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Blockchain and Holochain in Medical Education from Planetary Health and Climate Change Perspectives

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Abstract: As we are transitioning from the age of information to the age of artificial intelligence, this study aims to explore the potential of blockchain and Holochain technologies as solutions to the data privacy, security, and integrity concerns in medical education, and to provide standpoints of a medical education researcher for their use that also minimize negative impacts regarding planetary health and climate change. While these technologies offer promising solutions, their environmental impact has not been discussed in the literature with regard to medical education. This study offers two key standpoints for medical education researchers, educators, and policy makers to ensure the responsible use of Web3 technologies in this field. Standpoint 1: If the use of blockchain technology is necessary, avoid using proof-of-work blockchains. Standpoint 2: Use Holochain instead of blockchain.

Keywords: Blockchain; Holochain; planetary health; climate change; medical education

Introduction

Medical education is at the brink of an immense gradual change as we are transitioning from the age of information to the age of artificial intelligence (1). Data privacy and security are major concerns in this era. These concerns are not limited to the realm of artificial intelligence; they also extend to various areas within medical education, such as digital learning environments (2), learning analytics (3), ethics and scholarship (4), and even student wellbeing (5).

Blockchain (6) and Holochain (7) have been proposed as promising Web3 technologies (8) in order to overcome these data privacy, security, and integrity issues.

Blockchain is a distributed ledger technology for storing and transacting data in a way that is almost impossible to falsify. It can be used as a public electronic ledger that is shared openly among disparate users (nodes) and that creates an immutable record of the transactions. Each batch of digital records in the chain is called a block. Blockchain can be updated by consensus among the participants in the system, and when new data is entered, it cannot be changed. There is only one "true" chain that includes verifiable record of each and every entry made into the system.

Holochain is an open-source framework for building fully distributed, peer-to-peer applications. Holochain allows to develop truly serverless applications with appropriate levels of security, reliability, and performance. It is also scalable and more efficient than blockchain (9) without requiring token or mining. The purpose of Holochain is to enable humans to interact with each other by mutual-consent to a shared set of rules, without relying on any authority to dictate or unilaterally change those rules (10). Peer-to-peer interaction means you own and control your data, with no intermediary (e.g., Google, Facebook, Uber) collecting, selling, or losing it.

On the other hand, there is a growing discussion of planetary health and climate change issues in health professions education (11–14). However, the effect of utilizing these technologies on planetary health and climate change in the context of medical education was not discussed.

The objective of this study is to offer two key standpoints to medical education researchers, educators, and policy makers for utilizing these Web3 technologies in a way that minimizes the negative environmental impacts.

Standpoint 1: If the use of blockchain technology is necessary, avoid using proof-of-work blockchains.

Blockchain is a technology that uses a distributed ledger to store all transactions in a secure and decentralized manner (6). Each transaction is validated by a network of computers (for example, in Bitcoin network, miners who dedicated the processing capacity of their computers) before being added to the chain in chronological order, which is stored across multiple nodes (computers). In simpler terms, blockchain removes centralized actors such as banks and notaries from the equation of data exchange and validation, and uses a consensus mechanism operated by some more distributed actors (computers all around the world) for this validation process. This mechanism ensures that all nodes have a consistent copy of the blockchain and prevents fraudulent or unauthorized transactions.

Blockchains need to use a consensus algorithm to operate. The consensus algorithm is the underlying mechanism that allows the network of nodes (computers) in a blockchain to agree on the validity of transactions and the current state of the ledger (15). Since "one account one vote system" could easily be cheated by creating multiple fake accounts, which is known as sybil attack (16), the consensus system in proof-of-work blockchains requires miners to show a proof that they solved a difficult and computationally intensive cryptographic puzzle in order to add a new block (a batch of transactions waiting to be validated) to the chain. Performing this complex calculation requires high amount of energy, thus the cost of cheating is financially high (15).

Transforming electricity to heat in order for data validation is waste, no matter if it is produced from renewable sources (17). Estimates suggest that the energy consumption needed to sustain Bitcoin blockchain could lead to a rise in global temperatures of up to 2°C within the next three decades (18). Even though this has

been criticized as being an overestimation (19–21) and centralized alternatives such as banks, notaries, and centralized servers also consume energy, it is clear that more efficient approaches are needed for protecting planetary health.

However, it is not necessary for all blockchains to utilize proof-of-work, as there are several consensus mechanisms (15). Proof-of-stake, for example, is a different consensus algorithm to validate transactions and add new blocks to the chain. In a proof-of-stake blockchain, instead of miners competing to solve complex mathematical puzzles, nodes validate transactions and add new blocks based on the amount of cryptocurrency they hold or "stake" on the network (22). This has been designed to incentivize nodes (computers) to act in the best interests of the network, as they accept to lose their staked cryptocurrency if they act maliciously. Compared to proof-of-work, proof-of-stake is more energy-efficient, as it does not require high amounts of electricity consumption to validate transactions. Due to this reason, Ethereum, which is a popular blockchain network that allows programming smart contracts, switched from proof-of-work to proof-of-stake in order for decreasing energy consumption by over 99% (22).

Energy requirements aside, blockchain technology has been proposed to help ensuring the security and privacy of data by creating an immutable and transparent ledger. It has been suggested to increase trust between different parties involved in education data sharing, such as universities, institutions, and students (23). In medical education context, it was suggested that blockchain has an enormous potential to enable more efficient and secure tracking educational activities, providing an accountable mechanism for dealing with observations in entrustable professional activities, and removing third-party intermediaries for certification and credentialing (24). However, in actual practice, the application of blockchain is largely limited to verifying identity, certifying degrees, and facilitating some cases of cryptocurrency-based financial transactions such as paying school fees and donations (25). As an example application, a group of researchers proposed a blockchain-based solution to enhance the existing continuous medical education credits system by automating the credits accreditation and medical license renewal process (26). However, this kind of solution was unable to achieve a wider acceptance. The obstacles are legal issues (e.g. non-compliance with General Data Protection Rule of European Union), immutability issues (records are immutable on blockchain network), and scalability issues (slow and expensive) (27). Despite efforts to solve the scalability problem using solutions such as rollups (28), the data-centric approach of blockchain continues to pose challenges that hinder its widespread adoption. While decentralization is a crucial aspect, blockchain's data centric paradigm may not be the most effective solution to achieve it, as Walsh stated "there are reasons to be sceptical about blockchain and its application to healthcare professional education" (29).

Overall, this study recommends that blockchain technology not be employed for the decentralization of medical education data. However, if this technology must be utilized, caution should be taken to avoid proof-of-work blockchains,

which have been shown to have a negative impact on planetary health due to its energy-intensive nature.

Standpoint 2: Use Holochain instead of blockchain.

Holochain is an open-source framework for developing fully distributed applications (7). It provides a set of tools and protocols that enable developers to create peer-to-peer applications that can operate on any device with or without a connection. Holochain applications (hApps) do not rely on a central server or any intermediaries while miners or stakers are a kind of intermediary in blockchains. Each agent in a Holochain network has its own computing power and can interact with other agents without relying on any centralized authority (30). Moreover, contrary to blockchain, there is no scalability trilemma, which dictates that one of security, scalability, or decentralization must always be sacrificed (31), in Holochain technology because of having an agent-centric paradigm (32) instead of blockchain's data-centric approach. Developers can leverage this advantage to create truly peer-to-peer and scalable applications that can match the performance of centralized applications. There is a comprehensive source for developers to understand how a hApp can be built (33).

It has been demonstrated that Holochain can be utilized to build and implement a radically distributed system for health data (33). According to a performance evaluation, an Internet of Things healthcare solution based on Holochain technology is more resource-efficient and offers an adequate level of security and privacy, when compared to a solution based on blockchain (9). As these studies showed, Fritsch et al. (32) suggests that Holochain has the potential to enable distributed, participant-led governance models that can be more responsive to local needs and values. This can lead to more sustainable and equitable decision-making in medical education, as well as more efficient use of resources. Therefore, for the first time in medical education, data exchange and validation challenges such as monitoring educational activities, establishing accountability in entrustable professional activities, and eliminating third-party intermediaries from certification and credentialing processes can now be addressed without compromising scalability (7).

Holo, on the other hand, is a hosting platform for hApps (34). Holo provides a bridge between hApps and the traditional internet, allowing users to access and interact with hApps using a regular web browser. Holo provides a hosting infrastructure for hApps, allowing developers to deploy and scale their hApps without having to manage their own hosting infrastructure. Individuals contribute their unused storage and processing capacity, either on their personal devices or on dedicated devices called Holoports, to create this infrastructure. By doing so, the individuals are getting paid in HoloFuel, which is a digital currency backed by hosting power of Holo network, in return for their service (34). The operational principles of Holo are similar to Airbnb or Uber, which despite having no single room/car, can be considered as the largest hotel/taxi chain globally.

From the perspective of climate change, Holochain's and Holo's infrastructure model has the potential to be more environmentally sustainable compared to not

only proof-of-work blockchains but also traditional hosting models that are used to deal with medical education data. By utilizing unused storage and processing capacity on personal devices or dedicated Holoport devices, Holo reduces the need for energy-intensive data centers. This could make Holo a more eco-friendly alternative for hosting medical education data.

Although Holochain and Holo offer significant benefits in terms of planetary health, they have not been extensively tested in real-life scenarios unlike traditional hosting and blockchain systems (7). As a result, it is necessary to implement a gradual transition to avoid any potential adverse effects. However, they still seem as a viable alternative considering security and privacy issues of centralized solutions and scalability issues of blockchain technology. Based on the mentioned possible benefits, this study recommends the use of Holochain technology, rather than blockchain, to deal with important issues regarding data in medical education.

5. Conclusions

- The energy consumption required for proof-of-work blockchains has been shown to have negative impacts on planetary health, and this issue should be carefully considered before adopting blockchain technology. Thus, alternative consensus mechanisms such as proof-of-stake can be considered for their energy efficiency. Furthermore, the data-centric paradigm of blockchain may not be the most effective solution for achieving decentralization in medical education, as it poses legal, immutability, and scalability challenges.
- Holochain and Holo offer a promising alternative to traditional solutions and blockchain systems in the issues regarding medical education data. Holochain's agent-centric paradigm and Holo's hosting infrastructure may allow for a sustainable approach in terms of planetary health. Despite limited real-life testing, they offer security and scalability advantages over centralized solutions and blockchain.

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References

1. Wartman SA, Combs CD. Medical Education Must Move From the Information Age to the Age of Artificial Intelligence: *Academic Medicine*. 2018;93(8): 1107–1109. https://doi.org/10.1097/ACM.0000000000002044.
2. Thoma B, Turnquist A, Zaver F, Hall AK, Chan TM. Communication, learning and assessment: Exploring the dimensions of the digital learning environment. *Medical Teacher*. 2019;41(4): 385–390. https://doi.org/10.1080/0142159X.2019.1567911.
3. ten Cate O, Dahdal S, Lambert T, Neubauer F, Pless A, Pohlmann PF, et al. Ten caveats of learning analytics in health professions education: A consumer's perspective. *Medical Teacher*. 2020;42(6): 673–678. https://doi.org/10.1080/0142159X.2020.1733505.
4. Masters K. Ethics in medical education digital scholarship: AMEE Guide No. 134. *Medical Teacher*. 2020;42(3): 252–265. https://doi.org/10.1080/0142159X.2019.1695043.
5. Gengoux GW, Roberts LW. Ethical Use of Student Profiles to Predict and Prevent Development of Depression Symptoms During Medical School: *Academic Medicine*. 2019;94(2): 162–165. https://doi.org/10.1097/ACM.0000000000002436.

6. Meunier S. Blockchain 101. In: *Transforming Climate Finance and Green Investment with Blockchains*. Elsevier; 2018. p. 23–34. [Accessed 1st March 2023]. https://doi.org/10.1016/B978-0-12-814447-3.00003-3.
7. Kıyak YS, Poor A, Budakoğlu İİ, Coşkun Ö. Holochain: a novel technology without scalability bottlenecks of blockchain for secure data exchange in health professions education. *Discover Education*. 2022;1(1): 13. https://doi.org/10.1007/s44217-022-00013-y.
8. Nabben K. Web3 as 'self-infrastructuring': The challenge is how. *Big Data & Society*. 2023;10(1): 205395172311590. https://doi.org/10.1177/20539517231159002.
9. Zaman S, Khandaker MRA, Khan RT, Tariq F, Wong KK. Thinking Out of the Blocks: Holochain for Distributed Security in IoT Healthcare. *IEEE Access*. 2022;10: 37064–37081. https://doi.org/10.1109/ACCESS.2022.3163580.
10. Brock A, Zemel J. *Unenclosable Carriers and the Future of Communication*. Holochain. 2020. [Accessed 7th April 2022]. https://medium.com/holochain/unenclosable-carriers-and-the-future-of-communication-4ac6045ac894
11. Goshua A, Gomez J, Erny B, Burke M, Luby S, Sokolow S, et al. Addressing Climate Change and Its Effects on Human Health: A Call to Action for Medical Schools. *Academic Medicine*. 2021;96(3): 324–328. https://doi.org/10.1097/ACM.0000000000003861.
12. Schwerdtle PN, Maxwell J, Horton G, Bonnamy J. '12 tips for teaching environmental sustainability to health professionals'. *Medical Teacher*. 2020;42(2): 150–155. https://doi.org/10.1080/0142159X.2018.1551994.
13. Shaw E, Walpole S, McLean M, Alvarez-Nieto C, Barna S, Bazin K, et al. AMEE Consensus Statement: Planetary health and education for sustainable healthcare. *Medical Teacher*. 2021;43(3): 272–286. https://doi.org/10.1080/0142159X.2020.1860207.
14. Wellbery C, Sheffield P, Timmireddy K, Sarfaty M, Teherani A, Fallar R. It's Time for Medical Schools to Introduce Climate Change Into Their Curricula: *Academic Medicine*. 2018;93(12): 1774–1777. https://doi.org/10.1097/ACM.0000000000002368.
15. Xie M, Liu J, Chen S, Lin M. A survey on blockchain consensus mechanism: research overview, current advances and future directions. *International Journal of Intelligent Computing and Cybernetics*. 2022; https://doi.org/10.1108/IJICC-05-2022-0126.
16. Douceur JR. The Sybil Attack. In: Druschel P, Kaashoek F, Rowstron A (eds.) *Peer-to-Peer Systems*. Berlin, Heidelberg: Springer Berlin Heidelberg; 2002. p. 251–260. [Accessed 12th March 2023]. https://doi.org/10.1007/3-540-45748-8_24.
17. Schinckus C. Proof-of-work based blockchain technology and Anthropocene: An undermined situation? *Renewable and Sustainable Energy Reviews*. 2021;152: 111682. https://doi.org/10.1016/j.rser.2021.111682.
18. Mora C, Rollins RL, Taladay K, Kantar MB, Chock MK, Shimada M, et al. Bitcoin emissions alone could push global warming above 2°C. *Nature Climate Change*. 2018;8(11): 931–933. https://doi.org/10.1038/s41558-018-0321-8.
19. Dittmar L, Praktiknjo A. Could Bitcoin emissions push global warming above 2 °C? *Nature Climate Change*. 2019;9(9): 656–657. https://doi.org/10.1038/s41558-019-0534-5.
20. Houy N. Rational mining limits Bitcoin emissions. *Nature Climate Change*. 2019;9(9): 655–655. https://doi.org/10.1038/s41558-019-0533-6.
21. Masanet E, Shehabi A, Lei N, Vranken H, Koomey J, Malmodin J. Implausible projections overestimate near-term Bitcoin CO2 emissions. *Nature Climate Change*. 2019;9(9): 653–654. https://doi.org/10.1038/s41558-019-0535-4.
22. De Vries A. Cryptocurrencies on the road to sustainability: Ethereum paving the way for Bitcoin. *Patterns*. 2023;4(1): 100633. https://doi.org/10.1016/j.patter.2022.100633.
23. Alammary A, Alhazmi S, Almasri M, Gillani S. Blockchain-Based Applications in Education: A Systematic Review. *Applied Sciences*. 2019;9(12): 2400. https://doi.org/10.3390/app9122400.
24. Funk E, Riddell J, Ankel F, Cabrera D. Blockchain Technology: A Data Framework to Improve Validity, Trust, and Accountability of Information Exchange in Health Professions Education. *Academic Medicine*. 2018;93(12): 1791–1794. https://doi.org/10.1097/ACM.0000000000002326.
25. Park J. Promises and challenges of Blockchain in education. *Smart Learning Environments*. 2021;8(1): 33. https://doi.org/10.1186/s40561-021-00179-2.

26. Rathod J, Gupta A, Patel D. Using Blockchain Technology for Continuing Medical Education Credits System. In: *2020 Seventh International Conference on Software Defined Systems (SDS)*. Paris, France: IEEE; 2020. p. 214–219. [Accessed 16th July 2022]. https://doi.org/10.1109/SDS49854.2020.9143876.
27. Loukil F, Abed M, Boukadi K. Blockchain adoption in education: a systematic literature review. *Education and Information Technologies*. 2021;26(5): 5779–5797. https://doi.org/10.1007/s10639-021-10481-8.
28. Thibault LT, Sarry T, Hafid AS. Blockchain Scaling Using Rollups: A Comprehensive Survey. *IEEE Access*. 2022;10: 93039–93054. https://doi.org/10.1109/ACCESS.2022.3200051.
29. Walsh K. *Could blockchain be applied to healthcare professional education?*. The BMJ. 2019. [Accessed 10th March 2023]. https://blogs.bmj.com/bmj/2019/04/25/kieran-walsh-could-blockchain-be-applied-to-healthcare-professional-education/
30. Yang G. An Overview of Current Solutions for Privacy in the Internet of Things. *Frontiers in Artificial Intelligence*. 2022;5: 812732. https://doi.org/10.3389/frai.2022.812732.
31. Zhoua Q, Huang H, Zheng Z, Bian J. Solutions to Scalability of Blockchain: A Survey. *IEEE Access*. 2020;8: 16440–16455. https://doi.org/10.1109/ACCESS.2020.2967218.
32. Fritsch F, Emmett J, Friedman E, Kranjc R, Manski S, Zargham M, et al. Challenges and Approaches to Scaling the Global Commons. *Frontiers in Blockchain*. 2021;4: 578721. https://doi.org/10.3389/fbloc.2021.578721.
33. Holochain. *Get Started - Holochain Docs*. [Accessed 3rd April 2023]. https://developer.holochain.org/
34. Poor AJ. *Data Sovereignty in Action: Designing Building and Implementing a Radically Distributed Health Information System in Aotearoa New Zealand*. Auckland University of Technology; 2022.
35. *Holo*. Holo. [Accessed 12th March 2023]. https://holo.host/