**Empowering Micro-credentials using Blockchain and Artificial Intelligence**

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**Introduction**

The recognition and transfer of credits is becoming essential for students, as an increasing number of them are studying at different institutions, often at the same time online, in both traditional and unconventional settings. Micro-credentials can aid in this process by providing easily accessible and transparent evidence of skills or knowledge, certified by an authority, based on small units of learning. The development of Blockchain technology holds promise of becoming a useful enabler for supporting the storage and dissemination of micro-credentials on a global scale. Because of its immutability, Blockchain can be used to attest to students’ accomplishments securely and privately under their control. Artificial Intelligence (AI) can facilitate the micro-credential assessment process as well as their maintenance and dissemination on the Blockchain. This chapter describes the important features of these three technologies for higher educational contexts, and suggests how they can work together to improve learning for students, administration for institutions and ensure security for both.

**Micro-credentials**

Micro-credentials can provide easily accessible and transparent evidence of skills or knowledge, certified by an authority, based on small units of learning. Often in the form of badges, micro-credentials can be used by learners as proof to employers, and others of their qualifications. They can sometimes be used for accumulating credits, 'laddering' towards specific qualifications incrementally. Micro-credentials can be used as evidence of their skills or competencies to share with potential employers and other gatekeepers. So, micro-credentials, or Alternative Digital Credentials (ADCs), a term used by the International Council for Distance Education (ICDE), can also be used to lead to more formal credentials in the form of certificates, diplomas, and degrees. Micro-credentials can also be submitted by students as evidence in transferring their credits from one institution or organization to another in the same country or internationally. Higher education institutions can use micro-credentials to track student work, progress toward goals, and credentials earned.

Micro-credentials are more quickly earned by learners, generally at a lower cost than traditional qualifications. Moreover, they can be used without delay, which is especially useful for students when seeking employment. They more specifically identify actual knowledge and skills. They can also be used to monitor academic progress; share credentials earned at their previous and current institutions; and keep records of both formal and informal learning activities accumulated (Contact North, n. d.). These benefits should be seen considering the accelerated changes made by many institutions towards hybrid, blended and other forms of learning because of the Covid lockdown. Open badges could be considered as the most popular form of micro-credential. Rogers (2022) comments on their utility as digital credentials, noting their portability and verifiability because they can be checked online from anywhere.

Although micro-credentials do not offer the same level of education as certificates and degrees, they can often become “stackable”. Pathways to competencies can be created using micro-courses that can then be built up into a course equivalent with official credit recognition using badges or other forms of micro-credentials. The U.S. Department of Labor (2012) describes them as “a sequence of credentials that can be accumulated over time to build up an individual's qualifications and help an individual move along a career pathway to further education.”

*Challenges for micro-credentials*

There are however some problems for students using micro-credentials. They are not universally accepted by employers and institutions and so are often perceived to be not as valuable as a formal degree or diploma. Micro-credentials can also prove challenging for higher education institutions. Tracking, stacking, and verifying a wide assortment of micro-credentials can be onerous and cumbersome, increasing costs. Micro-credentials also tend to emphasise skills for employment rather than supporting more humanistic and holistic approaches to learning (Varadarajan, Koh, & Daniel 2023). Maintaining consistent standards, ensuring the quality and rigour of the micro-courses is potentially challenging. McGreal and Olcott (2022) argue that the implementation of micro-credentials in higher education institutions can be disruptive and so there is a need for a “strategic reset” if they are going to implement this new form of credentialing, either as a systemic change in processes or as an add-on service. Attention must also be paid to the currency of commonly accepted guidelines and standardised frameworks that are being promoted in Europe, Australia and Ontario, Canada (Antonaci, Henderikx, & Ubachs , 2020; Australian Government Department of Education, 2021; eCampus Ontario, n. d.). Brown, McGreal and Peters (2023) warn of the risks for institutions implementing micro-credentials, including loss of reputation due to a failed initiative and the possibility that micro-credentials will attract regular students who would normally pay full tuition. Nevertheless, they identify The State University of New York (SUNY), with 64 campuses as “an exemplary institution” creating learning pathways for students using for-credit, stackable micro-credentials.Micro-credentials must be secure, immutable and verifiable while being easily accessible and controllable. For this purpose, Blockchain technology can provide a solution.

**Blockchain**

Blockchain can be described as a digital ledger that is distributed on a network. The ledger is hosted on geographically distributed networks of databases that store information. The blocks in the chain are secure, verifiable, and permanent. The development of Blockchain technology holds promise of becoming a useful enabler for supporting the storage and dissemination of micro-credentials on a global scale. It consists of a ledger for transactions with the middleman cut out. There is no centralized governing authority and there is no need for any intermediary in controlling the transactions between individuals or institutions. The transactions are secured with encryption, verified, and recorded by the network nodes. Blockchain can be used to facilitate trust relationships among two or more people or institutions without the need for any central authority. The original records cannot be deleted or changed, and all transactions can be easily traced as each new block in the chain is time-stamped and linked to the original record. In this way, Blockchain can support secure decentralized networks of information. Data loss is not possible when no single node holds all the information (Sun, Wang & Wang, 2018). Thus, authentication can be achieved with enhanced performance and reliable scalability. A Blockchain can be used by both institutions and students to track their progress and their earned credentials, while ensuring privacy (Alsobhi, Alakhtar, Ubaid, Hussain, & Hussain, 2023).

The most well know use of Blockchain is for Bitcoin, which is a ledger for financial transactions known as a digital cryptocurrency. There is no centralised governing authority and there is no need for any intermediary in controlling the financial transactions between individuals. The transactions are secured with encryption, verified and recorded by the network nodes. Its core technologies include distributed accounting technology, asymmetric encryption algorithms and intelligent contracts. Bitcoins are created through a resource intensive process called data mining. Bitcoin can be converted into different currencies for purchasing or used directly as more businesses are becoming comfortable in accepting it. Bitcoin is based on Blockchain, but the technology has many other uses.

Blockchain can also facilitate transactions among two or more people of other information besides currencies. Blockchain can support secure private networks containing data, such as micro-credentials. The Blockchain identity verification feature supports fail-safe certification. Data loss is thus obviated, because unlike centralized databases, no single node holds all the information (Gunes & Firat 2022, Sun, Wang & Wang, 2018). Moreover, the original records cannot be deleted or changed and all transactions can be easily traced as each new block in the chain is sequence and time stamped. This can be achieved with enhanced performance and reliable scalability. Namasudra, Deka, Johri, Hosseinpour, & Gandomi (2021) refer to the immutability of Blockchain as well as the transparent decentralization, without the need for a trusted third party. At least one educator prefers the term “distributed ledger technology”, because the term ‘Blockchain” is too closely focused on Bitcoin and other crypto currencies (Downes, 2019).

*Blockchain and micro-credentials*

So, other information besides numbers can be housed in a Blockchain, and this includes micro-credentials. Unlike Bitcoin implementations which do not require permission of the users, educational Blockchain implementations require permissions from the owner of the Blockchain. Employers and others can only view the data with the student’s permission. But with this permission, employers can quickly and easily assess a candidate’s skills and qualifications. They can know with confidence what has been credentialed, by which institution(s) or organization and when.

A Blockchain micro-credential process works like this: An institution wishes to award credit to a student and so creates the first Block in the chain representing the transaction. The Block is then transmitted on the network to every node. Each node approves and validates the transaction. The block is then added to the chain, creating a permanent, transparent record. The student or anyone authorised by the student to access the record can download a copy of the micro-credential or certificate. It is permanently recorded. However, to date, Blockchain in education is in the very early stages of *adoption.*

*Blockchain in education*

Still, the primary benefit of Blockchain for education, highlighted by experts, is in micro-credentials (Ahsan, Akbar, Kam, & Abdulrahman, 2023; Casey, 2019; Clark, 2016; Gunes & Firat, 2022; Pianko, 2018; Sharples, 2016). The benefits of Blockchain can accrue to educational institutions, by reducing credential fraud, while enhancing efficiency and security, storage, and management of data. Students benefit from a trusted attestation of their knowledge. Employer benefit when they can be confident in assessing the validity of applicants' skills. Unlike the present norms for institutional certification, Blockchain data is associated with the individual student rather than the institution. With Blockchain, it is the student, who owns and has full control over who can access the information. Because the student cannot alter the information in the Blockchain, this ensures the legitimacy of the grade and information supplied in a badge, certificate, or diploma (Steiu, 2020).

Belshaw (2016) contended that “blockchain plus badges equals rocket fuel for verified trusted credentials.” Not only badges but also other micro-credentials and open standards support credit transfer among institutions. Xianmin, Xin, Huanqing and Keyun (2017) proposed the development of a Blockchain degree certification system leading to the decentralization of educational processes. The Blockchain can hold and protect verified and untampered students' certificates, examination results and timestamped dates. Alsobhi, Alakhtar, Ubaid, Hussain, & Hussain, 2023 argue hat Blockchain is an “ideal technology” for managing, storing and documenting micro-credentials.

Because of its immutability, Blockchain can be used to confidently attest to students' accomplishments. On the other hand, a diploma or certificate on paper may not be fully trusted. even when on parchment. External institutions and employers typically approach thedegree-granting body directly for an original copy. Moreover, both the issuing of credentials and the credit transfer process is under the control of the institutions and can be very cumbersome and inefficient. As more and more students gain credentials from multiple institutions or even private organizations, this process of going back to the source becomes increasingly untenable. The student needs to gain control of this process and Blockchain can provide a solution (Alsobhi, Alakhtar, et al., 2023; Raths, 2016).

Existing institutional transcript systems can be cumbersome and inefficient. Any uncertainty or inability to provide a certificate on request can be a serious impediment to often time-constrained students wishing to advance their careers. Digital systems using Blockchain can form the basis for an effective system of storing and distributing transcripts in a secure, timely, and accessible fashion (Bahauddin, Ferdinant, Elisabeth, & Ruwani, 2023; Nazaré, Duffy & Schmidt, 2016). Pianko (2018) referred to this digitization of credentials as “the death knell for the embossed transcript.”

 Mikroyannidis, Domingue, Bachler and Quick, (2018) have explored how Smart Blockchain Badges can be used for data science accreditation. Certification by Blockchain begins when the trusted institution issues the certificate and creates a Blockchain. The student then sends a Public Key to the institution requesting a transcript be sent to a potential employer. The institution then adds a hash certificate onto the Blockchain and sends the certificate, which is shared on different nodes and verified before being forwarded to the employer (Holotescu, 2018; Pathak, Gupta, Malsa, Ghosh, & Shaw, 2022). The learners conserve their keys to the credentials in an offline wallet, which facilitates the pre-creation and subsequent sharing of keys (and deleting them when used). There remains an ongoing need for a high level of trust in the issuing institution, but each individual micro-credential is only useful when it is tied to a person, so maintaining the privacy of the data is essential. This implies a high degree of learner control in the process.

With Blockchain the ownership rests with the individual not the institution. The credential is held in Blockchain for preservation, reliably ensuring the validity of the record, which can normally be a lengthy and tedious process (Alsobhi, Alakhtar, Ubaid, Hussain, & Hussain, 2023). Blockchain can also be used to collect micro-credentials to be submitted for prior learning assessment and possible accreditation at participating institutions. However, should learners be able to choose the parts of their history that they share with others? Can they omit Blocks that they do not feel are appropriate or that could damage their reputation? Can they create different narratives for diverse purposes or highlight and/or hide different experiences? The immutability of Blockchain can cause its own problems when mistakes cannot be erased. Watters (2016) asked “What happens if a student wants or needs a fresh start?”

So, Blockchain can provide a platform for awarding qualifications, for licensing and accreditation in managing student records. Blockchain can also be used to host a permanent distributed record of institutional reputation and output. With Blockchain supporting more control for the students, it has the capability of disrupting and further democratising education. Rooksby and Dimitrov (2017) implemented an Etherium blockchain system in a university for student grades and a cryptocurrency. They found significant “tensions” between the centralised and distributed systems, including those of trust mechanisms, openness boundaries, and procedural values.

Grech and Camilleri (2017) contended that certification is only one activity that is open to disruption by Blockchain. They claim that Blockchain is capable of disrupting “any field of activity that is founded on timestamped record-keeping of titles of ownership” naming the following educational fields: qualifications, licensing, accreditation, records management, intellectual property management and payments. Rahardja (2022) notes that Blockchain could be responsible for “upending the educational value chain.” of the university as a central authority. Wu (2022) further argues that a blockchain credit system applied to competency-based educationwcould be scalable. Other educational systems that are open to disruption using Blockchain include big data analysis, intelligent educational platforms, and networked learning communities (Xianmn, Xin, Huanqing & Keyun, 2017). Most vulnerable are institutions maintaining antiquated, opaque, and hierarchical centralised systems, whether they be analogue or digital (Levin, 2016b).

*Existing applications of Blockchain for education*

There are several implementations of Blockchain in education. Holberton School of Computer Science and Software in San Francisco claimed to be the first in the world to deliver certificates using Blockchain (Barbier, 2015). Another micro-credential implementation is *Blockstack*, that has adopted the Proof of Transfer Protocol (PoX), which ensures that students own their own data. This could be a key tool in fully realizing a user-owned Internet in a secure way. MIT has led in the creation of the Digital Credentials Consortium using Blockchain to create a decentralised infrastructure (Duffy, Pongratz & Schmidt, n. d.). Sony Global Education (2017, 2020) is developing an entirely new open and secure educational infrastructure using Blockchain. University College London's, Centre for Blockchain Technologies has been registering and verifying their degrees by Blockchain for several years (UCL, 2018). The European Union Joint Research Centre which studies student mobility and transfer credit issues, claimed that Blockchain will end paper-based certificates, increase learner control, and reduce costs but only if open standards are adopted (Grech & Camilleri, 2017. The small European country of Malta “the Blockchain Island” is the first country to implement a major blockchain initiative, creating a supportive legal environment for Blockchain implementations, and supporting research in finance, healthcare, and education (Grech, Sood & Arino, 2021).

More than 170 companies and institutions are now using BCDiploma, a blockchain application that enables one-click access to blockchain housed micro-credentials (BCDiploma, n. d.). Hyland Credentials, formerly Learning Machine, is a Blockchain technology company that offers a complete system of secured digital credentialing solutions supporting the issuance of official records (Hyland Credentials, n. d.). CIMEA has created *Diplome,* a Blockchain-based international ecosystem for qualifications and certifications, which focuses on individual learners (CIMEA, n. d., Lantero, L., & Marchionni, 2019). However, implementations have been problematic in some ways. Kishore, Chan, Muthupoltotage, Young, & Sundaram, (2021) implemented MITs *Blockcerts* open source application in the University of Hawai’i business school. They reported that although there was a significant reduction in costs and administrative workload, and high user satisfaction from all stakeholders, the participants expressed concerns around the perceived long-term value and security, because of insufficient technical knowledgeI.

Micro-credentials (badges) on the blockchain can be used in extremely high-stakes situations. The blockchain could be used to prove an indisputable connection between the content provided and the micro-credential. This allows for “rock-solid” credentialing on a level usually reserved for international banking (Belshaw 2016). Other uses of blockchain in education have also been suggested. Sharples (2016) proposed a Blockchain to support the academic reputation of faculty. Levin (2016a) sees a role for Blockchain in tracking institutional assets (textbooks, equipment, furniture etc.) and claiming that “Done right, it could even help slay the ‘waste, fraud, and abuse’ dragon.” Moreover, besides credentials, Xianmin, Xin, Huanqing and Keyun (2017) take the experience of Blockchain in finances to suggest several other modes of Blockchain application in education. These include systemic decentralisation, big data, intelligent platforms, self-organization, and learning community development. Others are creating educational virtual worlds and decentralised lands using Blockchain-based platforms like [*Open Sea*](https://opensea.io/) and [*Super Rare*](https://superrare.co/)*.* [*Cryptovoxels*](https://www.cryptovoxels.com/) is a full virtual world based on Ethereum Blockchain (Vass, 2020).

*Challenges of micro-credentials using Blockchain*

In considering Blockchain, as a large system for micro-credentials, users should be aware that it could be vulnerable to unexpected failures. The persistence of Blockchain, can also become a hindrance, for example if unwanted, fake, or illegal content is accidentally or maliciously added to a Blockchain, it cannot be removed. God forbid if a student loses the crypto key to their wallet. Then access becomes impossible. There is also a lack of technical talent with Blockchain skills. Implementing Blockchain, in educational environments has its own challenges, including the difficulty of changing established systems; legal questions on the ownership of the data; limitations in storage space; and the need for privacy protection (Xianmin, Xin, Huanqing & Keyun, 2017). The slow speed, and particularly the high energy cost of Blockchain, creation and maintenance are also concerns. Nevertheless, Sedlmeir, Buhl, Fridgen, and Keller (2020) argued that this is not a given and can be alleviated with compromises between performance, security, and energy consumption. Although there is evidence that institutional Blockchains do consume more energy than a centralised system, they claim that private Blockchains consume “many orders of magnitude less than that of cryptocurrencies.” arguing that the additional energy cost of switching to Blockchain from a centralized application is not excessive. When compared to cryptocurrency, Blockchains’ energy consumption in institutions is negligible.

There is also a shortage of useful Blockchain, applications that can be adopted or adapted for specific uses, while there are real risks of regulatory interventions by governments or of hacking by unauthorised individuals and organizations. The comparatively slow speed of Blockchain transactions can also be a major concern. The anonymity of Blockchain leaves it open to fraud; if data can be hacked, it can become virtually impossible to rectify the information on the Blockchain. Perhaps the greatest fear of Blockchain users (especially with crypto currencies) is the loss of the secret key, without which access to one’s data becomes impossible. Artificial Intelligence, working with Blockchain can be effective in ameliorating these security concerns.

**Artificial Intelligence**

Both Artificial Intelligence (AI) and Blockchain have been recognized to be “triggers” or disruptive technologies in education (Păvăloaia, & Necula, 2023; Sousa, Mas, Gonçalves, & Calandra, 2022).). AI can serve as an important extension for Blockchain empowered micro-credentials. (UNESCO, 2019). Moreover, according to Roscoe, Salehi, Nixon, Worsley, Piech, & Luckin, (2022), AI could be an effective tool in making education management and provision more open, equitable, and inclusive.

While the implementation of AI with Blockchain is just beginning, it is becoming evident that institutions could benefit by using AI to automate transactions and increase the efficiency of Blockchains. AI can be used to eliminate paper-based processing systems and effectively digitise supply chains. AI has provided optimal solutions, maximising the utility of large-scale distributed systems such as Blockchain (Marwala & Xing, 2018). For example, AI (using Blockchain for trust and security), can speedily track students’ progress and their status in the institution, while improving, record keeping, learner support and protecting privacy. In research projects, Blockchain plus AI can support both advanced data integrity, transparency, participant tracking, and ethical consent management (IBM, n. d), all of which are essential in validating and securing micro-credentials. Islam & Rahim (Under Review) support using AI and Blockchain to upgrade education management information systems, enhancing data collection and processing, including those that support personalized learning, secure credentialing, and sustainable teaching.

AI algorithms can be used to automate and simplify administrative processes such as verification and accreditation. They can also be used to confirm both the accuracy and authenticity of the data as well as discover any possible tampering. AI in the assessment process can confirm the identity of the students participating in the evaluation. It can then ensure that the participating students have achieved the learning outcomes attested to by the micro-credential. AI can also leverage students’ skills by combing the micro-credentials to discover skill gaps, and then proposing future field-relevant learning pathways (Lo, 2023). Micro-courses can also be analyzed to discover the learning difficulties of individual students and groups and recommend alternatives. The portability of micro-credentials empowered by Blockchain can be enhanced by AI enabling the secure dissemination of student accomplishments.

*Challenges with AI*

On the other hand, to date, AI has serious limitations in supporting micro-credential implementations. Although micro-credentials can be secured on decentralised, scalable networks using encryption in the Blockchain, sufficient computational resources must be made available. This is not always possible for smaller institutions with less resources. Moreover, AI cannot always be trusted to understand either personal learner differences or the broader context. Ethical considerations need to be addressed to ensure privacy, and limit surveillance. Sadiku, Musa and Chukwu (2022) refer to the present limited capability of AI and the lack of AI literacy among both students and instructors. The need for a robust technical infrastructure to support AI limits institutions and learners that do not have access to such advanced platforms.

Kilroy, Riley and Bhatta (2023) remind us of the bias problem in AI, noting that whatever is input will skew the output. They fear that biased AI could become more skilled at specific tasks than humans, and thus escape from human control, growing beyond humans’ ability to understand or in any way influence it. They argue that therefore AI needs to be tethered with an immutable “kill switch” on the Blockchain, that is both trackable and traceable and capable of reversing the AI. The AI must be controllable by the Blockchain to function. On the other hand, according to Zheng, Dai & Wu (2020) the future will be inclusive of decentralized blockchain systems. Using the term “blockchain intelligence” they posit that AI provides Blockchain with several benefits including intelligent real-time automated maintenance, quality assurance and malicious behaviour detection.

*A Framework for integrating Micro-credentials with Blockchain and AI*

So, an institution offers a micro-course that is accessed by a student. Using AI, the institution assesses the learning and skills of the learner, verifying the learning achievement and awarding accreditation, using AI to generate a micro-credential on a distributed blockchain with decentralized identity management. The student has a key to this blockchain, which he or she controls. The micro-credential on the blockchain remains verifiable, secure, and immutable. The student can, choose which micro-credentials to send to an employer or institution. According to Zheng, Dai & Wu (2020) the future will be inclusive of decentralized blockchain systems. Using the term “blockchain intelligence” they posit that AI provides Blockchain additional benefits, including intelligent real-time automated maintenance, quality assurance and malicious behaviour detection. On the other hand. Kilroy, Riley, and Bhatta (2023) remind us of the bias problem in AI, noting that whatever is input will skew the output. They fear that biased AI could become more skilled at specific tasks than humans, and thus escape from human control, growing beyond humans’ ability to understand or in any way influence it. They argue that therefore AI needs to be tethered with an immutable “kill switch” on the Blockchain, that is both trackable and traceable and capable of reversing the AI. See Figure 1.



Figure 1. Micri-credential system using Blockchain and AI

Table 1 below, shows a comparison of the three technologies: micro-credentials, Blockchain and AI, suggesting how they could work together in an educational context. Intelligent machines can support micro-credentials earned from participation in decentralised and short-term courses. Skills learnt using visual assistants can be validated securely and transparently on the Blockchain. The skills gap identified by employers can be better addressed through innovations such as micro-credentials when trust and efficiency are improved and optimised using Blockchain and AI.

| **Parameters** | **Micro-credentials** | **Blockchain** | **Artificial Intelligence** |
| --- | --- | --- | --- |
| **Definition** | Short-term, specialized learning credentials that validate specific skills or knowledge. | A decentralized, distributed ledger technology that securely records and verifies transactions across multiple parties. | The simulation of human intelligence by machines, enabling them to perform tasks that typically require human intelligence. |
| **Application** | Skill development and validation, professional certifications, upskilling, and reskilling. | Secure and transparent data management, identity verification, and data integrity. | Data analysis, natural language processing, machine learning, computer vision, robotics, virtual assistants, and automation. |
| **Verification** | Typically issued by educational institutions, professional organizations, or online platforms. | Consensus mechanisms, , and decentralized network consensus. | Neural networks, algorithms, and statistical models trained on large datasets. |
| **Decentralization** | Not decentralized; administered by educational institutions or online platforms. | Decentralized network architecture with distributed nodes. | Can be centralized or decentralized depending on the implementation. |
| **Security** | Low risk and less prone to hacking. Dependent on the verification of the issuing organization. | Cryptographic encryption, immutability, and consensus mechanisms ensure data integrity and security. | Vulnerable to attacks but can be enhanced through encryption and secure protocols. |
| **Scalability** | Easily scalableto large numbers of learners, due to digitization and online delivery. | Scalability challenges due to consensus mechanisms and the need for network participants. | Scalability depends on computational resources, data availability, and processing power. |
| **Impact** | Addresses the skills gap, facilitates continuous learning, and enhances employability and career enhancement | Enhances transparency, trust, and efficiency in education. | Enables automation, optimization, and innovation. |
| **Ethical Considerations** | Ensuring quality and standardization, avoiding bias, and protecting personal data. | Privacy concerns, data ownership, governance, and environmental impact. | Bias in algorithms, privacy concerns, job displacement, and ethical use of AI in areas such as surveillance and decision-making. |

Table 1: Comparison of Micro-credentials, Blockchain and AI from ChatGPT (Open AI, 2023)).

**Summary**

Educational institutions and companies can use Blockchain to create a traceable and usable record of their students’ accomplishments by hosting micro-credentials. AI can help administer, personalise and disseminate the micro-credentials. Blockchain and AI together can ensure the sustainability and accessibility of the micro-credentials. All the records are secured and permanent (Jones, 2018). This can become very important when an institution changes its name or even disappears.

Micro-credentials are becoming more popular as employers seek out attestations for candidates with specific skills that can be taught in small modular blocks (Athabasca University, 2023). Blockchain and AI are particularly appropriate for empowering these micro-credentials. Blockchain can provide for the effective security and privacy of the data, while AI can facilitate the maintenance and dissemination of the credentials, while both ensure that access is readily available for students under their control. Pereira (2016) considered Blockchain to be the perfect infrastructure for an ideal education system. He argued that Blockchain needed education more than education needed Blockchain recognizing that it can provide real value to “those at the top and at the bottom of the power structure.” AI is already beginning to transform approaches to education and has the potential to be an indispensable tool in assessing and accrediting skills and knowledge achieved by learners in different subject areas (Strunga, Urban, Surovková, & Thurzo, 2023; Talan & Kalinkara, 2023)

**Recommendations for future research**

Research into the technical and administrative integration of these three technologies should take priority. The focus can be on developing standards for technical interoperability as well as for acceptability among higher education institutions and employers. The emphasis should be on supporting student mobility, ensuring that micro-credentials can be secured and transferred to and from students, institutions, and employers. Another research focus area should be that of using adaptive learning processes to develop individual and group formal and informal learning pathways based on micro-credentials for students. Privacy and security issues need also to be examined, as well as the potential for bias in AI assessment algorithms. Surely, more powerful, and efficient learning systems should follow from further research into the empowerment of micro-credentials using Blockchain and AI.

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. See:

McGreal, R. (2023). Blockchain and Micro-credentials in Education. *International Journal of E-Learning & Distance Education Revue Internationale Du E-Learning Et La Formation à Distance*, *38*(1). <https://doi.org/10.55667/10.55667/ijede.2023.v38.i1.1250>

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