Blockchain and Peace Engineering and its Relationship to Engineering Education

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***Abstract*—Peace engineering implies taking positive and proactive actions to promote peace and justice. Blockchain, on the other hand, is a distributed sequence of blocks which acts like a public ledger. Motivations to develop blockchain based systems are usually related to transparency and trust. Inherently, blockchain ideals relate to peace engineering because of the way users can manage information globally: transparently and confidently. Application of blockchain in higher education may represent a fundamental change in the way professors deliver contents, manage courses, and even assess student work. Moreover, higher education institutions can find blockchain useful as it has the potential to change the way of providing certifications and the way knowledge is managed, produced, and shared. In this work, we review previous works that address blockchain implementation in higher education highlighting implementation advantages and possible disadvantages. Additionally, we explore further potential applications of smart contracts as a tool in blockchain based approaches to enhance engineering education programs.**

Keywords—Peace engineering; Blockchain; Higher Education

I. INTRODUCTION

In the pursuit of continuous improvement, higher education has started to consider and implement new paradigms like blended learning to enhance the teaching-learning experience [1]. Consequently, the transition from environments, totally face-to-face to blended, is producing more attention to digital education platforms. Engineering education, naturally, is aware of these phenomena and modern tools are starting to be used in programs.

On the other hand, engineering, as a profession which interplays with social, technical and environmental dimensions, cannot be isolated focusing on technical topics only [2]. Academic engineering programs that aim at developing technical skills on students but also social sensitivity and critical thinking aptitudes. These new goals are consequence of an intrinsic focus on Peace Engineering, an approach which emphasizes peace and justice promotion [3].

The use of technology to achieve those objectives is not completely new. Actually, one of the most recent technologies which is thought to be role changing in many aspects of society, and could help achieving them, is blockchain. Certainly, recent advances on this technology have revealed a remarkable potential in many fields [4].

The combination of blockchain and education is becoming more and more attractive as some works state [5]–[7]. The reason behind is related to some of the attractive features that blockchain offers: transparency and immutability. Nevertheless, the link between Peace Engineering and Blockchain in order to improve Engineering Education programs remains unexplored and partially unstated. Thus, in this work, we review previous proposals that emphasize the usage of blockchain in education and explore possible application of smart contracts in engineering education.

This paper is organized as follows: section II introduces the main ideas and concepts related to Peace Engineering and how those can be addressed by using blockchain, section III discusses the use of blockchain in education briefly highlighting advantages and disadvantages, section IV presents and discusses an approach to the employment of Smart Contracts in Engineering Education programs to address Peace Engineering, finally, section V concludes the work.

II. PEACE ENGINEERING AND BLOCKCHAIN

As engineering is present on every aspect of modern human life, it has the potential to change the entire panorama of society. The way engineering influence on it can be categorized in three: military engineering, civilian engineering and peace engineering [8]. Although the first two are ruled by ethical codes, the difference with the third one is clear: peace engineering is devoted to promote justice and peace in society by using technology [3].

Among the goals of Peace Engineering is to achieve sustainable development. This is of particular interest among developing countries, where incomes mostly proceed from unrenewable natural resources [9] and sustainable development isn't fully addressed [10]. Consequences of the latter remark are the unstable prosperity, due to fluctuating market prices, and possible social inequity, both roots of social conflict and, therefore, threads to peace.

Another goal is transparency, which could eliminate risks and practices of corruption and bribery. This does not only include developing countries, where corruption is a major issue, but also developed countries. Unfortunately, transparency by itself seems to be insufficient to eliminate corruption [11]. Therefore, efficient ways of using transparency are needed.

Undoubtedly, peace and justice are not easy to achieve as many actors are required to work together in concordance. However, Peace Engineering does not only involve engineers, but, because of the need for adapting engineering education programs, also higher education institutions. Relationship between Peace Engineering postulates and Engineering Education is intrinsic and undeniable.

A. Relationship to Blockchain

Blockchain technology has recently disrupted the way data can be stored and managed. Based on a distributed paradigm, a computer network holds a chain of blocks which serves as a distributed database and ledger. The definition of blockchain references to a trustworthy distributed system with two main attractive features: transparency and immutability [12]. Due to both, blockchain applications are diverse and are expected to change many fields as depicted in [13].

The aforementioned characteristics make blockchain a real and feasible tool to be used in Peace Engineering. As a matter of fact, previous works have explored the way sustainability may be achieved by using blockchain [14], [15]. On the other hand, being a public ledger, blockchain makes public all the contained data and thus, makes transparent the registered information [13]. It can be seen, from previous comments, that blockchain can promote sustainable development and transparency, however, these cases are not related to engineering education yet.

III. Blockchain and Education

There are several works that introduce blockchain in education. Among them, discussions, mainly, have provided ideas of how blockchain can be used and what features would be improved. Tapscott and Tapscott [16] refer to four strategic scenarios where blockchain would play a major role: (1) identity and student records, (2) new pedagogy, (3) costs and (4) Meta-university. Over the first scenario, it is possible to remark EduCTX [17], a European initiative to extend the European Credit Transfer and Accumulation System (ECTS) into a consortium blockchain. EduCTX saves learning results in the blockchain, therefore, immutability is inherited. Also, students, potential employers and third part higher education institutions can consult the blockchain in order to validate information. However, an important aspect which is missing on the proposed system is the link between the platform and the LMS (Learning Management System) that might be used by instructors. EduCTX relies on university's administration to register earned credits.

Regarding to the new pedagogy, although not directly focused on such, proposals like [18], [19] may produce an environment where "learning is earning" would change the way contents are evaluated. Unfortunately, as far as the literature was reviewed there are no implementations of blockchain to change pedagogy, only ideas. With respect to the costs aspect previously mentioned, it can be thought that implementation can follow to possible ways: (1) when costs are equivalent to money, trying to establish a bridge to cryptocurrencies or fiat, and (2) when costs are "symbolic" and those are assumed to be as universities internal or local cryptocurrency [19].

Finally, focusing on the meta-university, three points are addressed by Tapscott and Tapscott: (1) content exchange, (2) content co-innovation, and (3) global network. In a certain way, all of them refer to a system which can be used as a sharing platform. These points have been explored in [20], where it is proposed the employment of blockchain to distribute adequately intellectual products.

Applications of blockchain in education are naturally centered on certificates or diplomas emission and validation (student records) [17], [18], [21], [22], but there are also some works which attention is driven to learning outcomes [19], [23]–[25], i.e. intermediate learning results and not full course results only. We summarize respective advantages and disadvantages below.

A. Advantages

In general, blockchain applications to education offer many advantages which are inherited from blockchain main features. The immutability, tamper-proof and reliability are exploited in a such a way that universities and potential employers can verify easily the information supplied by students; considering it as an initial step to smart CVs. These same properties can open the door to a shared platform that allow academics and students hold a portfolio of achievements and, thus, a way of representing academic reputation. The latter idea is related to the "learning is earning" concept, where a student is given a reward according to the achievement reached.

As the connection between universities' blockchain and possible employers' networks allow better interaction, universities may trace students' successes or failures in a given employer institution to know which aspects can be improved to maximize success. Additionally, learning histories may be used to offer students opportunities according to their skills; all of this because of the interaction. On the other hand, smart contracts can be used to assure identities and manage cycle life of certifications. This would increase the reliability of such certificates and even provide more confidence to the institutions.

Blockchain can also allow universities create local cryptocurrencies that could be employed internally. Rewards of obtaining good scores would be given to students, encouraging them to improve their skills. This might flip the learning approach to a more learner centered one and create learner-centered ecosystems that would be based on blockchain. In such entities, learners would be able to rate courses and professors, share available resources and contents, record activities, among others.

The appropriate interface between blockchain, LMS and LRS (Learning Record Stores) may be seen as the precise tool to log different activities and store actual learning data. Considering that these activities may represent the ways students learn, keeping these logs can allow universities to analyze learning patterns to improve programs later.

B. Disadvantages

Although applications and advantages are clearly remarkable and encourages designing and using blockchain for education, there are many issues that should be considered

before. As Skiba recalled the words of Nazare, Duffy and Schmidt in [7]: "It is not a simple solution to fix everything that is wrong with today's credentials". We can identify and remark the following issues:

- Scalability – Even though blockchain for education is not expected to process millions of transactions per second, it is important to highlight that blockchain designs must consider possible bottlenecks.
- Easiness of adoption – Not every organization or institution is predisposed to change the way it manages information. Additionally, not every country has the same regulations with respect to blockchain. These points make blockchain adoption hard to achieved. As a matter of fact, information management regulations can vary across countries.
- Privacy – An important topic to be considered is the amount and type of data blockchain should store. Certainly, the more data, the better for third party institutions. However, not every person wants to share every detail of his or her academic life and achievements. Besides, current regulations require a better study of what is allowed to be done.
- Feasibility – Many applications of blockchain in education might be even considered as futuristic. Although these can be accomplished, ideas like a blockchain based system that monitors attendance of students by recognizing them with cameras may be years of development ahead.

C. *The relation of blockchain and engineering education*

Education, overall, can be seen as a wide scenario where blockchain can be applied. This, however, is reduced when the focus is centered on Engineering Education (EE).

Beginning by the fact that EE is being improved by the inclusion of new paradigms, as blended learning, instructors use technological tools very often; such tools can include LMS, simulators, and others computer-based instruments. In general, it is a matter of time to expect many of these tools to be based on blockchain. As it has been demonstrated that EE is better developed with blended learning [26], it is natural to start thinking about implementing blended learning by using blockchain.

Blended learning, defined as a combination of face-to-face and virtual learning, is composed by two elements, the presencial and the virtual ones [1]. Commonly, while the virtual stage is structured by using videos, discussions or forums and quizzes, the presencial is focused on knowledge verification and skills development. The niche where blockchain could be used is located here.

Recalling that diplomas by themselves cannot guarantee full acknowledgment of achieved learning results, it is important to propose a system which could store intermediate learning outcomes and make them immutable. At the same time, it cannot be denied the need for interfacing this system to the LMS used by the instructor, or even better: the need of turning this system into a decentralized and blockchain based LMS.

In order to match the requirements of EE and the aforementioned blockchain based LMS (b-LMS), it is proposed that the latter one would integrate enough tools to have following features:

- Students' learning logs – registers of what students achieve in assignments, which could be assessed by instructors or automatically graded by the b-LMS. Logs should include few keywords of the specific areas to which assignments correspond to allow searches.
- Students' privacy control – allowed permissions' that students declare to give third-part institutions the permission to access student's data.
- Student content sharing and reputation platform – means for students to acknowledge their ideas and allow them to share as resources with respective authorship mention.
- Teachers' log of students' activities – perceptions of the instructor given a student activity or attitude.
- Students' assignments manually and automatically graded – instructors can design automatic graded assignments and assignments that need him or her to grade.
- Students' tool to grade instructors – constant feedback that is given by students and allow universities to know students' opinions and perceptions.

Although limited in number, these features are thought to be part of the fundamental that may allow the construction of a blockchain based ecosystem for education. However, the question remains, how do blockchain approaches to engineering education may address peace engineering? We attempt to answer such question in the following section.

IV. Blockchain in Engineering Education and Peace Engineering

Let us begin this section by defining two important aspects, the first: the scenario where the approach is thought to be implemented, and the second: the proposed approach.

A. *Scenario*

The United Nations defined that culture of peace is based on justice, democracy, solidarity and cooperation, among others [27]. Complementarily, the pursuit of common good in society by means of technology in view of socio-technological and environmental aspects is considered a goal of Peace Engineering. Unfortunately, current curricula structure in engineering programs is not always driven to the common good goal [2] and because of that, the culture of peace is not entirely set or addressed in EE programs.

Although the lack of elements that promote the culture of peace and therefore, peace engineering, is regrettable, this is also the scenario where blockchain approaches to education may be located. Integration of this technology, engineering education and peace engineering may be devised as the way EE takes advantage of blockchain features to promote the culture of peace and thus, peace engineering fundamental values.

Among students' motives of concern are the acknowledgment of their learning outcomes and the way their grades were computed, which inherently means that transparency is a must. Moreover, a focus of attention for instructors is the need for recognition of appropriate ideas or intellectual property to realize real students' achievements. These remarks are currently addressed by LMS, which allows students to monitor their learning achievements and control students' contributions, e.g. to community's wikis. However, these systems are based on centralized models, therefore, they are in disadvantage with respect to decentralized models as blockchain.

On the other hand, being teamwork one of the most required skills on engineers, cooperation is encouraged by making students work in teams. Nevertheless, instructors usually worry about the ways they can measure impact or contribution of students in their teams; this concern is bigger when virtual dimensions are included in training.

Finally, as competition to formulate the best solution is innate in engineering, students are susceptible to increase stress levels producing discomfort. This may provoke psychosocial issues on students as mentioned in [28], which in turn might isolate students from the context, e.g. reality of fellow students, and affect teamwork skills.

B. *Proposed Approach*

As it has been stated, the proposed framework is based on the blockchain based LMS for Engineering Education which works over the Blended Learning approach; see Fig. 1. The benefits of this framework are inherited from the best advantages of Blended Learning usage in Engineering Education and the attractive features of blockchain. However, in order to address Peace Engineering the following is proposed:

- A reward system which allows students earn rewards in form of credits when they achieve desired learning outcomes.
- An anonymous public register of students and earned credits. To avoid public exposure, anonymity would be guaranteed by using hash-based directions and generating them periodically.
- A transactional system which allows students give or receive credits that earned.
- An automatic quiz platform which is based on smart contracts and provides credits to students automatically.
- A restrained smart contract platform which allows students make smart contracts with each other to enhance the interplay in them but capable of detect and prevent misbehavior.
- A percentage of the course grade assigned to credits-based activities which considers maximum amount of earned credits among all students and the distribution of them.
- A non-anonymous register of contributions made by students.

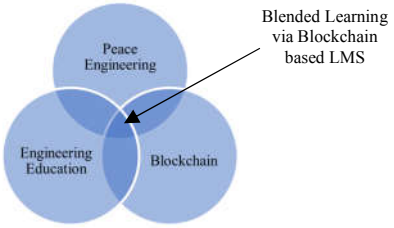

Fig. 1. An approach to integrate Peace Engineering, Blockchain and EE

C. *Discussion*

The proposed solution has two main ways of action: the first is the awareness of students of how the rest of the class is doing by using the anonymous public register. This may produce in them a solidarity attitude towards students with bad performance. As a matter of fact, by letting them transfer credits, students may help each other safely if the percentage of course grade is computed adequately. An example, although sensitive to extreme values, might be:

$$S_i = \frac{c_i}{\max c_k} 100 \qquad (1)$$

Considering S_i as the score of the $i-th$ student, c_i the amount of credits earned and $\max c_k$ the maximum amount of credits earned by all students.

However, this should be adequately monitored as students might present non-proactive attitudes. Therefore, it is highly advised to combine credits-based activities with critical-thinking development topics. Probably, the best courses to implement this methodology are those related to engineering design.

The second way of action is transparency. Because credits are provided by using smart contracts, students always know how they performed on a specific activity. Additionally, smart contracts may return verdicts with specific feedback provided by instructors.

Both ways of action relate directly to Peace Engineering. The first one in providing a social sensitive component to engineering education and the second one by providing students enough feedback, transparency and traceability of accomplishments.

On the other hand, an interesting subject to be discussed is if blockchain is really needed in this proposal. Answer can be divided in two parts. First, as education is turning the way achievements registration work, it is not advisable to remain

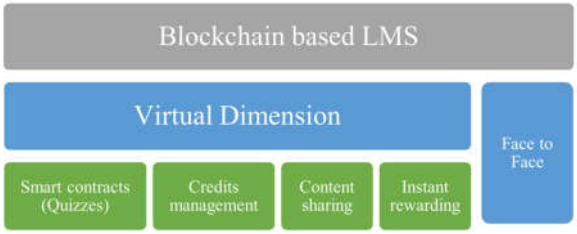

Fig. 2. Smart Contracts approach

away of this change. b-LMS have the potential of becoming a full internal credit university platform, where, for example, students can earn credits to spend in campus only or ideas can be collected and shared safely. Second, although diplomas can, in fact, say that a student has accomplished or passed some requirement, the merely fact that diplomas are awarded when certain score is reached does not say much about the way this score was reached or how was the student during that time and why such score was achieved. This information, corresponding to the intermediate learning processes, is highly valuable and should not be manipulated and neither be subjective. Therefore, an appropriate combination of smart contracts-based quizzes, credits management, content sharing and instant rewarding for the virtual part of blended learning in engineering programs and face-to-face teaching (Fig. 2) in decentralized blockchain based LMS can result in improvement of EE and promotion of Peace Engineering in different stages of engineers' formation.

V. Conclusions

Nowadays, Blockchain is considered one of the trend technologies that may impact greatly on society. Blended learning in Engineering Education, on the other hand, is attracting more attention due to the evidence that suggests better performance and lower abandonment rates when used. From another stand point, Peace Engineering is defined as the employment of engineering to achieve peace and justice.

Relationship between all of them is complementary. Blockchain is supposed to be the technological framework that allows an intrinsic approach to Peace Engineering. Blended Learning in Engineering Education is considered as the teaching-learning paradigm to-be implemented in Blockchain. Therefore, it is natural to think of an approach to LMS based on blockchain: b-LMS.

The proposed framework is aimed to allow recording (1) students' achievements and automatic quizzes results regarding to the intermediate learning processes and (2) complete course earned grade. Moreover, in order to enhance Engineering Education, ways of content sharing and instant rewarding via automatic quizzes are thought to be part of the virtual component in the blended learning approach.

Additionally, students' performance on automatic quizzes is rewarded with so called credits, which are earned via smart contracts published by instructors. These credits can also be transferred or used in smart contracts among students to encourage solidarity and collaboration attitudes. In that sense, students receive in their formation elements of the culture of peace, and therefore, are trained considering Peace Engineering values.

An important part of the proposed approach is the way the percentage of grade corresponding to credits-based activities is computed. In a way, this can be seen as a strategy to reward fair wealth distribution which in the end is controlled by students. Self-organization of the students' community in a course can also promote collaboration.

Future works should focus intensively on the implementation considerations for b-LMS and the study of the effects, positive or negative, of the described approach.

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