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Blockchained education: challenging the long-standing model of academic institutions

Azael Capetillo[1] · **Daniel Camacho**[1] · **Macedonio Alanis**[1]

Abstract
The model of higher education institutions has remained widely unchallenged over time. Although study topics keep evolving and the inclusion of increasingly sophisticated technologies have revolutionised the format of lectures and learning experiences. Their value chain remains unchanged, with institutions acting as intermediaries, between professors (knowledge) and students (recipients), and as central authorities granting and validating student knowledge. The work here presented is a review of blockchain technology and its application in education, emphasising the opportunities for disrupting the current value chain of academic institutions. Blockchain technology's prime novelty constitutes an incorruptible digital ledger of transactions, capable of recording virtually any nature of value exchange. When coupled with other emerging technologies such as the internet of things and big data, new paths for the decentralised exchange of education and recording of knowledge and skills appear. The result is an extensive analysis of the evolution of blockchain technology for education applications, along with a forecast of plausible scenarios of disruption for academic institutions. Blockchain technology is steadily advancing at accelerating rates; applications aimed at decentralising educational institutions are already available. Meanwhile, the technology keeps gaining momentum in a growing base of adepts.

Keywords Blockchain · Higher education · Access to information · Educational innovation · Experiential learning · Futures

1 Introduction

The world is changing at an alarming speed, introducing novel technologies for education, changing the historical channels where education was delivered, and modifying the conductual patterns of students and employees. All these factors create the perfect mix for disruption.

Technology is changing the way students learn and behave in a classroom. New technology educational trends include the use of tools for augmenting our brain performance, automated systems that assist our daily activities, the widespread use of mobile devices, and the access to a vast amount of information on demand, to name a few [1].

In the past, it used to be the norm that a "University Title" was a requirement to enter the professional world. Nowadays this is being put into question due to the increasing cost of higher education, the introduction of alternative credentials filling the marketplace, and companies demanding proven skills, without caring for a specific university title or education [2].

In contrast with these trends, higher education institutions have remained widely unchanged over time, and although the topics of study evolve and new technology is constantly arriving in the classrooms, their value chain persists unchanged, with institutions acting as intermediaries, between professors (knowledge) and students (recipients), and as central authorities granting and validating student knowledge. Coupling Blockchain technology with other emerging technologies such as the internet of things (IoT) and big data, and applying them in education could provide an opportunity for disrupting the current value chain of academic institutions by decentralizing the exchange of education and recording of knowledge and skills.

✉ Azael Capetillo
azael.capetillo@tec.mx

Daniel Camacho
Camacho@tec.mx

Macedonio Alanis
Alanis@tec.mx

[1] Escuela de Ingeniería y Ciencias, Tecnológico de Monterrey, Av. Eugenio Garza Sada 2501, 64849 Monterrey, NL, México

2 Literature review

Distributed ledger technology (DLT) has enabled the rise of cryptocurrencies, which allows the digital transaction of value through complex algorithmic functions. Research on the technology is advancing rapidly (Fig. 1). In 2012 there were only two academic articles with the word "Blockchain" in the title as listed in google scholar. Since then, research has grown exponentially, and today there are over 2,010 articles with the word "Blockchain" in the title appearing in google scholar searches.

2.1 Distributed computing

Blockchain is the technology behind the most popular cryptocurrencies such as Bitcoin and Ethereum (2018), and perhaps the most widely known DLT representative. Nevertheless, it is worth noting that Blockchain is just one of the *distributed ledger technologies*; other technologies with similar capabilities, such as the Tangle used by IOTA [3], a leaderless protocol where there are no block producers, and every user is free to issue new transactions and attach them on different Tangle parts without an entity that acts as middlemen. However, this paper does not intend to deal with the technicalities of Blockchain, but with its possible application for education.

Blockchain networks can be classified as public, private, and semi-private (consortium). Public networks allow anyone with the software to access and potentially add to the Blockchain; examples are Bitcoin and Ethereum (2018). Private networks work within an organisation or consortium via an intranet-style system. A select group of nodes gives access to the network. Multichain [4] and Monero [5] are examples of these networks. Like Ripple (2018), semi-private networks use public-based architecture yet are privately controlled by centralised ownership of software [6]. Each type of Blockchain network has its own rules and specific assets to trade encoded in its structure [7]. Blockchain aims to create a decentralised network where no third parties control the information [8] by enabling a distributed record of digital
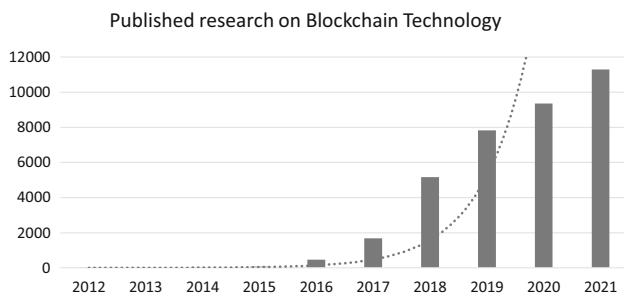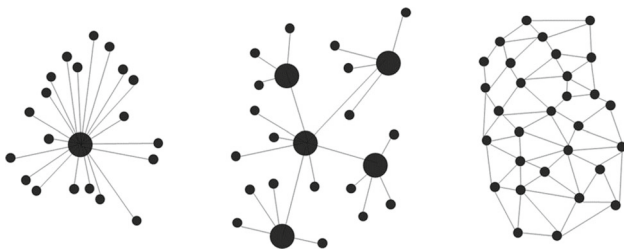
events in a chain of linked data, redundantly stored on every participant node, where additional blocks of data are added by consensus of the majority of the participants [9]. Those interacting with the network can do it either as users or as nodes. Users require local software commonly known as a crypto wallet to trade assets across the network. The wallet provides a unique network address and private key [10] and can be installed directly on a device or accessed by a web browser [7]. Nodes need to install the Blockchain software directly on their devices, which stores a complete copy of the Blockchain and allows them to write directly into the ledger, validate the information in the network and synchronise all the copies of the ledger [7]. For a complete explanation of the technology, Turkanović et al. [8] offer a detailed technical description of the mechanisms in Blockchain.

The nodes are continually verifying the Blockchain's validity by mathematical protocols, ensuring that it is identical to all other copies in the network, the version running on the majority of the nodes is taken as the official version. This is known as "mining", and miners receive coins/tokens in exchange for their processing power [10]. This process makes the hacking or destruction of records extremely difficult. It would require altering over half the network nodes, considering that public networks such as Bitcoin or Ethereum already count hundreds of thousands of nodes and are continuously growing. Moreover, to destroy the Blockchain, it would be necessary to eliminate all the ledger records in the world [7].

The ledger in the Blockchain network only allows appending information, forming new blocks with every recorded transaction. Each block is chained to the previous blocks in the network, creating a chain of blocks; this means that transactions can only be added but not edited or deleted [7].

The before mentioned traits of Blockchain technology—distributed computing, precise tracking of events, revision by consensus, enduring quality of information and resilient data infrastructure—results in a differentiated value proposition encompassing (1) self-sovereignty and identity, (2) high levels of trust, (3) transparency and provenance, (4) immutability of registered events and (5) disintermediation [7].

Grech and Camilleri [7] explains the concepts with three different examples. The first case would be a centralised database, where information is stored and executed on a single central node, a good example is the national land registry. A variation of this is a decentralised ledger where several parties share the responsibilities of a single central ledger. For instance, when regional offices administer the national land registry, each with the authority to store and process transactions within its region. In both cases, if the server is down, there is no access to the ledger. Finally, a third example is the use of Blockchain as a decentralised and distributed ledger. No central authority controls the network, and every node

Fig. 1 Approximated number of published articles, listed on google scholar, with the word "Blockchain" on the title

Fig. 2 Different types of databases: centralized (left), decentralized (middle), distributed (right)

keeps a complete copy of the ledger. Any ledger modification requires consensus from the nodes. Every copy of the ledger has the authority to do changes and addition, which will then be recorded on every copy of the ledger on every node (Fig. 2).

2.2 Blockchain applications

As previously mentioned, Blockchain is not exclusive to cryptocurrencies; in fact, it can be used to exchange a variety of assets like land titles, ID documents, certificates and more [7]. As the technology advances and is better understood, novel applications beyond the financial sector keep arising, for example, to manage intellectual property rights [9, 11], to administer open innovation processes [12], and for the integration of the internet of things [13]. In the medical sciences, Blockchain has found diverse applications [11, 14, 15]. Moreover, in education, it is being used to keep student records and manage assets and financial resources [7, 9, 10, 16–18], Sony [8, 19, 20], to name a few.

In 2016 the Government Office for Science, UK [21] noted three primary opportunities derived from the Blockchain technology's particular functionalities. (1) Cryptocurrency exchanges, (2) the development of novel applications by third parties to create new efficiencies, and (3) the creation of a new form of contracts, also known as "Smart Contracts", which is a potential derivation of the technology worth analysing.

Blockchain is, at its core, a technology to develop immutable records on a decentralised network. This characteristic improves the network's security through a distributed-information model, using consensus like its firewall, and working with encrypted mathematical protocols. As a consequence, its applications are practically endless and not only restrained to financial activities.

2.3 Smart contracts

Melanie Swan [22] forecasts three stages of adoption for Blockchain technology. In the first stage, named Blockchain 1.0, the technology founds applications mainly as an online cryptocurrency. The second stage, Blockchain 2.0, will exploit smart contracts' functionality, finding applications to track contracts, financial records, public records, and property ownership. The third stage, Blockchain 3.0, expands beyond financial services and smart contracts, finds application in science, medicine and education,and envisions a future in which the technology makes hidden information that otherwise would have been inaccessible to the public openly available through distributed networks, [11].

Smart contracts work as programed triggers that execute pre-agreed transactions, as per a contract, yet without intermediaries [10], enabling business and legal agreements to be stored and executed digitally [9]. Grech and Camilleri [7] defined smart contracts as "small computer programs stored on a Blockchain, which will perform a transaction under specified conditions", with declarations such as "transfer X to Y if Z occurs". At the most basic level, smart contracts appear as "a set of promises specified in digital form, including protocols within which the parties perform on these promises [23]." The technology could find a variety of applications in the form of automated invoicing [9].

Smart contracts are self-executing, meaning that once the commitment has been embedded on a Blockchain, the transaction will automatically occur when the conditions are met, without the need for third parties or intermediaries [7]. They exploit the capabilities of immutability, decentralisation and direct mediation of the Distributed Ledger Technology.

Their applications have been explored for financial instruments, self-governing processes, decentralised gambling, student loans, and legal processes, to name a few [23–25].

Smart contracts, in general, are only a tool for the automation of interactions between participants enabling a completely self-sustaining, self-governing and self-regulating ecosystem. It is achieved due to established protocols in the form of mathematical algorithms, ultimately resulting in the freedom to operate without interventions or the involvement of third parties.

2.4 Non fungible tokens

Non-Fungible Tokens (NFT) are a type of cryptocurrency derived from smart contracts [26]. They were first proposed in Ethereum Improvement Proposals (EIP)-721 [27] and EIP-1155 [28], and have found a niche application in trading digital art by allowing a blockchain-based token to securely map ownership rights to digital assets [29].

A specific characteristic of NFTs is that they are unique and cannot be exchanged life-for-like [26] as opposed to a digital cryptocurrency, like Bitcoin where every token has the same value each NFT is different from the other. In the physical world, fungible goods have a long history of trading in auctions and marketplaces, examples range from items of artistic or historical significance to rare trading cards [29]. In contrast, it has been difficult to trade nonfungible goods in

the digital world as their authenticity was hard to verify [29]. This problem is solved by using NFTs on smart contracts (in Ethereum), allowing a creator to easily prove the existence and ownership of a digital asset [26].

NFTs could find an application in the education system for example by turning students' IDs into tokens. Another use could be the creation of a digital degree on the blockchain, with the said degree to have a specific kind of token, in practice this would be the implementation of an ERC-721 as an NFT based protocol for a basic implementation, evolving to the implementation of an ERC-1155 for a more advance implementation allowing universities to create fungible and non-fungible tokens for the same student and degree, this due to the 1155 protocol being the Multi-Token Standard, enabling it to create both fungible and non-fungible tokens from the same smart contract, making them compatible by nature. Whether it is an ERC721 or an ERC1155, both standards allow their users to ensure that what they possess within their wallets or address, is unequivocally theirs, and no one else's, transitioning from a trust-based database system to a new concept, mathematically certain databases.

2.5 Blockchained education: projects review

Devine [10] described two possible applications of Blockchain in education. One with Smart Contracts to shape an autonomous learning experience by using an analogy from the financial implementation of Blockchain. A unit of value is created to represent learning achievements, with one side being the monetary value and the other the learning and teaching activity. In this model, which he named Blockchain learning, teachers function as miners placing learning blocks and creating the opportunity for the learning to occur through their teaching actions, comparable to an income, ready to be spent by students. The second application is the use of Blockchain to offset the cost of learning using peer-to-peer networks, providing a financial reward for students offering services to the University. The first application fit within the Blockchain 1.0 described earlier.

Sharples and Domingue [9] proposed a permanent distributed record of intellectual effort and associated reputational reward that would go beyond the academic community, using rating mechanisms similar to those found in multisided platforms such as Uber or Amazon. Their system acts as a hybrid between institutional records and a fee system payment, in which students receive "Kudos" (a fictional academic reputation currency) as they complete milestones like passing a test or completing a course. In contrast, students pay the institution in cryptocurrency (e.g. Bitcoin) for the mentoring to achieve the milestones. In this model, educational institutions would carry the "mining" process to obtain reputation credits. The proposed educational Blockchain would also work as a record of authorship for intellectual works

(e.g. scholarly articles, artworks, poems, great ideas) that could add to a student e-portfolio. A version, including the major characteristic of the proposed system, is already in operation by the Open University through their OpenLearn platform, where students earn OpenLearn badges that are available in a student Learning Passport. This solution fits within the Blockchain 1.0 applications.

Blockcerts is an open standard for Blockchain credentials developed by the MIT Media Lab in collaboration with Learning Machine, a software developer. The platform allows users to register official records, giving individuals *"the capacity to possess and share their own official records"* [30].

Hoy [11] described the potential use of Blockchain to help librarians gather, preserve, and share authorship information. For example, Blockchain could verify versions of journal articles with the use of a timestamp. Hoy [11] gives insight into how such an application has already been tested for the authentication of medical science archives by Irving and Holden [14]. Another application described by Hoy, is the use of Blockchain as a digital rights management (DRM) tool, allowing digital materials to be uniquely identified, controlled, and transferred. These applications could be implemented in education to have verifiable records of academic achievements.

Turkanović et al. [8] talks about the problems with the lack of interoperability of student records in educational institutions and calls the example of students emigrating to a foreign country and the difficulties involved in retrieving their academic records. That is the motivation behind EduCTX, a Blockchain platform for global higher education credits, based on the concept of the European Credit Transfer and Accumulation System. EduCTX consists of a trusted, decentralised higher education credit, and grading system, offering a unified record for students and academic institutions, where peers of the Blockchain network are higher education institutions and users of the platforms are students and other organisations. A proof of concept for EduCTX was implemented based on the Ark Blockchain Platform.

Sony [19] developed a Blockchain system to keep track of educational achievements and activity records, with the capacity to integrate multiple educational institutions to safely interchange school grades, educational records and digital transcripts. The applications also aim to analyse data using artificial intelligence (AI) to provide improvement suggestions to the curriculum and management of institutional education. The platform has been built on IBM Blockchain powered by Hyperledger 1.0, and its main features are (a) the authentication and control for the usage rights of educational data and (b) an application programming interface for handling such rights.

Bore et al. [16] worked on a Blockchain-enabled School Information Hub (SIH) applied to the Kenya school system,

Table 1 Eight possible uses for Blockchain technology in education [7]

Scenario	Term
To permanently secure certificates	Short term
To verify multi-step accreditation	Short term
To receive payments	Short term
For automatic recognition and transfer of credits	Medium-term
As a lifelong learning passport	Medium-term
To track intellectual property and reward its use and re-use	Medium-term
For student identification	Medium-term
To provide students with government funding, via vouchers	Long term

aiming at improving their record-keeping process. They identified problems that could be solved using Blockchain technology capabilities. For example, the reliability of records of a transfer student could be addressed by establishing verifiable control points and managing compliance assurance (data), ensuring the integrity of recorded transactions (immutability), and the execution of operations by identifiable entities (non-repeatability). These features give the capability to keep irreversible records of all entries and changes to school registers, assuring their correct attribution by contemporary means, and ensuring the immutability of the entered data by network consensus using cryptographic algorithms. The before mentioned Blockchain application aimed to solve four main challenges, (1) keep a reliable record of students and teachers registered in the public school systems, thus avoiding extra expenses created by "ghosts" teachers or students. (2) Improving the transparency and accountability of budget allocation and spending within the school system. (3) Improving the learning environment, correlating school performance data with teacher/students records. And (4) improving the learning experience with the creation of personalised education programs.

Grech and Camilleri [7] discussed in depth the use of Blockchain for issuing academic certificates. The technical extent of their work is worth noting, as it is a useful source of reference to understand the mechanisms of Blockchain technology, mainly when applied to issue certificates of educational value. Their work is firmly based on the capacity and benefits of using Blockchain technology to issue academic certificates and provides thorough information on the products developed by various providers for this purpose. Their work is a critical review, addressing issues on code and practices standardisation. The authors provide eight usage scenarios for Blockchain in education in the short, medium and long term (Table 1).

Gazali et al. [24] explored the use of Blockchain to re-invent the National Higher Education Fund Corporation (PTPTN) of Malaysia, which acts as the primary source of financing tertiary education in the country. In this case, Blockchain could be used to ensure timely payments from borrowers as well as to improve the management system of the funding institution. All of these are achieved through a Smart contract application based on the Ethereum platform. The proposed use of Blockchain would create a smart contract between the student and the financial institution, in which the academic institution is in charge of reporting the student's academic status. The correct use of smart contracts could reduce issues of transparency and management costs.

Raju et al. [31] present the conceptual design of a *data bank* as an institution of trust based on Blockchain to govern healthcare and education. The proposed *data bank* aims to deliver a substantial improvement in both the scope and quality of health and education services. This is achieved by assessing data that is continuous and complete to make informed decisions.

Rooksby and Dimitrov [18] implemented a Blockchain system based on Ethereum to store student grades and provide a cryptocurrency based on academic results. The system focused on student grades and had the functionality to (a) store student records (course enrollment information, grades and final degree), (b) use a University-specific cryptocurrency (Kelvin Coin), and (c) allow payments of Kelvin Coins, automatically allocated to the top-performing students via smart contracts. The system is a functional prototype to demonstrate the potential of the technology to provide trustworthy records (tamperproof and transparent), and transparency for awarding grades. Rooksby and Dimitrov discussed the tensions between the University as a central organisation and a distributed autonomous organisation. Reflecting on their mechanisms of trust, openness and the different procedures endured by the two types of organisations. Most importantly, they noted that for their exercise, Blockchain did not provide gains in efficiency or cost reduction in the administrative process of the University.

Chen et al. [32] looked at potential applications for Blockchain technology in education, based on the features and benefits of the technology, highlighting the use of smart contracts as a way for teachers and students to carry out instructing and learning activities. For example, enabling the concept of "learning is earning" [9] where students can earn tokens by learning the topics financed through a marketplace. Among other applications, Chen et al. [32] also mention the use of smart contracts for evaluation processes leveraging the immutability, traceability, and reliability of the technology. For example, students could submit their work to a learning platform where a smart contract will review their performance, and the results will be recorded into blocks, saving all types of student works and behaviours into blocks as evidence for evaluation.

Alammary et al. [33] identified 12 applications of blockchain technology in education which were (1) certificates management, (2) Competencies and learning outcomes, (3) Evaluating students' professional ability, (4) Securing collaborative learning environment, (5) Protecting learning objects, (6) Fees and credits transfer, (7) Obtaining digital guardianship consent, (8) Competitions management, (9) Copyrights management, (10) Enhancing students' interactions in e-learning, (11) Examination review, (12) Supporting lifelong learning.

Raimundo and Rosário [34] ran a systematic bibliometric literature review of research on blockchain applications in higher education, integrating a total of 37 articles on the current implications of its use for improving higher education processes. The main themes of their research are (1) Organising of Higher Education Institutions, (2) Smart contracts, (3) Privacy and accreditation processes, (4) Knowledge management, certification and engineering education, (5) Innovation in education, (6) Emerging Technologies and Educational Projects, (7) E-Learning, and (8) Document organization.

Guustaaf et al. [35] summarized the features provided by blockchain technology on several higher education projects. Among the features provided by the technology are decentralisation, anonymity, transaction rates, smart contracts, consensus mechanisms, and traceability.

2.6 Blockchained education: categories for innovation

Various authors agree on the apparent application of the technology to store student records, which could then be shared publicly with third parties, providing a safe and enduring record, resilient against data loss [9, 10]. E.g. the University of Nicosia is already running its academic certificate records on a Blockchain network [36], thus, third party users could verify a student record directly by accessing the University Blockchain [37]. Sony [19] has developed a system, applying Blockchain technology, for the authentication, sharing and rights management of educational institutions' records. Blockchained records could allow the integration of creative works, artistic developments, among other types of intellectual work [37].

As the technology is better understood, sophisticated applications keep arising, most of them based on analogies of the value transaction with financial tokens, changing what is referred to by value (e.g. intellectual value) and mining (allocation of value blocks).

Tapscott and Tapscott [20] described four main categories for innovation in higher education, their challenges and the possible use of Blockchain technology to address them. These categories were used to classify the types of innovation of the various Blockchain projects analysed in this research.

The first category (1) Identity and student records; presents three main challenges being (a) maintaining the privacy and security of data stored digitally, (b) the validity of the information recorded, and (c) time spent studying. In this case, Blockchain technology could be used to encrypt the data collected by institutions securely. The information recorded and encrypted would remain valid and official within the chain; this would be of use for general student information, like certificates and student records. With the development of adequate tools, a Blockchain system could be able to recognise students for everything they learn, independently of settings, i.e. within a university course, on professional experience, life experience and more.

The second category is described as (2) New pedagogy. Universities rely on the prestige of their academic models to ensure third parties about the quality of education acquired by the students. The conventional model of learning is relatively similar in many Universities, with teachers acting as broadcasters and students as recipients of a one-way message. Such a model might not be any longer appropriate for the digital age. With information widely available online, self-paced computer learning programs could carry the mastery of knowledge (situations where there is a right and wrong answer). At the same time, classroom time is used for debate, discussion and collaboration around projects. New pedagogy models would be based on learning by doing, in a heterodox learning process where students capitalise on what they have learned in topics they are passionate about, such as the case of Vitalik Buttering, the founder of Ethereum [20]. An approximation of this model is the Thiel Fellowship program, which awards *"$100,000 to young people who want to build new things instead of sitting in a classroom"* (Thiel Fellowship, n.d.). Blockchain is enabling new collaborative models; one example is the Consensus System (ConsenSys) [38], one of the earlies development under the Ethereum code, the models allow for a *holocratic* management of science, based on collaboration rather than hierarchical structures. ConsenSys allows its members to choose between two to five projects to work on. Everyone owns a piece of the project, in the form of tokens under the Ethereum platform. For the classroom the key objectives are agility, openness, and consensus; i.e. identify what needs learning, distribute the work among students, agree on their roles, responsibilities and rewards, and codify these rights in smart contracts.

The third category is (3) Education costs. Blockchain technology allows for (a) a reliable proof-of-truth mechanism, e.g. to confirm if students signed in MOOCs completed the course, took the tests, and mastered the material, (b) payment mechanisms and (c) learning plans established under smart contracts [22]. The Blockchain "pay for success" scheme [22] could enable private companies to support the development of skills they are interested, in by financing individual students to achieve specific learning goals and reward them

accordingly, making students accountable for their progress. Blockchain could be used to reward the application of the learned skills,for example, a student could pay back the student debt by teaching the topic he previously learned, the Blockchain database would match skills with market demand. The system could be developed to such a level where it could calculate the precise value of each element of the learning curricula, allowing funding providers to pay for a student's complete education in exchange for a student's future earnings [20].

The fourth category relates to (4) The meta-university. The brainchild idea of MIT President Emeritus Dr Charles Vest, who offered a vision in which the open-access movement created an accessible, empowering, dynamic and communally constructed framework of open material to build or enhance higher education worldwide. Where the web provides the communication infrastructure, an open-access library would give the knowledge [20]. According to Dr Charles, such a system could accelerate the diffusion of knowledge and education. Under this framework, Tapscott and Tapscott [20] envision three stages for the application of Blockchain. The first stage involves content exchange, the second is content co-innovation, and finally, in phase three, Colleges and Universities become a node in a global network of the education ecosystem. Under a vision of a worldwide network of learning, students would receive custom learning experiences, coming from a diverse source of institutions, with Blockchain serving as the tracking platform for the student's progress and performance [20].

Whether it is the identity and student records, educational costs, new pedagogy, or the meta-university, we are facing the concept of a new type of University. By creating this Blockchain-based environment in which students and professors can rely on a decentralised, distributed, immutable and self-regulated system, turning the long-standing model of educational institutions, into a new and improved version, we are now on the edge of the "Smart University" era.

3 Blockchained education analysis: methodology

According to Satel [39] Innovations can be catalogued into four types: sustaining, disruptive, breakthrough, and basic research—the latter will be referred to as fundamental for ease of purpose and to keep with the single word. These categories are based on two criteria (i) how well is the problem defined, and (ii) how well is the domain defined (Table 2).

Products can also be classified according to their functionality. The concept of Job to be Done (JTBD) [40] states that the reason a customer buys a product, service or a specific solution is due to the Job these items fulfil. A "job" is the fundamental action a customer wants to achieve with a

Table 2 The types of innovation matrix [39]

How well is the problem defined?	Well	Breakthrough Breaks an established paradigm	Sustaining Improves existing capabilities in existing markets
	Not well	Fundamental Uncovers new knowledge on the mechanisms of a given phenomenon	Disruptive Develops a new basis of competition in the market
		Not well	well
		How well is the domain defined?	

Table 3 Functionality—Market matrix (JTBD organic growth matrix) [42]

Functionality	New	Related growth Adds new functionalities to the product	New growth Adds new functionalities, offered to new markets
	Existing	Core growth Improve the main functionality of the product	Disruptive growth Enable the product to new (non-consumption) market
		Existing	New
		Market	

product. The *JTBD* involves the idea that we "hire" products for their functionality [41]. Silverstain et al. [42] described four main types of organic growth strategies based on the functionality or JTBD of a product these are (a) core growth, (b) related job growth, (c) new job growth and (d) disruptive growth (Table 3).

The revised Blockchain education projects were classified according to their category of innovation [20], their type of innovation (Table 2) based on the model by Satel [39], and their functionality (Table 3) based on the JTBD organic growth model by Silverstain et al. [42].

First, it was necessary to identify the project category to establish the type of innovation it represented. For example, if the Blockchain project presented an improvement in the way identity and student records are taken, it would be classified as "Sustaining". If the project developed new ways to carry out the activities of the given category, that is, changes the established value chain of the activities in the group, classifies as "Disruptive". A fundamental innovation would require the

project to uncover previously unknown mechanics or interactions within the given category of impact. Moreover, for breakthrough innovation, the project should have presented a mechanism to completely replace the established practices within the given category, for example, to eliminate education costs.

The project functionality was classified according to the features integrated into the given project category, for example, a project functionality identified as "Core" represents an improvement in the way activities are currently carried out in the given category. If the project presented an added feature, like the inclusion of big data analytics within the identity and student records, then it would classify as "Related" growth. The "Disruptive" growth applied in cases when the project enabled new dynamics or mechanisms to allow the access of new users. For example, the introduction of a mechanism to pay for education costs enabled a new group of users to enter the higher education market, who otherwise would not have access to it. The "New" growth refers to projects enabling the introduction of new user groups and new markets. An example is the case of the educational Blockchain model, which is enabling new mechanisms to provide education, and at the same time, is enabling new users who could not attend an established institution. The difference between "Disruptive" growth and the "New" growth is that while disruptive enables new users in the same market, new growth enables new users in new markets. Table 4 presents the results of the classification in Innovation and Growth of the various Blockchain education projects here described.

4 Results and discussion

Most of the reviewed Blockchain projects presented a sustaining innovation while providing "Core" growths (improvements). These projects presented mainly a replacement of technology, changing the previously used tools or methods, in new ways based on Blockchain technology. Such projects tend to offer a modest improvement in the "Category" of innovation, for example, making student records more easily accessible or increasing their security. However, these innovations are not "game changers" and do not represent a shift in the standing model of academic institutions. Their impact is more in the performance of the already established mechanisms of the standing model of educational institutions.

Fewer projects presented "sustaining innovations" with "Related" growths, like the official records and data integration [16], Sony [19]. These projects gave an added functionality enabled by Blockchain technology that was previously not possible within the "Category" of innovation. In one of the cases Sony [19] is planning to add artificial intelligence into the Blockchain platform for the management of "Identity and students records", similarly Bore et al. [16] is adding data analytics to correlate information leveraging the reliability of the data provided by the Blockchain platform.

Devine [10] presented a project of "Disruptive" innovation which enables "New pedagogy" mechanisms creating a new learning platform and educational system based on the "Smart contract" capabilities of Blockchain technology. Nevertheless, it remains a "Core" improvement in the way education is provided and accessed and does not enables new users or markets.

Devine [10] also proposes a new mechanism to cover "Educational costs" complying with "Disruptive" innovation qualities, enabling new users who otherwise would not be able to cover the educational costs, thus providing a "Disruptive" growth in the category of "Educational costs".

Sharples and Domingue [9] proposes a new learning platform and an educational system based on the capabilities of Blockchain technology. Such a platform applies as a "Disruptive" innovation in the category of "New pedagogy" as it changes the mechanism to access, provide and grade education. Moreover, such a platform offers a "New" growth as it would enable new markets and new users to access and provide education.

4.1 Blockchain disruption

Kelly [43] noted, from a previous observation by Marshall McLuhan, how the first version of a new media imitates the media it replaces, like the first commercial computers which employed the metaphor of the office, having "desktop", "folders" and "files" [43]. For this paper, we will refer to this process as the "first step of technology evolution". Brian Arthur [44] carried out an in-depth study of the fundamentals of technology evolution. He observed the autopoietic properties of technologies, which is the capability of technologies to build upon previous technologies, or said in another manner,a technology will spawn further new technologies, e.g. the creators of the internet never imagined the concept of Netflix, Facebook, the smartphone or WhatsApp. For this paper, we will refer to this process as the "second step of technology evolution".

Blockchain technology is an immediate improvement in the security, reliability and resilience of information in comparison with centralised databases. Is not surprising to find the first generation of Blockchain applications being merely a "one-to-one" replacement of the previous media, in this case, centralised databases (first step of technology evolution). Besides, as stated by the previously mentioned second step of technology evolution, there will be new technology derived from the functionalities enabled by Blockchain technology, as is now happening with the creation of Smart Contracts and NFTs.

Table 4 Analysis of Blockchain education projects

Author	Application	Category	Innovation	Growth
University of Nicosia [37]	Official records and data integration	Identity and student records	Sustaining	Core
Devine [10]	Blockchain learning: Smart Contracts to shape an autonomous learning experience	New pedagogy	Disruptive	Core
Devine [10]	Offset education costs	Education costs	Disruptive	Disruptive
Sharples and Domingue [9]	Educational Blockchain model	New pedagogy	Disruptive	New
Blockcerts [30]	Official records and data integration	Identity and students records	Sustaining	Core
Hoy [11]	Gather, share and preserve authorship information	Identity and students records	Sustaining	Core
Turkanović et al. [8]	Official records and data integration	Identity and students records	Sustaining	Core
Sony (Sony [19]	Official records and data integration	Identity and students records	Sustaining	Related
Bore et al. [16]	Official records and data integration	Identity and students records	Sustaining	Related
Grech and Camilleri [7]	Official records and data integration	Identity and students records	Sustaining	Core
Gazali et al. [24]	Ensure timely payments	Education costs	Sustaining	Core
Raju et al. [31]	Official records and data integration	Identity and students records	Sustaining	Core
Rooksby and Dimitrov [18]	Official records and data integration	Identity and students records	Sustaining	Core

Universities and other higher-education organisations face a significant challenge in the form of Blockhained education. Universities trade on the trust gained by reputation [18], and the Blockchained education might be capable of providing the same levels of "trust " with mathematical algorithms, making use of new technological infrastructure and value chains.

An arising concern of the trading of an educational asset, is the commoditisation of education itself, in a system in which a user could trade educational products without worry about their intellectual value, in such a system, education is reduced to a marketplace of knowledge and reputation [9]. However, this topic would require further study.

4.2 Digital education: blockchain meta university concept

In the fall of 2011, the University of Standford offered a free massive open online course (MOOC) on the topic of Artificial Intelligence by two of its institution's leading experts. The course received over 160,000 worldwide student registrations. Among them, 20,000 students from over 190 countries finished the course successfully and received a "statement of accomplishment" from the course teachers [45]. The globalisation of digital education (e-education) is bound to happen. It happened before with e-mail, e-commerce, and in some countries with e-government [46]. In this day and age, student knowledge is not limited by what they address in the classroom.

The COVID-19 pandemic effects in 2020 made clear the importance and value of the digitalisation of education. Educational institutions face the challenge to migrate from the physical to the virtual classroom at a neck break speed [47]. Even before COVID-19, some states like Florida in the USA required students one course virtually before graduation [48]. Furthermore, when schools re-open, the newly adopted practices of online learning might remain as part of the academic curricula [49]. The digital classroom brings a new wave of challenges for students and professors alike. For example, the recollection of the student learning evidence is a challenge for professors, and the diminished human interaction in the learning process might be a challenge for students. In 2002 a group of researchers explored the possibility to replace the classroom lecture for the topic of "Principle of Economics" with an online or hybrid lecture and found that students in the online course performed significantly worse than their face-to-face classroom counterparts [50]. Advances in information technology have moved a long way since then, and now not only the new generation of students and professors are prone and comfortable with information technologies, but also the tools available for online education have increased in number and quality [51]. However, although the gap has been reduced, recent studies still suggest a difference in performance between online and face-to-face education. For instance, [52] carried out a meta-analysis comparing 189 participants in webinar conditions with 192 participants in either face-to-face or asynchronous online learning conditions. Although they found that webinars were slightly more effective in promoting participant knowledge than face-to-face and asynchronous learning, the difference

in performance was statistically insignificant. However, it can serve as an indicator of how the online education method is catching up with traditional teaching. Showing similar results, [48] compared the performance in contemporaneous and downstream outcomes of students taking an online course versus students in a face-to-face format for the initial attempt and credit recovery. They found that contemporaneous outcomes were positive for the online learning students in both initial attempt and credit recovery. However, there was a significant difference in performance in follow-on courses with students on the online course performing significantly lower than their counterparts taking the traditional course.

Educational institutions without the systems or infrastructure to move into the digital education era are prone to be disrupted. Blockchain technology has capabilities that could address many of the problems and exploit the opportunities of online learning such as the need to validate the quality of increased availability of digital content and the need to recollect evidence of the learning process. Blockchain technology could become the backbone system of the digital education era by enabling a Blockchain Meta University Network.

The Blockchain Meta University could be either an open or public blockchain. It would enable an exponential stream of users to create content on this new network, taking advantage of their resources, which is an optimal scenario from an operational point of view—resulting in a variety of content coexisting within the Blockchain Meta University Network (or BMUN). Once a blockchain network is in place, with its payment token, and an exponential stream of users and nodes, specific applications for the said network can be developed Table 5.

A new branch of development within an educational institution could be to create a Blockchain. With this, the University could have governance and control over its platform. It would be able to incentivise users with their proprietary token for a variety of applications, from tuition payments to complementary services within the campus.

5 Conclusions

Most of the currently envisioned applications of Blockchain technology in academic institutions represent a sustaining innovation merely changing one technology (existing databases) for other (Blockchain platforms), making limited use of the improved qualities provided by the novel technology like the reliability and ease of access.

A few applications with disruptive qualities have been envisioned, affecting "Educational Costs" and "New pedagogy" methods. However, neither the technology nor the satellite infrastructure might be ready to support a change in the current model of academic institutions, and a Blockchain

Table 5 The blockchain meta university netowork capabilities and applications

Capability	Application
Immutable records	From alumni to professors' records, everything could be recorded on the BMUN
Direct Mediation	With proof of work algorithm and a consensus work style, the UBN would work as an environment and the nodes as witnesses for any activity, without third-party intervention
Decentralisation	with a public blockchain model, everything would be distributed and decentralised, creating a complete, self-regulated and self-sustained environment
Database management and sharing	Enabling the BMUN to host different internal projects, all the information would work on the same language basis, eliminating bureaucracy and fastening all processes on a digital basis
Digital assets	A whole variety of Digital Assets could coexist in the BMUN, from the University payment token to every need the University may have in the form of a utility token
Meta-University	By sharing the same UBN, different universities could accept and use the same payment token, and share their resource, creating compatible databases held on the same network (BMUN)
New Pedagogy	BMUN the pedagogy methods could be improved by enabling the alumni to develop and create new blockchain solutions
Educational cost	Using a payment token with educational applications, Education would be accessible to everyone willing to participate with their computational power on the UBN

Table 5 (continued)

Capability	Application
Identity and students record	with the UBN implementation and utility token creation, all records would share a secure, distributed and efficient existence, also enabling more control over identity and security among the alumni

platform might not replace educational institutions in the short term.

Various technical issues need to be solved to exploit the full capabilities of Blockchain technology in an educational or academic organisation to become a fully functional academic ledger that will replace current academic institutions.

Already, Blockchain technology could solve different problems regarding students ID security, by implementing a system of student ID tokens, working on a crypto wallet, using Blockchain, ensuring the safety of the students' information and reinforcing the university standards for students activity validations, not only as an access confirmation for the campus or classrooms but also as an online security solution, ensuring the student identity during online courses.

The development of a Blockchain system could be part of each university's research and development department. It would open a new stream of projects, creating a platform for the development of new ideas, whether it is from students or professors, enabling the institution to innovate in this new technology as part of their presence in the educational field.

However, whether it is for the long, medium or short term, to improve the university business model or just a way to stay relevant to the new technologies. It is important to note that, the logical conclusion is to begin the incursion of blockchain adoption toward educational institutions, as part of the 4.0 revolution.

We are merely in the first generation of Blockchain technology, and most probably, the infrastructure required for the total disruption of the model of academic institutions is not yet available. However, following the observations from Kelly [43] and Arthur [44], we can infer that the first building blocks of disruption have already been laid.

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