SoftwareX 19 (2022) 101167

Contents lists available at ScienceDirect

SoftwareX

journal homepage: www.elsevier.com/locate/softx

Original software publication

BlockTrainHK: An online learning game for experiencing blockchain concepts

Yung Po Tsang [a,*], Chun Ho Wu [b], Carman Ka Man Lee [a]

[a] Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong
[b] Department of Supply Chain and Information Management, The Hang Seng University of Hong Kong, Hong Kong

ARTICLE INFO

Article history:
Received 8 April 2022
Received in revised form 16 June 2022
Accepted 20 July 2022

Keywords:
Blockchain
Game
Teaching
Learning

ABSTRACT

Although blockchain is regarded as a promising and revolutionary technology, not everyone, particular non-technical students, can effectively understand and appraise its mechanism. To spread knowledge of blockchain technology, an online educational game for learning blockchain concepts named 'BlockTrainHK' is designed and developed from the React Native framework. Users from multi-disciplinary backgrounds can experience the block mining process, where the whole journey of building the blockchain and other advanced concepts, including immutability, Merkle tree, and zero knowledge proof, can be revealed, such that technical barriers of learning blockchain can be overcome.

Code metadata

Current code version	V1.0.0
Permanent link to code/repository used for this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-22-00080
Permanent link to reproducible capsule	N/A
Legal code license	MIT
Code versioning system used	git
Software code languages, tools and services used	JavaScript, CSS, HTML, React
Compilation requirements, operating environments and dependencies	Creation of the game image through the Dockerfile
If available, link to developer documentation/manual	N/A
Support email for questions	yungpo.tsang@polyu.edu.hk

Software metadata

Current software version	V1.0.0
Permanent link to executables of this version	https://game.blocktrainhk.com/
Legal Software License	MIT
Computing platforms/Operating Systems	Web-based
Installation requirements & dependencies	Browsers (Google Chrome, Mozilla Firefox, Microsoft Edge etc.)
If available, link to user manual - if formally published include a reference to the publication in the reference list	N/A
Support email for questions	yungpo.tsang@polyu.edu.hk

1. Motivation and significance

Starting from 2008, blockchain is deemed as a means to strengthen the anonymity, immutability, and distributed control in a wide range of computer applications, such as financial services and supply chain traceability [1]. Beyond data decentralisation in a peer-to-peer network, the presence of blockchain has created several innovative business models, such as cryptocurrencies and non-fungible tokens (NFT), for the exchange of electronic cash, artwork, music and so on [2,3]. It brings not only technical value to revamp existing vulnerable computer systems, but also market value to the public. Although the blockchain has been gradually popularised in the market and academia, only

* Corresponding author.
E-mail address: yungpo.tsang@polyu.edu.hk (Y.P. Tsang).

https://doi.org/10.1016/j.softx.2022.101167
2352-7110/

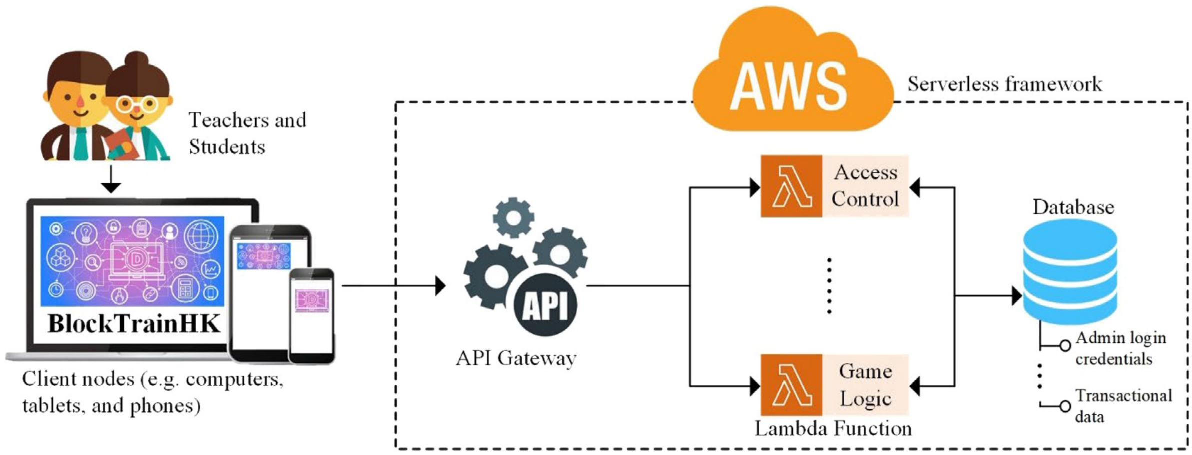

Fig. 1. System architecture of the BlockTrainHK.

a limited group of users who are completely familiar with the computer science concepts can comprehensively understand its functions and mechanisms. Other users from multi-disciplinary backgrounds, basically laymen, may blindly believe the advantages of the blockchain without comprehensively understanding the technology itself. Therefore, there is a need for a learning tool to teach blockchain concepts to laymen such that they can know why the blockchain is secure and trustworthy in the peer-to-peer network, which is an essential step for popularising the blockchain technology in multi-disciplinary education.

In April 2019, a game for teaching blockchain concepts was built to demonstrate the entire block mining process so as to learn the distributed ledger technology (DLT) with transparent, append-only, and immutable characteristics [4]. In the game, the blockchain mechanism is illustrated using a case of building the data chain for students' grades in different courses. More importantly, the concept of the one-way hash function is replaced by the complete division rule so that the ease of completing block mining process has been greatly improved. The characteristic of the hash algorithm, namely difficult to produce but easy to verify, can be effectively maintained. Since the above game is paper-based and involves role-playing, it is challenging to completely motivate students to participate in the game, and not environmentally-friendly to prepare certain amount of paper-based game materials. Furthermore, amid the COVID-19 pandemic, current teaching activities are conducted in a hybrid/blended learning mode, in which only a few students attend face-to-face classes, so the existing game cannot match the current learning mode.

In view of the above situation, the paper-based and role-played blockchain game is therefore revamped on an online learning platform, while a competition-based learning approach is incorporated to enhance students' engagement for learning blockchain concepts. In this work, an online learning platform, named as 'BlockTrainHK', is designed and developed to address the aforementioned concerns for learning blockchain in the field of engineering education. Students, under the control of teachers, can participate in the game through the web browsers on their devices anywhere. Under the game settings, students are the target for experiencing and learning the journey of building blocks in the blockchain, along with essential concepts from the original blockchain game and additional concepts, including immutability, Merkle tree and zero knowledge proof for data authenticity. In summary, the significance of the proposed learning software can be depicted in two-facets. Firstly, the learning environment for blockchain technology can be further enriched to stimulate the attention and interest of students who find it difficult to understand the complicated computer science theories. Through the learning platform, their understanding on blockchain can be deepened through the solid foundation in appraising the functions and mechanisms. Secondly, the proposed platform can contribute to educational research in adopting game-based learning pedagogy for learning computer science concepts, namely blockchain, where the learning performance, motivation, and satisfaction can be evaluated.

2. Software description

In this section, the software 'BlockTrainHK' is comprehensively illustrated with the aid of its architecture and functionalities. Moreover, essential user interfaces are extracted to explain the game logic behind the platform.

2.1. Software architecture

In order to reveal the blockchain concepts in the learning and teaching platform, the software 'BlockTrainHK' is built as a react application with the serverless framework on the AWS platform, where AWS Lambda functions are embedded to perform event-driven services and programs, as shown in Fig. 1. Teachers and students can start the react application through web browsers in their client devices, for example computers, tablets and phones. Through the API gateway, the AWS Lambda functions can be activated to execute customised codes in response to specific events, which are connected with the database for data storage and retrieval. The software functionalities and game logic presented in the next section are revealed to support the teaching and learning activities.

2.2. Software functionalities

Based on the above software architecture, two games, namely (i) PoW mining process and (ii) PoW mining process with Merkle tree, are designed and developed to reveal the entire journey of the blockchain. The blockchains formulated in both games are related to the case scenario of supply chain traceability for wine transactions. Before illustration of the game logic, several basic functionalities in the learning platform are constructed to smoothen the game operations, including (i) access control management, (ii) spreadsheet model for the blockchain data, and (iii) visualisation of the competition results. For access control management, the role of the teacher role is to generate the passcode through inputting the game settings such that clients, namely students, can be effectively partitioned and under the control

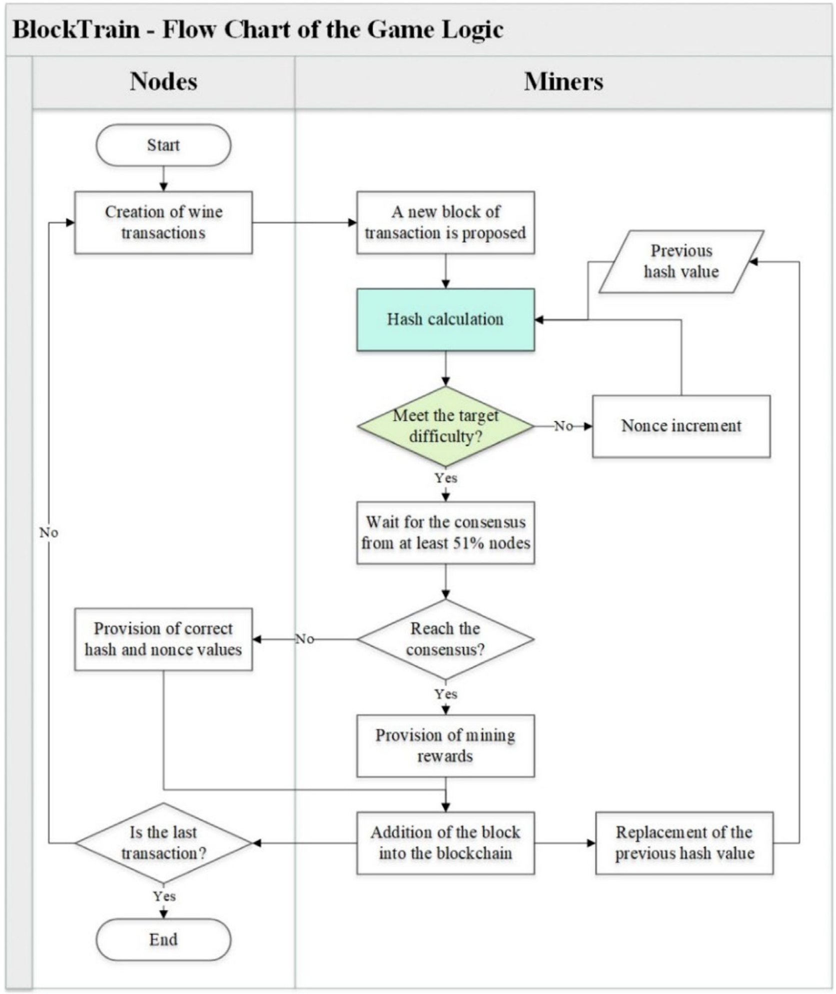

Fig. 2. Game logic process flow of BlockTrainHK.

of teachers. In other words, the learning platform supports independent control of multiple groups of clients simultaneously. Secondly, for smoothing the learning progress during the class, a spreadsheet model of pre-calculated block data is established to set up the game environment, in which correct hash and nonce values for all the rounds of block mining process are known. Thirdly, the mining rewards are graphically visualised in the platform to show the computational capability of the clients, which contributes to the competition-based learning environment.

Beyond the above basic functionalities, two games are developed in the learning platform to experience the block mining process and the data structure of Merkle tree for handling multiple transactions. When the clients enter the game, the set of public and private identities (IDs) are provided to make the transactions transparent but anonymous. In the game environment, teachers and students play the roles of nodes and miners, respectively, and the generic flow chart of the game logic is shown in Fig. 2. The entire game logic is designed according to the proof of work (PoW) algorithm with the given set of transaction data. The major difference between games 1 and 2 is the number of wine transactions to be handled, where students are required to mine multiple transactions in a block under game 2 settings. Due to the above difference, the hash algorithms and target difficulties are customised for teaching and learning purposes.

In Game 1 (block mining), the nodes are responsible for creating wine transactions containing (i) customer ID, (ii) product ID, (iii) product quantity, (iv) product name, and (v) delivery date, while miners are needed to calculate the correct hash and nonce values. As shown in Table 1, the transaction data are converted into a set of variables for the customised hash algorithm, while the conversion between the characters and decimal values follows the American Standard Code for Information Interchange (ASCII) [5]. Therefore, the hash value can be calculated by using the hash algorithm expressed in Eq. (1), where the last three digits of the current hash in the block $t-1$ are extracted for the previous hash (H_{t-1}) in the block t. Through the increment of the nonce, for $Nonce \in [1, 21]$, the target difficulty for block mining is that correct hash values should be completely divisible by 3 and 7 simultaneously. Once the miners have completed the hash calculation and uploaded the results, the formulation of the consensus in the whole network is achieved. If the consensus cannot be properly established, the authorised nodes (i.e. teachers) can forcedly complete the block mining process by using the correct hash and nonce values. Moreover, the current hash value is stored as the previous hash value in the next round of block mining. The above steps of transaction creation, hash calculation, and consensus establishment are repeated until all the wine transactions are mined and chained in the blockchain.

$$H_t = 10\left(\sum_{i=1}^{6} x_i\right) + H_{t-1} + Nonce \tag{1}$$

In Game 2 (block mining with the Merkle tree structure), most of the game logic and operations are similar to Game 1, in which the hash calculation process is different due to the presence of

Table 1
Game variables for the hash calculation.

Data field	Variable	Variable setting in Game 1	Variable setting in Game 2
Data index	x_1	–	Full value
Customer ID	x_2	First letter	Full value
Product ID	x_3	First letter	Full value
Product quantity	x_4	Full value	Full value
Product name	x_5	First letter	Full value
Delivery date	x_6	First two digits	Full value

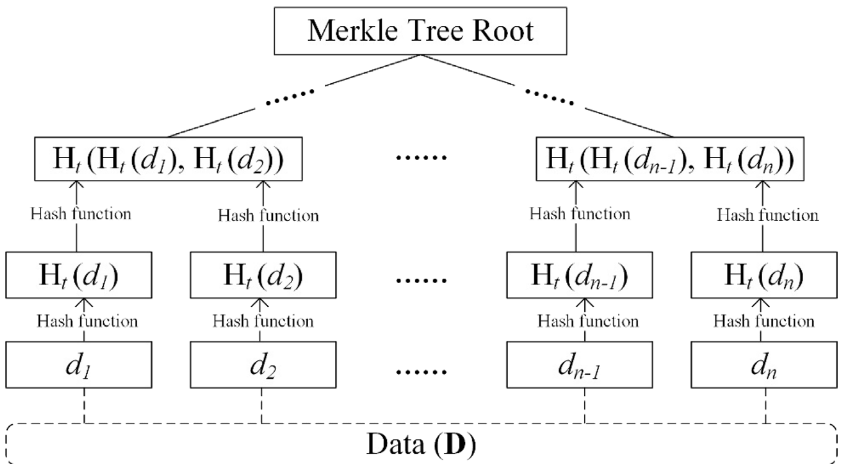

Fig. 3. Merkle tree data structure in the hash calculation.

the Merkle tree data structure. To better mimic the real-life hash algorithm, like SHA-256, the full values of all the data fields are considered such that the digit sum of the data is used to calculate the hash value. Given data $D = \{d_1, d_2, \ldots, d_n\}$, the hash values of the data can be calculated by using Eq. (2), where each datum is represented by a string of numerical digits related to the six aforementioned data fields $\{x_{1k}, x_{2k}, x_{3k}, x_{4k}, x_{5k}, x_{6k}\}$ for datum d_k in Game 1. After calculating the hash values of all the data, the Merkle tree root can be aggregated as shown in Fig. 3 [6], while the same target difficulty as in Game 1 is adopted. To be specific, the times of hash calculation (π_{hc}) for handling n transactional data are expressed in Eq. (3). When the number of transactional data is an odd number, a dummy datum which is a replica of the datum d_n is considered for calculating the Merkle tree root. After calculation of the Merkle tree root, the new block can be validated and added into the blockchain when more than half of the nodes verify the calculation, and the current Merkle tree root is set as the previous hash value in the next block. According to the pre-defined blockchain data, the above steps are repeated so as to mine all the transactional data in the blockchain.

$$H_t\left(d_k\right) = 10\left(\sum_{i=1}^{6}\left[\sum_{j=0}^{\lfloor \log(x_{ik}) \rfloor} \frac{x_{ik} \bmod 10^{i+1} - x_{ik} \bmod 10^{i}}{10^{i}}\right] + R_{t-1}\right) + Nonce \tag{2}$$

$$\pi_{hc} = \begin{cases} (n)\sum_{i=0}^{\log_2(n)}\left(\frac{1}{2^i}\right), & \text{where } n \text{ is an even number} \\ (n+1)\sum_{i=0}^{\log_2(n+1)}\left(\frac{1}{2^i}\right), & \text{where } n \text{ is an odd number} \end{cases} \tag{3}$$

3. Illustrative examples

In this section, the processes of the proposed learning platform for teaching blockchain concepts are illustrated in Figs. 4 and 5 for the role of teachers and students, respectively, where only the essential user interfaces are shown.

To initialise the game, the teachers are required to specify the game settings together with the blockchain data file, and thus the corresponding virtual room with a specific passcode, for example 20470941594. Students can participate in the game by inputting their own student ID and the corresponding passcode. When the number of miners (i.e. students) is larger than 3, the nodes (i.e. teachers) can propose a new block of wine transactions for the block mining and validation process. Regarding the transaction (customer ID: STcus0003; product ID: D9838; product quantity: 215; product name: Gamay; delivery date: 08Oct21), the correct hash and nonce values are 5082 (i.e. [83(S) + 68(D) + 215 + 71(G) + 8] + 623 + 9) and 9, given that the previous hash value is 623, in accordance with Eq. (1). Students can upload their answers for verification until reaching at least 51% consensus in the network such that a new block is added into the blockchain and the rewards are distributed to students who provide the correct answers. The first successful student can obtain the score which is equal to the total number of successful miners, and the second successful student can get the first successful student's score minus 1, and so on. Afterwards, the teachers can propose another block of wine transactions for repeating the above steps until the end of pre-defined blockchain data. At the end of the game, the scores obtained by students can be visualised in bar chart and data table form. In Game 2, as mentioned above, the major difference is the incorporation of the Merkle tree data structure in the hash calculation. Regarding the transaction (data index: 1; customer ID: TP01; product ID: W1021; product quantity: 250; product name: Merlot; delivery date: 15Sep2020), the digit sum of the transactional data is 172 such that the hash and nonce values are 1764 and 14, respectively, given that the previous Merkle tree root is 21.

Apart from the block mining process, both games 1 and 2 also offer additional experience on data integrity through showing the immutable characteristics and applications of the Merkle tree, as shown in Fig. 6. After completion of the games, the entire

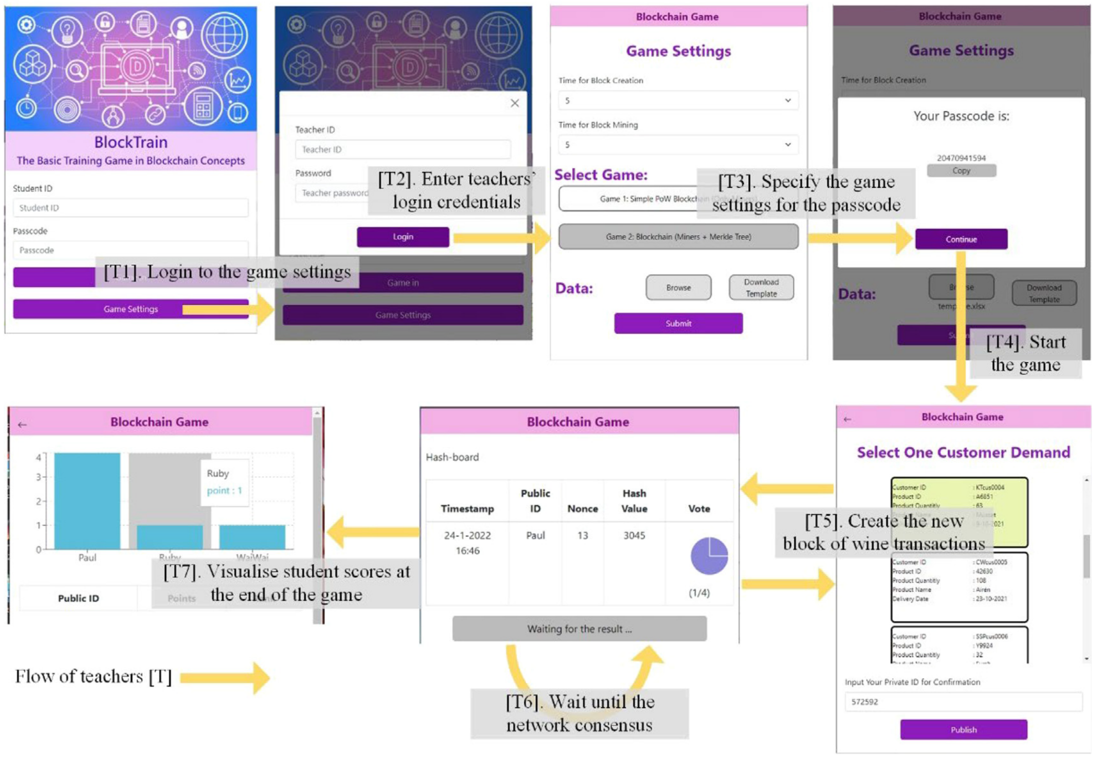

Fig. 4. Graphical illustration of the game process for teachers.

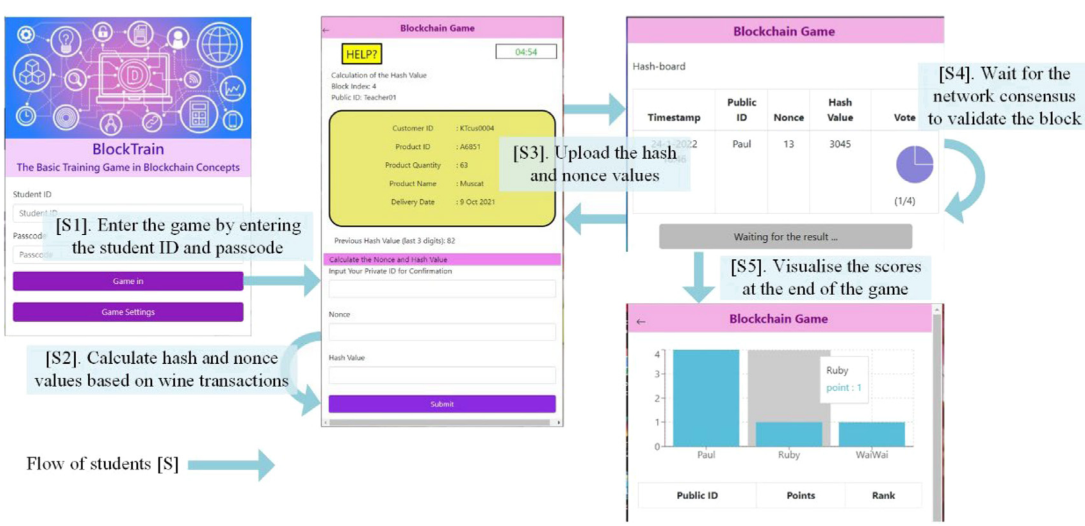

Fig. 5. Graphical illustration of the game process for teachers.

blockchain can be exported, which can demonstrate the effect of changing data/hash values. Moreover, the concepts of zero knowledge proof are applied to verify specific data without disclosing any of the other hashed data.

In summary, specific blockchain concepts and features learnt from the games 1 and 2 are described as follows. In Game 1, students can have the first-person experience for PoW mechanism and public–private key pairs, while features of immutability, decentralisation, security, immediate finality, and network consensus are involved. In Game 2, apart from the above concepts and features, students can additionally experience (i) the Merkle tree construction with its root calculation and (ii) zero knowledge proof for data verification.

4. Impact

In the context of educational research, game-based learning approaches are always popular for enhancing the teaching effectiveness and learning engagement, for example the beer game for learning supply chain management concepts [7] and Run Marco for learning programming concepts [8]. The above educational games generally lead to a number of research questions for examining students' interest, performance, and satisfaction towards enriching science, technology, engineering, and mathematics (STEM) education [9]. Although there are some existing blockchain learning tools available in the market, including a paper-based blockchain game [4], board game [10] and technical

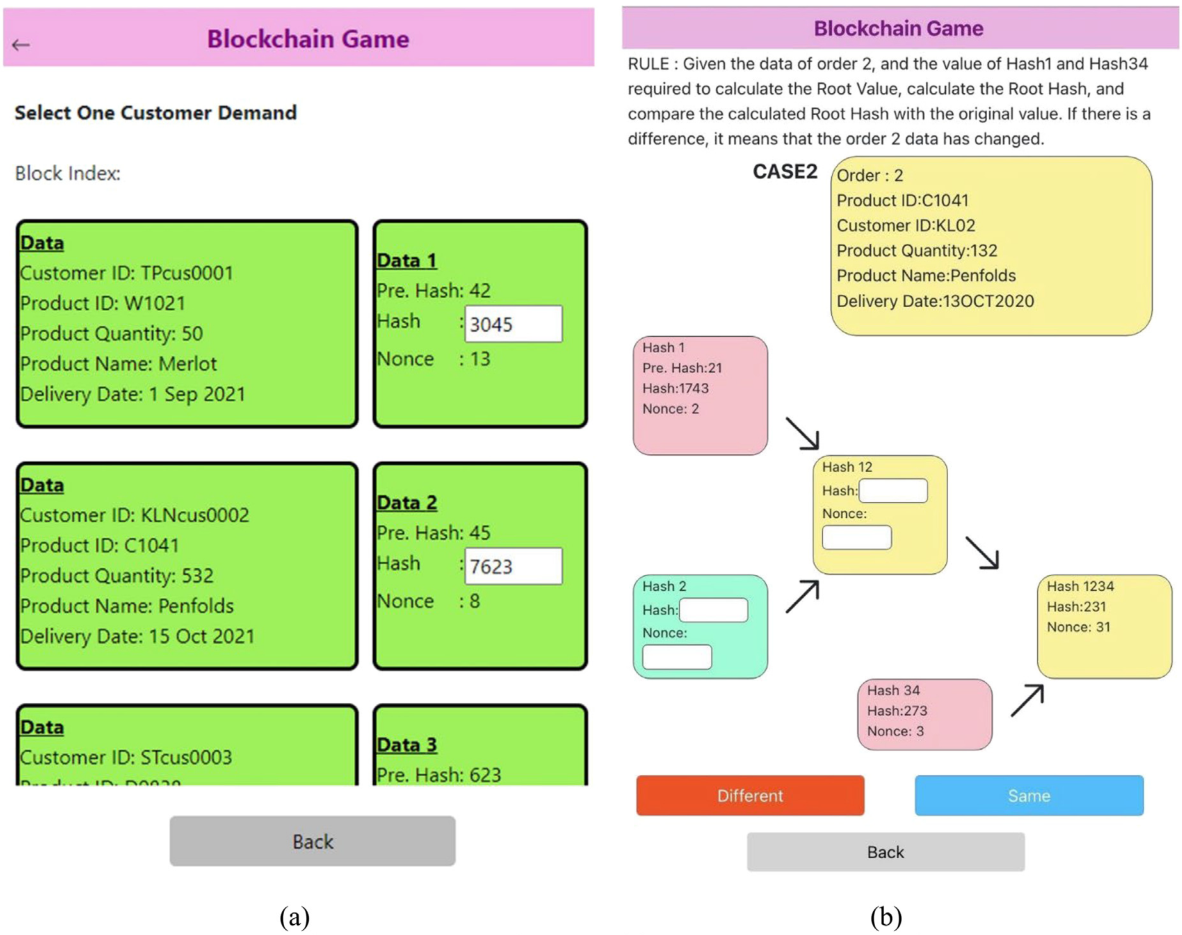

Fig. 6. Post-exercises after the completion of game; in (a), the whole mined and verified blockchain can be exported after the completion of Game 1, where the cryptographic links between blocks are visualised; in (b), the zero knowledge proof can be experienced to validate the authenticity of the given data after the completion of Game 2, when the transactions were mined in the Merkle tree structure.

self-learning materials [11], they are difficult to implement in the STEM subjects under the blended learning pedagogy targeted for multi-disciplinary students. Through the learning platform, the students can be involved in building a blockchain of wine transactions among their peers with various blockchain concepts. In addition, the effectiveness of the proposed platform for students without a technical background, such as business management and the arts, can be investigated to assess the popularisation of STEM education through the proposed platform in higher education. It is essential to facilitate the formulation of synergy from multi-disciplinary knowledge. Therefore, the corresponding educational research model for measuring (i) prior and post student interest, (ii) prior and post student performance, and (iii) student satisfaction can be pursued based on the proposed learning platform.

Apart from effectively propagating blockchain knowledge in higher education, the proposed learning platform can also be a STEM education tool to refine the relevant teaching and learning pedagogies. Instead of learning all the essential concepts from the games, classes with hybridised lecturing and game-playing approaches can be designed, while the games are seen as tools to deepen students' understanding on complicated concepts and knowledge. Subsequently, experiments are required to measure the teaching and learning effectiveness with respect to the course content arrangement. With various course design settings, the student interest, performance and satisfaction can be investigated to determine the appropriate game-based pedagogy for disseminating advanced computer science knowledge. Due to the presence of the COVID-19 pandemic, the blended learning pedagogy is widely applied in various disciplinary subjects, while several online learning tools should be built to assist the teaching and learning activities. Therefore, the above experiments on the course content design can support to revamp traditional lecturing approaches to stimulate students' attention and interest in an online learning environment.

Overall speaking, the proposed learning platform can be beneficial in the blockchain education in higher education for both technical and non-technical students. Differing to building the blockchain using programming codes, the games are regarded as another approach for disseminating the corresponding knowledge to students who can experience the block mining process and other mechanisms. To commercialise the proposed learning platform, subscription-based services can be provided to intended users (e.g. lecturers) to set up their own games with the customised blockchain data. Corresponding passcodes can be generated to effectively control their own group of students such that multiple groups of students can participate in the games simultaneously. Consequently, more talent in the market can be cultivated to support the rapid development of blockchain technology.

5. Conclusions

In summary, an educational platform, namely 'BlockTrainHK', is designed and developed to promote blockchain concepts in higher education, in which two games are established for building a blockchain of wine transactions during classes with the concepts of consensus algorithm, hash function, Merkle tree, and zero knowledge proof. In order to popularise the educational platform for students with both technical and non-technical backgrounds, the entire game logic is simplified and structured to reach consensus among peers step by step, where the hash function is specifically customised by using simple mathematical calculation, instead of the real-life secure hash algorithms. By doing so, whatever the background of students, they can effectively participate in learning blockchain concepts so as to facilitate the future development of blockchain technologies is various industries, such as the arts and business management.

CRediT authorship contribution statement

Yung Po Tsang: Conceptualization, Methodology, Software, Investigation, Writing – original draft. **Chun Ho Wu:** Software, Data curation, Writing – review & editing. **Carman Ka Man Lee:** Resources, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This work was supported by a funded project of Online Teaching Development and Educational Research Grant (Stage I) from the Department of Industrial and Systems Engineering (ISE) of The Hong Kong Polytechnic University (PolyU), and funded by Research Grants Council of the HKSAR, China [RMGS Project Acc. No.: 700043].

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.softx.2022.101167.

References

[1] Lu Y. Implementing blockchain in information systems: a review. Enterprise Inf Syst 2021. http://dx.doi.org/10.1080/17517575.2021.2008513.
[2] Lee JY. A decentralized token economy: How blockchain and cryptocurrency can revolutionize business. Bus Horizons 2019;62(6):773–84.
[3] Wang Q, Li R, Wang Q, Chen S. Non-fungible token (NFT): Overview, evaluation, opportunities and challenges. 2021, arXiv 2021; preprint arXiv:2105.07447.
[4] IBM. The blockchain game: A great new tool for your classroom. 2022, https://www.ibm.com/blogs/blockchain/2019/04/the-blockchain-game-a-great-new-tool-for-your-classroom/. [Accessed 26 January 2022].
[5] ASCII code - the extended ASCII table. 2022, https://www.ascii-code.com/. [Accessed 17 May 2022].
[6] Lee D, Park N. Blockchain based privacy preserving multimedia intelligent video surveillance using secure Merkle tree. Multimedia Tools Appl 2021;80(26):34517–34.
[7] Kaminsky P, Simchi-Levi D. A new computerized beer game: A tool for teaching the value of integrated supply chain management. Global Supply Chain Technol. Manag. 1998;1(1):216–25.
[8] Giannakoulas A, Xinogalos S. A pilot study on the effectiveness and acceptance of an educational game for teaching programming concepts to primary school students. Educ Inf Technol 2018;23(5):2029–52.
[9] Martín-Páez T, Aguilera D, Perales-Palacios FJ, Vílchez-González JM. What are we talking about when we talk about STEM education? A review of literature. Sci. Educ. 2019;103(4):799–822.
[10] Cortiz D, Calegari N, Oliveira F, Gatti DC. Game design for blockchain learning. 2021, arXiv 2021; preprint arXiv:2104.07086.
[11] Ethereum. Learn by coding. 2022, https://ethereum.org/en/developers/learning-tools/. [Accessed 26 January 2022].