Applying Blockchain Technology in eLearning systems: Overview, Analysis and Potential Solutions

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***Abstract*—Technological innovations such as M-Learning, automatic graded systems, virtual and augmented reality, online classes, and the gamification of learning are rapidly being integrated in the field of contemporary education. One of these technologies is Blockchain, which has already proved to be a disruptive in several fields, such as finance, healthcare, human resources and advertising. Multiple organizations from different industries are developing blockchain-based systems, but the application of Blockchain in education is still novel.**

The goal of this paper is to present an overview of existing literature in this field, and the potential of application of Blockchain technology in education. We present a simple solution of an eLearning system for learning programming on the basis of automatic grading developed in the language Python.

Keywords: automatic grading systems, blockchain technology, eLearning, gamification, online classes.

I. INTRODUCTION

Contemporary educational systems are experiencing a shift from traditional to online and/or hybrid and blended learning methods. During the COVID-19 crisis two main modes of delivery have distinguished itself in higher education, full online learning and blended (hybrid) learning modes. Both modes require innovative tools to support teaching and learning, in offering flexible learning pathways, which include a combination of digital solutions for different pedagogies, approaches and technological platforms. Innovations such as automatic graded systems, virtual and augmented reality systems, and the overall gamification of learning present new approaches to education in the Digital Era [1].

One of the emerging technologies to support these new learning paradigms is blockchain [2]. Primarily used for cryptocurrencies such as Bitcoin [3], the underlying technology itself is regarded as a disruptive technology in Industry 4.0 [4]. Blockchain has an outlook to impact not only the financial and commercial sector, but healthcare, government and education sectors as well.

As still regarded a novel technology, blockchain found only several use cases in education. According to the authors of [2] and references therein, blockchain can primarily be used for storing and managing degree information, i.e. in credentialing. Common uses cases include students receiving a certificate upon completing an assessment, which will be stored on a blockchain network [5]. In addition, the learning process itself could be incorporated into a blockchain network, as learning activities, their design and implementation could be kept on a blockchain network, especially in eLearning [6–8]. The authors of [7] propose a blockchain-based framework to connect multiple educational institutions to enhance data security and remove trust concerns amongst users or between third-party institutions accessing applications and services. Using such a framework, the distribution of educational data can be used with smart contracts in order to warranty that institutions will continue to be in control of their data entrance. As a result, the institutions would be alert of the source of collected data sources, and be up-to-date when their data is log on by others. In [9], blockchain integration with cloud computing is proposed, which could facilitate the demonstration, use, and learning of blockchain technology at universities and other technology training situations. Teaching a blockchain application will be easier in the Cloud, without needing or dedicating additional local hardware. The authors emphasize on the benefits of incorporating blockchain in the curriculum of computer science, information technology, and software engineering studies, although at higher or graduate levels at first.

However, being a novel technology, blockchain itself can be too complex to understand, and a system built to support the technology can be a challenge [8, 9]. At the learning process level, to understand blockchain, previous knowledge related to cryptography, cybersecurity, databases, data structures, networking and distributed systems is often required.

In this paper, the authors have considered designing system to introduce a learner to the basics of Blockchain through the Python programming language, with an option for automated testing. In such a way, the learner could ultimately understand blockchain technology by building one in Python. This paper presents the first step in our research in Blockchain-based eLearning systems, and is a foundation for future development and usages, and is organized as follows. Section II gives an overview of the basics of blockchain technology, and the application in eLearning. Section III presents our system design with main components highlighted. Section IV focuses on the comparison with existing, commercially available auto grading systems in Python, pointing out the advantages and disadvantages of those systems. Finally, Section V concludes the paper.

II. BLOCKCHAIN IN ELEARNING

This section examines existing blockchain-based solutions in eLearning. Subsection A gives a brief overview of basic blockchain concepts. A basic blockchain protocol stack is presented, along with several (but not all) consensus mechanisms. Subsection B gives a more in-depth analysis of existing blockchain-based solutions in eLearning.

A. Blockchain basics overview

A blockchain can be viewed as a distributed append-only ledger, or timestamped data structure [10]. The technology enables a peer-to-peer network, comprising of, in general, non-trusting nodes to interact, without having a need for a central node [11]. The general blockchain protocol stack can be broken down into several layers as shown in Fig. 1.

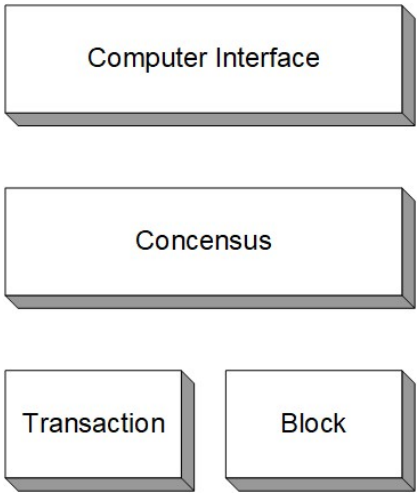

Figure 1. The blockchain protocol stack.

Transactions describe events in the network (such as changes to bank accounts, updates to an electronic health record, student passing an exam, etc.). Every transaction also contains a unique cryptographic signature making them resilient to modifications. At least one node signs this transaction, and it is distributed to the rest of the network. Nodes that verify all the blockchain rules are called full nodes, and these nodes group the transactions into blocks. A block can be viewed as a data structure consisting of a set of transactions, together with a header that connects the new block to the previous one. All blocks hence form a chain, and can trace back to the first block, called the genesis block.

TABLE I.
TYPES OF BLOCKCHAIN TECHNOLOGIES AND THEIR CONSENSUS MECHANISMS

Blockchain technology	Consensus mechanism
Bitcoin	Proof of Work
Ethereum	Proof of Work, Proof of Stake
Hyperledger Fabric	SOLO, Kafka, Proof of Stake
Hyperledger Sawtooth	Proof of Elapsed Time
Tendermint	Practical Byzantine Fault Tolerance

A no central entity should not be able to control the process of adding blocks to the blockchain; therefore, nodes must reach to an agreement on which transactions must be kept in the blockchain. This management system is accomplished with a consensus mechanism. Different blockchain technologies use different consensus mechanisms, as shown in Table I. Blockchains focused on cryptocurrency, such as Bitcoin [3] and Ethereum [12], use Proof-of-Work (PoW); however, other mechanisms such as Proof-of-Stake (PoS), Byzantine Fault Tolerance (BFT) exist and are not computationally heavy such as PoW, and different technologies use them. Some blockchains, i.e. the Hyperledger family, can use different mechanisms in their deployment [13].

Users that use their devices as nodes in the network communicate to the blockchain via a user interface. Depending on the blockchain type, the user interface can e.g. store a state, consisting of all the transactions that have been made by that specific user.

B. Application of blockchain in eLearning

As to the authors' knowledge, fully developed and deployed Blockchain-based eLearning systems do not exist, although several start-ups and propositions have been found in [7, 9] and references therein. Exceptions are the University of Nicosia, which was the first school to use blockchain technology to manage students' certificates received from massive open online courses, while MIT and the UK Open University have similar blockchain-based certification projects.

In [7], the blockchain-based framework consists of nodes that can be either institutions or students. The goal is to use nodes to verify transactions consisting of educational data, without the need of a central server. This framework uses a type of blockchain that is private, enhancing data security and excludes trust concerns amongst users. The ultimate goal of the work presented in [7] is to implement the framework on an active e-learning platform, such as the e-learning systems of distance learning, classroom learning, mobile learning, blended learning or online learning platforms.

Whereas [7] used blockchain to securely distribute educational data, the work presented in [9] aims to use smart contracts to automate and expose assessments procedures, facilitate the negotiation of personalized curricula, and generate student credentials using blockchains with the PoS consensus mechanism. Student activities such as curriculum selection is stored on the blockchain as a separate transaction [9, Fig.7]. Furthermore, student assessments are carried out as a set of transaction, the first transaction being accessing the assessment, while the other is result submission [9, Fig. 9]. Their use cases called for a public permissioned blockchain such as Hyperlegder Fabric [13].

Both approaches use blockchain as a tool to improve different aspects of eLearning, and point out that obstacles still exist, mostly due the infancy of the technology. Another disadvantage is that blockchain is still mostly used for financial transactions in the form of cryptocurrency, and other uses, although promising, are still being viewed as skeptical.

III. PROPOSED SYSTEM

Based on previous literature, we have proposed a system to primarily help understand the concepts of blockchain to new learners with an automatic grading test-based system using the Python programming language.

Learners who are just starting with blockchain technology are often met with difficulties due to the lack of knowledge in data structures such as linked lists and their implementation, hashing, and advanced topics (and in some cases basic) in cryptography.

Our proposed system is based on an automatic grading systems which have already been implemented for the purpose of learning basic programming concepts, but also objective-oriented programming and data structures [14, 15]. Considering the disadvantages of existing systems, we propose a solution, shown in Fig. 2, consisting of the following topics:

1. Topics on Linked lists (renewal of learning from the beginning), which includes an animated theoretical part, assessment (quiz), and two programming assignments. The first assignment is to use linked lists already embedded in the code, while in the second assignment, the learner must create and implement linked lists with no starting code.
2. Topics in Hash functions, a short course for all learners. As with linked lists, an animated theoretical part is first presented, followed by a short assessment (quiz), concluding with four programming assignments. The first is to use hashing in already embedded code, while the remaining three assignments deal with open addressing, quadratic probing, and linear probing, respectively.
3. Topics in cryptography, a short course for all learners. After an animated theoretical part and an assessment, two programming assignments are presented to the learner. The first assignment is the use of a cryptographic algorithm in already existing code, while the second assignment deals with implementing a simple cryptography algorithm with no starting code.
4. The first out of two blockchain topics includes a course. As with previous topics, a theoretical part with an animation is presented, followed by an interactive section. This topic concludes with an assessment in a form of a quiz.
5. The second blockchain topic in our solution consists of implementing one's own blockchain by coding it in the Python programming language through six assignments. All assignments are coupled with a theoretical part. The first and second programming assignments deal with representing transactions and creating blocks, respectively. The third assignments focuses on generating block hashes and the blockchain class. The fourth assignment handles adding blocks to the blockchain, while the fifth assignment is all about checking for a broken chain. Finally, the sixth assignment is implementing the PoW consensus mechanism.

After each of the topics' assessments, an autograded system informs the learner if he/she has passed the current topic successfully, and can only continue with the next topic if the previous is passed.

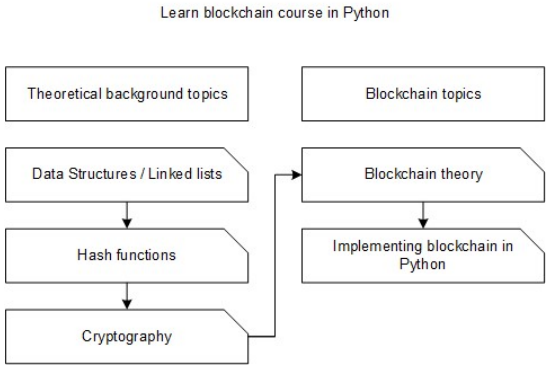

Figure 2. Blockchain course elements.

IV. COMPARISON WITH AVAILABLE TOOLS

Commercially available tools for general programming in a web application exist, however none of them are explicitly related to blockchain technology. For instance, the e-learning system Codecademy, enables the learning of many programming languages and many frameworks as well. In the beginning, Codecademy offered completely free access to their system; however, during the last years, they introduced commercial memberships like the PRO Membership [16].

The only existing solution within Codecademy that functions on a similar manner is the commercial course Learn the Basics of Blockchain with Python [17] which requires a PRO Membership, as shown in Fig. 3. The course enables interactive learning of blockchain technologies at a fundamental level only.

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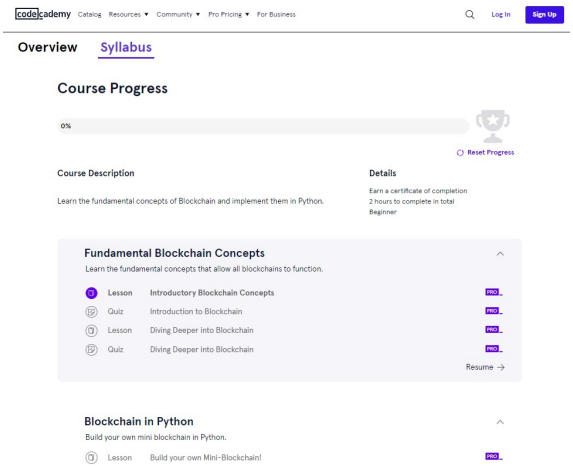

Figure 3. Codecademy Blockchain course requires a paid PRO membership.

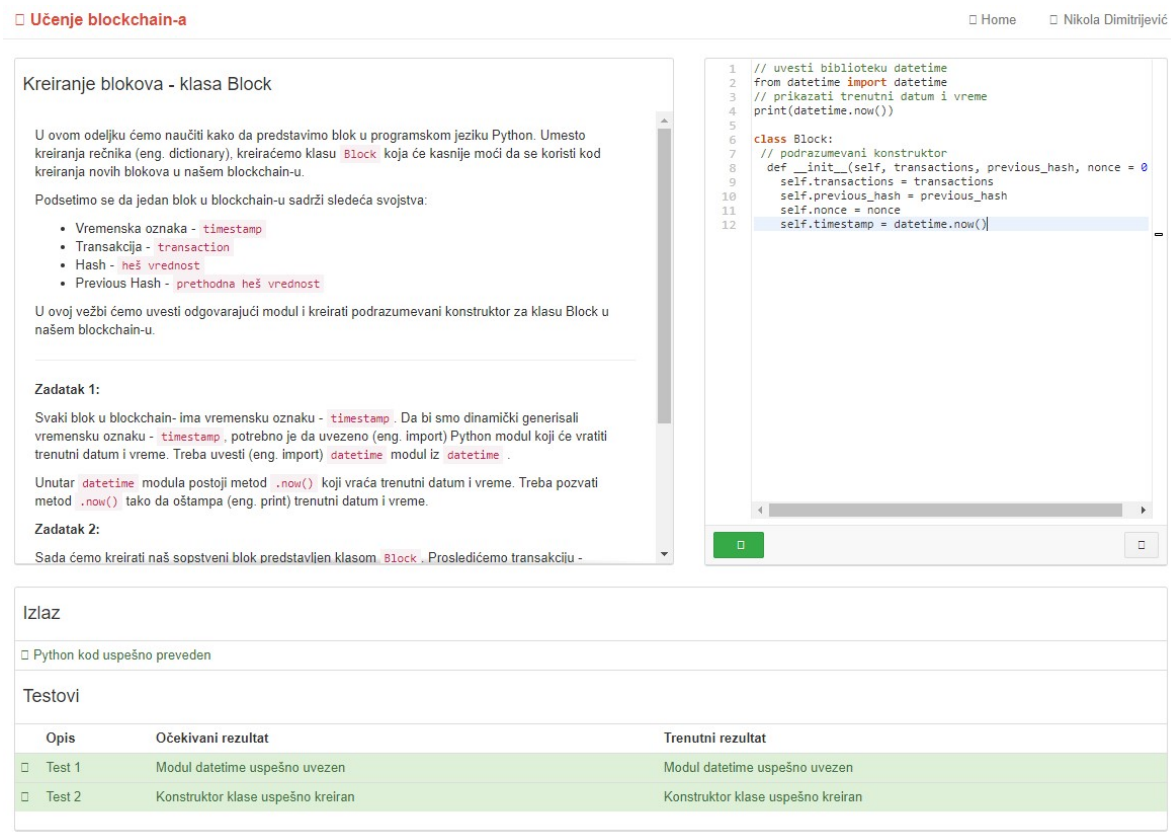

Figure 4. Creating block in our solution.

Our own solution, shown in Fig. 4, has several advantages compared with the paid Codecademy course. Namely, the course does not address the topics needed to understand blockchain technology – no topics regarding linked lists, hash functions, or cryptography. All these topics are indeed needed to understand the basic functionality of blockchain. Codecademy does not even offer similar courses that could fill the knowledge gap. Furthermore, in this course there is no implementation of your own blockchain as a step-by-step process.

Whereas Codecademy offer a paid course with limited knowledge outcomes, IBM's course on Blockchain Essentials [18] is divided into two parts: an overview of blockchain at a non-technical level, and an in-depth class which requires previous knowledge in multiple programming languages, Docker, and Linux. Our proposed system retains does not require additional tools or specific operating systems, as it can be all completed within the web application.

V. Conclusion

In this paper, we have presented a solution to learn blockchain technology by building one's own blockchain, with all previous knowledge being incorporated in the form of theoretical background and assessments. Furthermore, the blockchain portions of the proposed solution with programming assignments are automatically graded. The language of choice was Python, as it can handle various levels of assignment complexity easily, while retaining a low-level entry point for learners of all skill levels. Our solution is the first step in a blockchain-based learning system, and future improvements include adaptive learning assignments of the autograded system part, and blockchain-based credentialing for passing the blockchain course itself.

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