

Education theories and best practices in the field of blockchain

Authors: Alexander Panayotov, Petko Ruskov, Georgi Mitev, Deyan Parushev, Petar Blagov

Abstract: Purpose – to present the state of the art of blockchain education for students, experts and teachers in the world and Bulgaria, and to share the experience of the authors in the field. A specially designed methodology, based on a deep literature review, analysis and synthesis, the long experience in education, and results of implementing it are described. Information sources include best practices, written material, provided by the web and the students, teachers' observations, and group discussions during the planning of the education. Practical implications – the practice, curricula and extracurricular development can facilitate stakeholders to formulate and implement a blockchain educational environment. The explanation could lead other authors and teachers to achieve different and better syllabuses and innovations in the blockchain education processes. The value of the paper is in the survey and the practical presentation of the leading innovative blockchain theories and practices. Based on the practice of following and implementing blockchain education innovative examples, these papers will add value and allow further improvement and growth of education and blockchain, including EBSI (The European Blockchain Services Infrastructure) capacity building.

Keywords: education, training, DLT, blockchain, best practices, EBSI

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1. INTRODUCTION

Lifelong education and training of people, institutions, and nations is the main strategy for developing and growing in our global and turbulent environment. Successful education and self-education of the population allow countries to be competitive today.

On the other side, educators' biggest challenge is a lack of student and worker engagement in the education process [1]. Information overload, easy access to information sources, tiredness, disturbance, feelings of hopelessness, and so on are many possible reasons for students' and specialists' lack of motivation to learn. The educational staff's goal is to solve the problem by improving the way students are being taught. Distributed Ledger Technology (DLT) and blockchain are no exceptions to this trend in education and training. It teaches and provides multi-disciplinary (law, business, and technology) theory and practices.

The major components of blockchain education are:

- Blockchain Curriculum and Syllabuses
- Blockchain Faculty and Teachers

- Blockchain Extracurricular Programs
- The Blockchain Ecosystem

1.1. Global state of blockchain

DLT and Blockchain technology have been creating waves as some of the most disruptive and promising ICT technologies [2]. Most people have likened it to the dawn of the dot-com era which revolutionized how businesses operate and led to the creation of industries worth billions of dollars [2]. Industry experts are convinced that the impact of blockchain could be as significant as that of the Internet age. If that is the case, then it might be time for global authorities to consider the introduction of blockchain education into school curriculums [3].

Blockchain education is important because it allows understanding of the technology itself and what it is capable of achieving for the community. The most basic explanation of Blockchain is that it is a decentralized ledger that has the capacity to store data progressively, but stored data cannot be altered or changed [3]. Additionally, its network is supported by computers distributed all over the world rather than taking the traditional approach where networks are supported by servers. Cryptocurrencies are expected to be the future of money which means blockchain will be at the center of it all when that happens. The impact of blockchain technology also expands beyond the scope of the financial system. For example, decentralized ledger technologies can be used to create secure automated systems that can be used to run corporations. Further, the technology can be used to create hotel systems that handle customer information from the moment they check in, to the moment they check out. One of the latest examples of blockchain use is Peer-to-Peer (P2P) electric vehicle (EV) charging, which is facilitated by smart contracts and aims to allow private EV chargers to be shared publicly. The idea is to allow the owners of said chargers to earn some extra cash when they are not using the chargers by allowing other EV owners to charge through their outlet. This is just one of the many applications of blockchain technology.

1.2. State of the art education worldwide

Blockchain education and training is something that corporations dealing with the technology have been trying to achieve in order to not only empower people, but also give them a basic understanding of how it works, as well as its benefits. Some of these institutions and organizations are the Linux Foundation and IBM, which have been offering certificate courses on blockchain technology.

1.2.1. Academic education

MIT, Stanford, Berkeley, Princeton, Duke, NYU, John Hopkins, Cornell and all others of the top universities have been offering courses on blockchain education.

Stanford has particularly taken an interesting approach that involves introducing blockchain and cryptocurrency as a unit in its Computer Science course. The aim of the unit

is to educate Computer Science students on how blockchains work and how to create decentralized apps that can interact with decentralized ledger technology. Stanford's approach could be one of the alternative methods that institutions can adopt in order to spread blockchain education. It is a particularly interesting approach because it highlights the potential trend that most other universities and institutions of higher learning are likely to adopt, rather than creating a whole new course that is about blockchain. It also helps that such an approach is already in use because sectors such as IT are constantly changing and new content is added to the curriculums every once in a while. It should, therefore, be no different for blockchain especially since it is also a subject that focuses on computer technology.

In October 2016, **Berkeley** has created a community called the Berkeley Bitcoin Association - a group of about a dozen members who founded Blockchain at Berkeley (B@B) - an organization dedicated to becoming the blockchain hub of the East Bay. They also debuted the world's first undergraduate university-accredited blockchain course, Blockchain Fundamentals, taught to about 50 students. Alongside Blockchain at Berkeley's education team grew a consultancy that aimed to bridge the gap between geeky bitcoin enthusiasts and technology innovative early-adopters in the industry to develop Proof-of-Concepts for disruptive blockchain use cases. Since then, as a result of other ambitious B@B members, Research and Governance teams have also emerged. [4]

The **UCL** CBT was founded in 2015 to research the effects of Distributed Ledger Technologies and Blockchain into socio-economic systems and to promote the safe and organic development and adoption of Blockchain-based platforms. The center is the nucleus for DLT and Blockchain research and engagement across eight different departments at UCL and for its Research and Industry Associate network. Their Research and Industry Associate community consists of over 245 researchers and practitioners from UCL, other academic institutions and companies utilizing DLT. [5].

1.2.2. Business and community education and training

To date, many organizations offer some form of blockchain training and DLT competence improvement. However, there are only few that are have unparallel stake in the field in terms of quality and recognition, to a point that some are considered a de-facto standard and benchmark. Those include:

- The Linux Foundation – creating a suite of tools and frameworks for building private blockchain solutions – they are a leader in providing trainings for designing and solving business problems via highly customized, custom-built DLT solutions, primarily through the Hyperledger toolset [6].
- Ethereum Foundation gave birth to Ethereum, the first programmable blockchain platform. It only seems right that their standards are accepted as the benchmark in public blockchain technologies. They offer a vast educational guide to the world of Ethereum, with focus on how Ethereum works, how to connect and benefit from it, and of course, how to program it. Some of their content is explained later in this paper as it proved to be quite useful in

academic and corporate settings. Both technical and non-technical articles, guides, and resources are freely available [7].

- DLT Education created the first free edX online course for Blockchain & Hyperledger for the Linux Foundation Hyperledger Project. To date they have over 80,000 enrolled students. Their content is suitable for beginners interested in blockchain [8]. In 2016, they produced the 5-day Cryptocurrency Bootcamp for Women and Under-represented Scholars for MIT Media Lab Digital Currency Initiative. Furthermore, they produce workshops, lectures, hackathons and courses in Japan, India, Singapore, Saudi Arabia, Belgium, Spain, Canada and Brazil.
- British Blockchain Association (BBA) is the world's most prestigious and most influential voice on Blockchain. Established in 2017, BBA is the leading industry think-tank for blockchain, with extensive network presence in six continents. BBA promotes Evidence Based adoption of Blockchain and other distributed ledger technologies. Home to the UK's National Blockchain Roadmap VISION 2030, UK's DLT Excellence Standards Framework, Centre for Evidence Based Blockchain (CEBB), The Journal of the British Blockchain Association (JBBA), Blockchain Associations Forum (BAF), Student Forum (BBA SF) and the Industry Advisory Think-Tank [9].

1.3. European education and training

The **CHAISE**, as a Sector Skills Alliance addresses the European growing demand for blockchain and distributed ledger technologies skills [10]. The CHAISE project has developed the European Blockchain Skills Strategy as a key milestone project. The strategy provides well-coordinated and practicable approach to answer to the needs for current and future blockchain skills and competences, and deliver better training solutions that will meet the needs of the 21st century [11].

2. PROBLEMS RELATED TO BLOCKCHAIN EDUCATION

The specifics of blockchain – being a decentralized, disintermediated means of transacting between participants – create a radical shift in the way it is perceived, understood and managed. This results in the introduction of many obstacles in the way of passing the blockchain knowledge along in an academic or business environment. We have identified four main factors that impact the quality of blockchain education. Namely, blockchain is:

1. A very immature technology
2. An eclectic field of knowledge
3. Notably misunderstood
4. Lacking in experienced experts

The combination of those circumstances presents a significant challenge to managing the blockchain education process. We will discuss those reasons, and the issues that arise from them, in details.

2.1. New field of knowledge

While the concept of decentralization is not itself new, the introduction of blockchain – in the face of Bitcoin, the first blockchain protocol, in 2009 – was the first practical, large-scale working decentralized financial solution. Six years later, in 2015, the release of Ethereum marked the beginning of the second generation blockchain protocols and the introduction of smart contracts. Since then, blockchain quickly captured the attention of academics, business executives, venture capitalists and industry leaders among others.

This accelerated research and development process slowly helped blockchain begin the transition from an intuitive vision, towards a formal field of scientific knowledge, but the process is nowhere near complete. Best practices and standards are still being formed. Terms and definitions are either non-existent or not semantically strict. Changes to core protocol rules happen at a very fast rate, that makes it difficult to track and adapt to. Tools and frameworks are not reliable and not ready for large-scale projects. Regulating blockchain is a point of heated debate. The legal status of blockchain-based solutions can vary drastically depending on specific jurisdictions around the globe. All of these issues create an atmosphere of uncertainty, that makes it difficult to streamline the education process.

2.2. Cross-discipline field

Blockchain has quickly become a hot topic across various professional circles – computer science, law, business, economics, mathematics, cryptography, etc. And that is natural, considering that blockchain itself is not a technology, rather, a unique combination of already existing technologies and techniques from different scientific fields. A typical solution includes:

- Cryptography – cryptographic hashing; public key cryptography
- Computer networks
- Computer programming
- Games theory principles governing participant motivation and trust
- Economics principles related to crypto money creation and distribution; cost of transactions, etc.
- Unique business models
- Financial assets (cryptocurrencies)

The sheer number of different fields of knowledge involved make blockchain a truly cross-discipline space, that is yet to be fully explored and made sense of from a legal, business, economic and even social standpoint. All of this creates a big challenge in structuring and teaching a course about such an eclectic domain that blockchain is.

2.3. Wide-spread misconceptions and a very fast pace of change

The innovative nature of blockchain and its rapid rise to fame has led to vast audiences' attempt to capitalize on this process. However, as is evident from the short, yet turbulent history of crypto assets, the technology's maturity and user understanding are far from a satisfying level. The extreme Bitcoin price fluctuations, the Initial coin offering (ICO) bubble, the numerous thefts of funds ranging from exploits of smart contracts or simply user negligence and mishandling of personal assets, are a strong proof of this.

It is no surprise that numerous misconceptions were born out of this chaos. The shrouded in mystery beginning of blockchain (i.e., Bitcoin) and its notorious usage in criminal circles, some short years after its inception, only served to fuel this misunderstanding, sometimes reaching the level of conspiracy theories about the purpose of blockchain. The very fast development and evolution rate of the entire ecosystem adds additional barriers in the way of general audiences to build solid domain understanding and keep in touch with the latest security practices. Synthesizing constantly changing information and overcoming widespread misconceptions is a serious challenge to the education process.

2.4. Lack of expertise

While blockchain is new, its rapid popularity led to a sizable asymmetry between the huge demand for blockchain experts, and their short supply. Some estimates reveal that gap to be an order of magnitude wide (14 vacancies for a single expert). This, in turn, following basic economic principles of demand and supply, pushes the price of blockchain expertise to new heights. Expectedly, this fact has a negative impact on the education process as well, as it requires a team of experienced blockchain professionals, with knowledge ranging across the different fields it consists of, while remuneration levels academic institutions provide remain relatively low.

3. OUR BEST PRACTICES FOR TEACHING BLOCKCHAIN

3.1. Approaching blockchain education

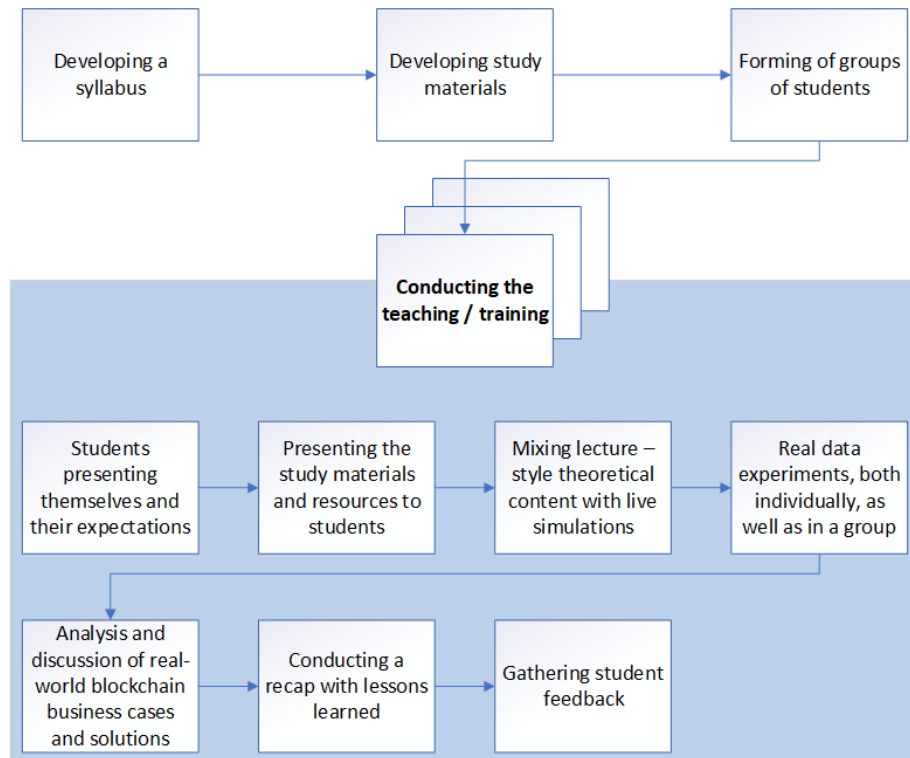
Overcoming the challenges discussed above is difficult, however, in the course of our work, we have found methods and practices that have proven to be very helpful in structuring a successful education process and can be used as general guidelines. Those include:

- Strictly define key terms and components of a blockchain solution
- Strong focus on the core concepts of blockchain (e.g., decentralization, security, trust, etc.)
- Choosing a small number, well-developed tools and frameworks to work with (e.g., Truffle, Ganache, etc.)
- Mandatory out-of-class activities in teams that includes research and practical exercises
- Use of simulations and other software to aid the teaching process
- Choosing a small number of trusted and quality sources of information

3.2. The process

Considering the numerous challenges that stand in the way of delivering quality blockchain education, in the course of our work we tested multiple approaches. While this work is still ongoing, a process emerged that consistently shows good results. This process of structuring the delivery of blockchain education is visually represented in Fig. 1.

Figure 1. The blockchain education process



3.3. Results

Following the guidelines laid out above, and incorporating them into the process we discussed, we structured blockchain education courses in two environments – academic and business. In both, we managed to achieve very positive results.

1. In the university blockchain courses we trained over 400 students. They rated the experience with over 90% satisfaction and emerged with enough knowledge and skills to create a working decentralized application (dApp).
2. In the business trainings, the participants were preselected via a basic computer science and blockchain test. Over 90% of all participants got internationally certified as blockchain experts as a result of the provided training, and over 97% emerged satisfied.

Overall, while this approach needs further development and adapting, we have proven that the many challenges facing blockchain education can indeed be overcome to provide quality knowledge and results.

4. TEACHING STATE OF THE ART BLOCKCHAIN METHODOLOGIES, TOOLS AND RESOURCES

4.1. Financial innovations and concepts in blockchain education

The financial world has seen drastic change since the introduction of blockchain more than thirteen years ago. Different verticals of the finance business have been disrupted. From public financial cryptocurrencies with market capitalization of hundreds of billions of dollars (Bitcoin), to bank consortiums creating an alternative means of payment to traditional banking (Ripple), to wider frameworks for building entire financial ecosystems on top of blockchain (R3 Corda). Since these use cases are arguably the most popular and intuitive when it comes to blockchain, a teaching syllabus will not be complete without explaining the impact of DLT on the financial world as we know it.

4.1.1. Financial models and protocols

Decentralized Finance (DeFi) means using a decentralized system to manage financial services. DeFi is a decentralized ecosystem that provides a wide range of financial services using blockchain technology. The DeFi applications are not controlled or managed by a central authority, so they're more reliable and secure. The Decentralized Ledger Technology helps to make applications that are decentralized, meaning that they are not controlled by one person or organization. These applications can directly connect people involved in a transaction, without the need for intermediaries or brokers. Smart contracts can also be used to process complex transactions, which means that the code that is used to organize these transactions is automatically executed according to predefined rules.

DeFi is an initiative and movement that wants to create a new financial system where people can access financial services without the need for banks or other institutions. This system is intended to be more transparent, fair, and efficient than the current system. Decentralized finance is a new way of doing things in the world of finance. Transactions are done on the blockchain, which is like an open-source system. This means that anyone in the world can access the necessary financial services.

Decentralized financial services can be used for lots of different things, like paying bills, buying things, and more. Decentralized payment services let you pay people without having to go through a middleman. This means you can cut costs and make payments more quickly.

Tokenized assets are traded between the people involved without any need for a central authority. Derivatives trade in DeFi is done directly between the parties involved without a broker. Decentralized financial services are growing in popularity, and there are many different ways they can be used. Decentralized finance is a new way of doing business that uses digital assets and tokens to create more stable and secure financial products.

Cryptocurrencies are digital tokens that use cryptography to secure their transactions and to control the creation of new units. Cryptocurrencies can be used to buy goods and services, or can be traded on exchanges. Some people use DeFi applications to work with their cryptocurrencies in different ways, including lending them out, making them available to others, and receiving interest in return. Right now, DeFi offers a lot of different testing

grounds for experiments with finance concepts. Some are already in use, others are in the process of being tested, and new ideas are being developed all the time. The idea of "decentralized finance" is being put into practice in various ways.

Decentralized finance is a new way of managing money that is different from traditional banking. It involves using technology to make transactions between people and businesses more secure and efficient.

All these concepts are covered and explained as part of the teaching course, accompanied with real-world examples of how blockchain transforms the financial field.

4.1.2. DeFi methods

With the yield method a user provides some sort of liquidity. In return, the user receives reward in the form of an interest rate (yield).

Another one is the liquidity pool. This concept gained high traction with Uniswap. Liquidity pools extend the functionality of automated market makers. In a traditional exchange, brokers function as middlemen that handle transactions, allowing the users to trade peer-to-peer. A liquidity pool on the other hand utilizes smart incentives to create a peer-to-contract protocol.

Borrowing and lending is another popular DeFi use case. Here the liquidity pool mechanism lets users borrow and lend assets. A popular borrowing and lending protocol is Aave.

Because of the blockchain technology certain use cases can be created, which cannot exist in the mainstream financial system. For example, borrowing and lending through collateralization. Therefore, a user can risk going into liquidation if the value of their collateral falls.

4.2. Ethereum Development tools and educational community

The first step in blockchain education inevitably passes through Ethereum. It was the first smart contract oriented blockchain. Because of this, it is commonly referred to as the second generation blockchain protocol. This gives the ability of educators and developers to use its environment for introducing different types of education platforms and decentralized applications relevant to the learning process.

It has become quite important, because Ethereum's vast resource base, educational environment and learning materials were introduced first and had the most time to grow and mature.

Vitalik Buterin and Gavin Wood both founded Ethereum with focus on having a decentralized environment for developing dApps. Gavin Wood contributed and helped to create two pivotal assets:

- Ethereum Yellow paper (the initial technical documentation of Ethereum) [12]
- Solidity programming language

4.2.1. Ethereum Educational Environment

The Ethereum development documentation is the richest technical documentation that one can find for a blockchain protocol today and is constantly kept up-to-date and updated by the Ethereum foundation and the community [13].

The following topics provide an excellent entry point to blockchain-related knowledge:

- Decentralized Finance (DeFi)
- Non-fungible tokens (NFTs)
- Stable Coins
- Decentralized Autonomous Organizations (DAOs)
- Decentralized applications

One can get started on these topics easily by visiting and exploring the Learn hub on Ethereum's platform. Ethereum.org is giving an interactive environment for learning and educating right from the start including:

- Already pre-build development and educational environments (also known as sandboxes)
- Interactive game tutorials (being able to learn and play at the same time keeping the person involved interested in the process the whole time)
- Developer bootcamps
- Community tutorials

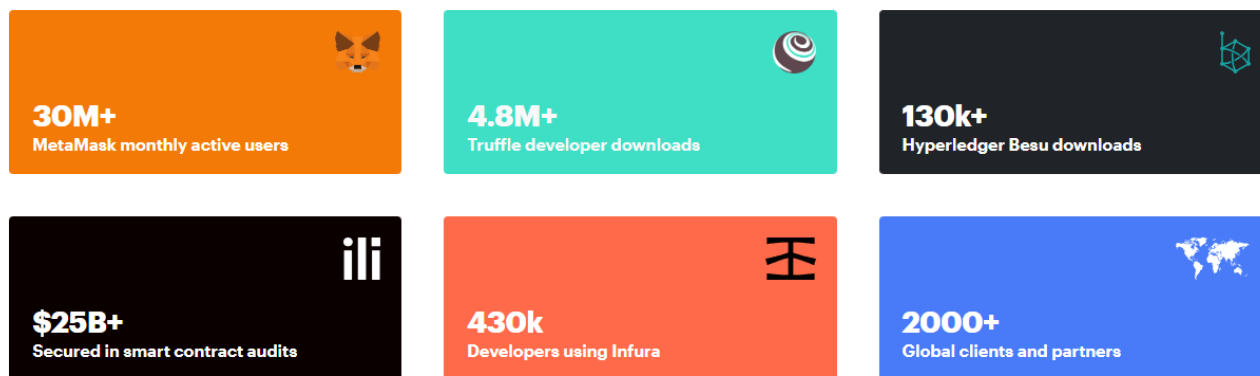
4.2.2. Educational and Development Frameworks

There are a couple of Frameworks widely used up to date, that give opportunities for learning and development. One of those is Truffle Suite. It is a complete toolset for Smart Contract development. It is made by ConsenSys and is part of an even bigger development stack for Ethereum, which includes:

- Codefi
- Diligence (Security audits for Smart Contracts)
- Infura (Instant API Access to Ethereum and IPFS)
- MetaMask
- Quorum

ConsenSys can currently be considered, as the provider for the most comprehensive tools and frameworks for the Ethereum environment. Tools like MetaMask and Infura are critical for the early stages of education courses – they present an easy initial setup and understandable UI. Statistics about their wide usage and adoption is shown on Figure 2.

Figure 2. Adoption rates of popular Ethereum tools are rapidly increasing.



Source: <https://consensys.net/>

Another popular framework is Hardhat. It is a development environment for Ethereum software. It consists of different components for editing, compiling, debugging and deploying smart contracts and dApps, all of which work together to create a complete development environment. It consists of:

- Hardhat Runner (execution environment)
- Hardhat Network (a local test Ethereum node used for development)

Hardhat is a good choice for starting education on blockchain development, because it gives a clear and direct approach when trying to solve Smart Contract development problems and issues. Also, this stack is much lighter than the ConsenSys full framework development stack and in this regard could be considered as a really good alternative for blockchain development educational courses.

Sandboxes are really good when a quick example of blockchain use case is needed. However, they represent a pre-build solution that usually runs on the web. Going through Sandbox solutions should usually be done after deeper understanding of the technical fundamentals of specific blockchain protocols. Some of the most useful and popular Sandbox solutions are:

- Remix – developing, deploying and administering smart contracts for Ethereum
- Eth.build – an educational sandbox for web3 including programming and open-source building blocks

We have found that it is best to follow a process that gradually incorporates more complex tools and frameworks as part of the teaching content. This process is illustrated in Figure 3.

5. CONCLUSION AND FUTURE DEVELOPMENT OF BLOCKCHAIN EDUCATION

DLT or Blockchain is considered as the next technology, business and law socioeconomic mega trend following the Internet. It is capable to provide people with an all-inclusive and disruptive technology. But to receive DLT advantages community need to learn, develop

and apply the needed regulation, business and technology competencies, and to change the rules of the game.

Figure 3. Gradually laying out blockchain knowledge and related tools.



Based on our practice and students' feedback, we can conclude that the students care a lot about what and how educators cover in the educational process. Teachers need to be more focused on the learning process and content and less on grades and traditions. Educators must change to new teaching environments and methodologies and be accurate about what the students value. There is nothing to be afraid to bring the lecturer's true self to the class, show the lessons learned, and who they really are.

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