId=en) connects job seekers to employers. Additionally, employers may use the matchmaking system to find potential employees, train, and hire them. In 2018, Southern Alberta Institute of Technology (https://www.sait.ca/) used ODEM to issue students in their Pre-Employment Automotive Service Technician program certificates on blockchain.

Arizona State University (ASU) and Trusted Learner Network (TLN) (https://trust.asu.edu/)
Arizona State University and Salesforce (https://www.salesforce.com/) have partnered to develop the Trusted Learner Network using a private permissioned Hyperledger Sawtooth blockchain provided by Salesforce. Their first pilot is focused on reverse transfer—the process in which ASU sends learner course completion records from enrolled ASU students to the community college(s) where the student was previously enrolled. Many transfer students have not completed their associate degrees when they transfer from two year to four-year institutions. Reverse transfer credits make it possible for students to be awarded an associate degree from their previous community college while actively attending their four-year institution, granting the benefit of a recognized, career-boosting AA. This pilot is being coordinated with Maricopa County Community College District.

Identity

Evernym (https://www.evernym.com/)

Evernym provides SSI software solutions and services, covering the business, legal, policy, and technical aspects of SSI. They invented the Sovrin Network (https://sovrin.org/) and contributed the original codebase to create the Hyperledger Indy and Aries projects. Evernym offers enterprise solutions for organizations to connect and share data with individuals and consumer solutions like their Connect.Me digital wallet (https://connect.me/) for individuals to privately and securely share their identity-related data. In higher education, Evernym's Early Access Program enables new digital experiences across the entire student lifecycle. Universities can issue and accept verifiable digital credentials, much as they do with physical IDs. Students can use these digital credentials to access services on campus, apply for jobs or loans, get student discounts, and log in to university systems.

Online Education and Courseware

BitDegree—Lithuania (https://www.bitdegree.org/)

BitDegree offers learning opportunities for students with connections to employers and job training. Students may pay a small fee to take a course with training designed by employers for hard-to-fill occupations. Upon completion of the course, they are paid with a BitDegree token. Students may also apply for scholarships to cover the fee for their courses and are still paid a reward upon completion. The platform is based on Ethereum smart contracts, and students are issued verifiable credentials using OpenCerts. BitDegree launched as a fully operational platform in 2018, is a finalist in the European Commission's Blockchains for Social Good competition (https://ec.europa.eu/research/eic/index.cfm?pg=prizes_blockchains), and is a member of the International Association for Trusted Blockchain Applications (https://inatba.org/).

QualiChain—United Kingdom (https://qualichain-project.eu/)

QualiChain is being developed as a decentralized education system where learners can take courses, create and share learning artifacts, receive formal and informal, formative, and summative assessments from teachers and peers, and earn verifiable credentials. It will also include a reputation system for students to rate courses and teachers (Mikroyannidis, Third, and Domingue 2019). QualiChain is a research experiment at Knowledge Media Institute's (http://kmi.open.ac.uk/) Open Blockchain Lab (https://blockchain.open.ac.uk) and is being funded by the European Commission's Horizon 2020 programme (https://ec.europa.eu/programmes/horizon2020/en).

Open Education Resources (OER), Peer Review, and Libraries

International Journal of Open Educational Resources (IJOER) (https://www.ijoer.org/)
IJOER is an open-access, double-blind peer review journal. It is published bi-annually and is sponsored by the American Public University System (https://www.apus.edu/) and Policy Studies Organization (https://www.ipsonet.org/). The journal is published using WordPress and has been experimenting with providing researchers proof of authorship using two plugins, WP Blockchain (https://wp-blockchain.com/) and WordProof (https://wordpress.org/plugins/wordproof-timestamp/), which provide historical records of when content was published and any subsequent changes.

PeerMiles—United Kingdom (https://peermiles-project.kmi.open.ac.uk/)

PeerMiles is a research project at Knowledge Media Institute's Knowledge Media Institute's (http://kmi.open.ac.uk/) Open Blockchain Lab (https://blockchain.open.ac.uk) that is investigating decentralized peer reviews. It is looking at how research article reviewing is perceived by authors, reviewers, and editors. It uses Ethereum and uses tokens to reward and recognize effort (Zeeshan et al. 2018).

Blockchain for Peer Review—The Netherlands (https://www.blockchainpeerreview.org/)

Blockchain for Peer Review was a not-for-profit pilot project developed by Digital Science (http://www.digital-science.com/) and Katalysis (https://www.katalysis.io/). They leveraged smart contracts using Ethermint (https://ethermint.zone/), an implementation of Ethereum, to explore the peer review process may be improved. The project was discontinued in November of 2019 but not without some useful takeaways for decentralized peer review initiatives (https://www.blockchainpeerreview.org/2019/11/determining-the-future-of-the-blockchain-for-peer-review-initiative/).

San Jose State University School of Information (https://ischoolblogs.sjsu.edu/blockchains/)

Researchers used an IMLS grant to explore the potential uses of blockchain technologies in libraries. With this grant, they hosted a national forum (https://ischoolblogs.sjsu.edu/blockchains/national-forum/), delivered a Library 2.0 virtual conference, "Blockchain Applied: Impact on the Information Profession," (https://www.library20.com/page/blockchain-recordings), sponsored a MOOC on blockchain and decentralization for information industries (https://ischool.sjsu.edu/blockchain-mooc), and published a book (https://www.alastore.ala.org/content/blockchain-library-futures-series-book-3) outlining opportunities and challenges for blockchains in libraries. The researchers are currently seeking funding to experiment with an SSI universal resolver that will enable individuals with verifiable digital credentials to gain access to resources at all participating libraries.

Notes

1 https://bitcoin.org/
2 https://www.blockcerts.org/about.html
3 https://ethereum.org/
4 https://www.hyperledger.org/
5 https://credentials.workday.com/docs/overview/
6 https://mywayto.com
7 https://pistis.io/
8 https://greenlightlocker.com/
9 https://trust.asu.edu/
10 https://www.salesforce.com/
11 https://odem.cloud/
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