

## ORIGINAL ARTICLE



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## Blockchain-Based secure framework for e-learning during COVID-19

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### Abstract

**Background/Objectives:** Tremendous growth of information and communication technologies (ICTs) have positively affected the field of E-Learning (EL). However, recently the education mode is shifted from the traditional classroom towards EL due to widespread COVID-19. The selection of suitable EL tool and security of EL data and environment are still the key challenges that need to be addressed. The objective of this paper is to guide the EL Practitioners in the selection of suitable EL tool and to provide a detailed framework for maintaining privacy and security of EL data and environment. **Purpose:** This study aims to help EL practitioners in the selection of suitable EL tool and to provide a secure framework for the security of EL data and environment. **Method:** Real-time statistics are gathered and analyzed to visualize the impact of COVID-19 on education around the world. The increasing demand for EL during COVID-19 is analyzed, and a detailed taxonomy is provided to make the EL practitioners aware of existing distance learning solutions. A comparison of commonly used EL tools is provided that will help in the selection of EL tools according to institutional requirements. A Blockchain-based EL framework is proposed that will help EL designer in managing the security of EL data and environment. **Conclusion:** The proposed framework is expected to provide a promising solution for developing a fair and open learning online education environment and will overcome the deficiencies caused by school closures during COVID-19.

**Keywords:** COVID-19; Blockchain; Security; Privacy; E-Learning; Digital Curriculum

### 1 Introduction

E-Learning (EL) is one of the popular modes of interactive learning that is free from the limitation of time and space. It is a good source of promoting quality education by getting the benefits of external resources and encouraging self-learning among individuals. However, it faces a lot of challenges such as complications of EL assessment, lack of assessment standards, the authenticity of EL certificates and most importantly, lack of security<sup>(1-3)</sup>. The EL model of education is prevailing in almost every part of the world, especially in developed countries which are having sufficient ICT infrastructure. Recently, the widespread COVID 19 (Corona Virus disease of 2019) has made the traditional face- to-face learning a risky process, and most countries are shifting towards

EL mode of education to avoid spreading of this life-threatening virus. As the economies and ICT infrastructure of many countries is not sufficient for this rapid paradigm shift from the traditional classroom mechanism to EL. Therefore, a lot of challenges are being raised daily. One of the key challenges that need to be addressed to make this EL process affective is incorporating sufficient end-to-end security mechanisms during the EL process<sup>(4-7)</sup>.

Blockchain was introduced in 2008 to serve as a transaction ledger of cryptocurrency bitcoin without involving the third party and making the transaction process transparent and secure. Blockchain is a growing list of records known as blocks in which each block is associated with the previous block using cryptographic techniques and together make a chain of blocks. This chain is spread over many computers, and each computer has a copy of it. These days, Blockchain is widely used in securing online systems by providing a distributed and reliable model<sup>(8-11)</sup>. It is like a peer to peer decentralized network that maintains security by enabling the self-protection mechanism at the individual node level. As records are stored on all the nodes that are part of the Blockchain, illegal manipulation of a record needed to make changes in almost more than 50% of the nodes that is practically impossible. The key benefits associated with Blockchain are transparency and verification of records; therefore it is best suitable in the EL process<sup>(12-15)</sup>.

The alarming virality of COVID-19 has put traditional mode of learning to a halt, and EL apps are becoming the only source of suspended, educational activities. Several solutions were presented on an urgent basis to overcome the disruptive situation around the globe. EL execution fully depends on the internet, and there are a lot of illegal activities and security attacks taking place on the internet<sup>(16)</sup>. As a result, the EL environment is also exposed to various security threats. One of the key reasons for the increase in security threats in the current time is a huge paradigm shift from the traditional educational system to EL because of wide spread COVID-19. In such a situation, the focus of EL solution providers is towards providing quick EL solutions for educational institutions without carefully addressing the security aspect<sup>(17-21)</sup>.

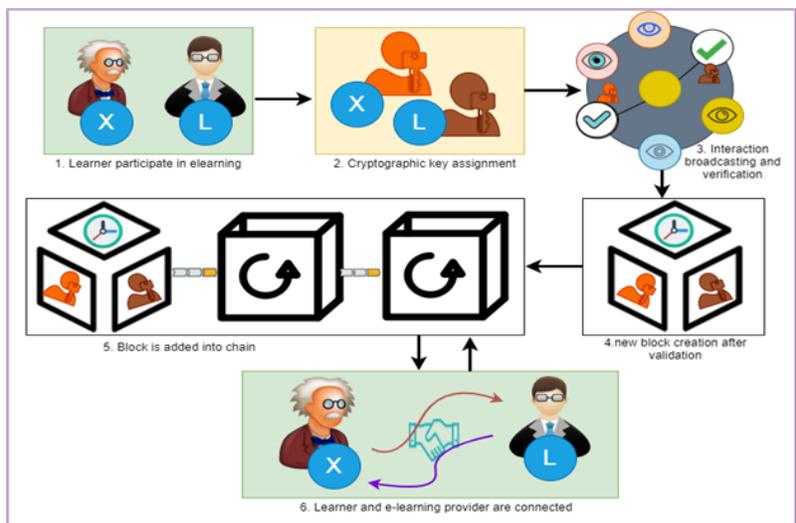


Fig 1. How Blockchain works in EL environment

Security in EL means that all the learning resources are available to the students without any impairment. In such a situation, Blockchain helps in providing a secure and transparent solution for EL environment. Figure 1 provides a scenario of Blockchain usage in EL. According to Figure 1; learner participates in an online course and EL provider access learner’s record for checking prerequisites and other criteria for progression. Once the learner and EL service provider are authenticated using cryptographic hashing techniques, a secure and transparent communication channel is established between them. Once, all the authentication is done, the information of the learner and EL provider are added into the block. When the learner finishes his course, a new block is created that includes course information, results of the course and the timestamp. The learner gets verification about achieved course qualification through Blockchain. The learner can see and manage his qualifications online and can share it with potential employers as well. Further, as the information in Blockchain is multilingual; the chance of missing documents can be avoided. Therefore, EL providers can also access the record of the learner for future recommendations. In the future, the potential employer can also validate the authenticity of the learner’s certificate. Thus, Blockchain not only makes the EL environment secure; rather, it also provides other supportive functionalities<sup>(22-26)</sup>.

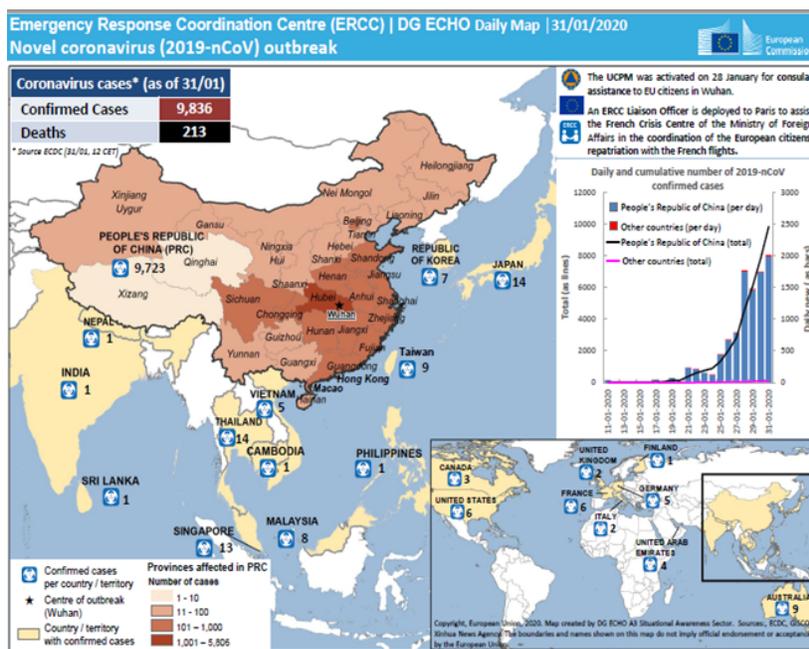
The remaining part of this paper is organized as: Section 2 provides the review of literature which includes the effect of COVID 19 worldwide, the effect of COVID-19 on education, a paradigm shift towards EL, existing EL tools and their comparison along with privacy and security issues associated with EL tools. Section3 describes our proposed framework, followed by section 4 that discusses the key findings. Section 5 concludes the paper and provides directions for future research.

## 2 Literature Review

COVID-19 was originated in late 2019 when a mysterious illness was reported in Wuhan a city of China. Since then, it has spread to more than 100 countries in the world and has become a critical global issue. WHO is working round the clock to provide advice, help and prepare the countries, increase expert networks to manage and control the wide spreading of COVID-19. It has also launched free messaging services (in various languages) in collaboration with Whatsapp and Facebook to provide awareness to the common people regarding this rapidly growing communicable disease. In the section below we provide a broad picture of COVID-19 and its impact worldwide

### 2.1 Effects of COVID-19

Most cases of COVID-19 appeared at the end of December 2019 in Wuhan, a city of China in the form of severe pneumonia. However, within a few weeks, this disease has impacted almost more than 100 countries of the world. Some of the common reasons for this widespread disease include imported cases in travelers, close contact with affected persons and community-acquired cases where infection source is unknown. Currently, COVID-19 has become the most important global issue and a lot of world organizations, including WHO is working to overcome this problem (27-29). Most of the countries have adapted lock-down strategy to overcome the widespread of this fatal disease. Reports of COVID-19 spread is generated daily to keep the people up-to-date. Emergency Response Coordination Centre (ERCC) that is responsible for managing emergencies round the clock has presented its reports about COVID-19 on a weekly basis (21,30). In this study, the reports of COVID-19 from the end of January to end of March provides the effect of this disease worldwide as shown in Figures 2 and 3.



and Vietnam (5 out of 9836) each, UAE (4 out of 9836), Canada (3 out of 9836) and UK and Italy (2 out of 9836) each. On the other hand, only one case was reported in the Philippines, Cambodia, Sri Lanka, Nepal, Finland, and India each. No case was reported from other parts of the world until the end of January 2020. From the total reported cases, 213 out of 9836 were dead, and this shows the death ratio of almost 2.16 %. According to another report that was presented by same organization on 27<sup>th</sup> March 2020 and presented in Figure 3, the number of confirmed COVID-19 cases reached 528,025 which was about 54% increase in COVID-19 cases as compared to the report of 31<sup>st</sup> January 2020. This rapid increase was an alarming situation for all the world. The picture of COVID-19 was changed in the last two months. China that was the key victim of COVID-19 till the end of December became second in the list. USA and Italy became the key victims of COVID-19 at the end of March 2020. Some other key victim countries include Spain, Germany, Iran, France, the UK, Switzerland, and South Korea.

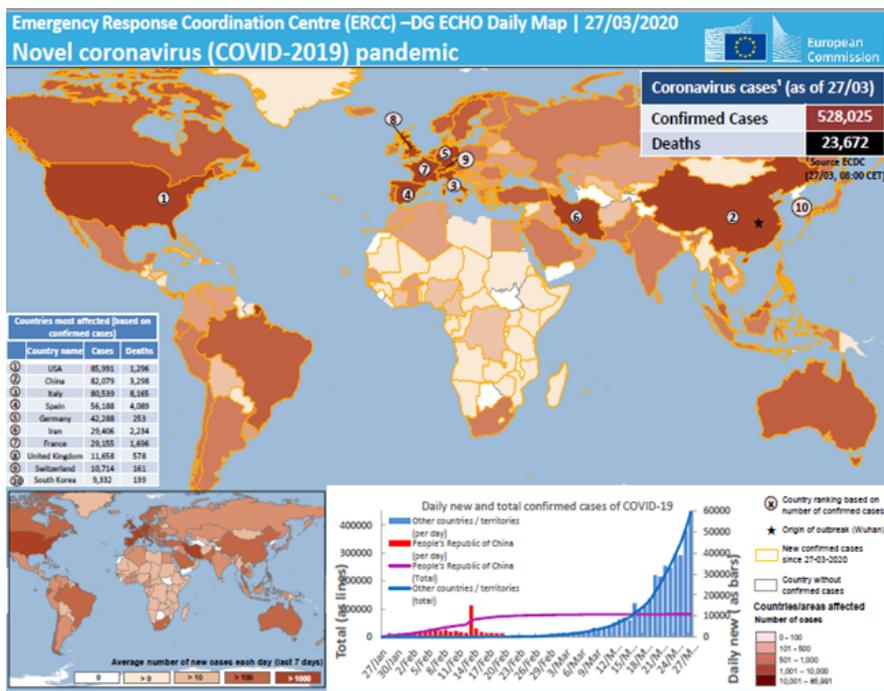


Fig 3. ERCC COVID-19 statistics on 27 March 2020 (32)

If we analyze the statistics of Figure 3, death statistics from COVID-19 increased to 23672 out of 528,025 that is almost 4.5 %. If we compare the results of 31 January with that of 27 December, the situation is alarming as reported cases increased to 54 % and death ratio also increased from 2.16% to 4.5%. The lower part of figure 3 is showing bi-weekly statistics for the last two months, from 27 January to 27 March. Figure 3 depicts that China has dealt with the issue effectively since the expansion curve declined drastically after the mid of February. On the other hand, the spread of COVID-19 is significantly increasing in other territories of the world. China was the origin of COVID-19, around 2/3 of the global cases were recorded from the Chinese province of Hubei, where it emerged in December 2019. China has controlled this widespread disease so fast that now the majority of the cases are out of china. Some strict measures taken by the Chinese government include strict lockdown policy, isolation techniques, use of mask and hazmat suits, etc. China has not only controlled COVID-19 rather it has also reduced the death ratio by taking timely measures. Figure 4 provides a comparison of COVID-19 cases in the Hubei province of China and the rest of the world (33,34).

The graph in Figure 4 shows a significant reduction in COVID-19 cases in China over time. On the contrary, it is increasing significantly in other parts of the world. This shows that the rest of the world needs to follow the measures that were taken by the Chinese government so that the world may get rid of this global epidemic disease.

Worldometer is also providing its statistics about COVID-19 on an hourly basis. This reference website is run by an international team of researchers, developers and volunteers to provide real-time statistics about world population, economics, government, food, energy, society and media, health and water. Figure 5 provides the detailed statistics of COVID-19 as per Worldometer statistics from 22nd January to 27th March. The graph of Figure 5 shows the total number of COVID-19 cases worldwide, those which were cured and the statistics of fatalities or death.

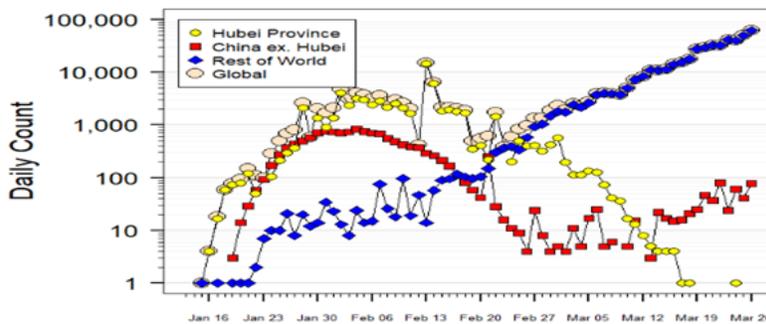


Fig 4. COVID-19 daily cases by region (16 January 2020- 26 March 2020) (35,36)

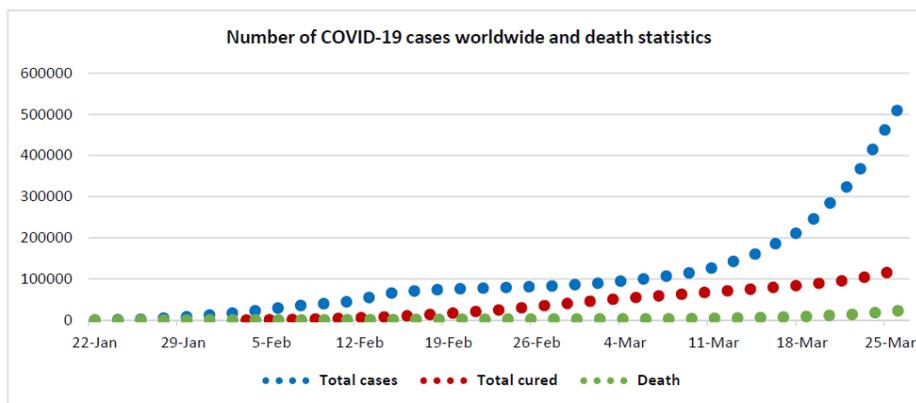


Fig 5. COVID-19 Statistics by Worldometer (22 Jan to 26 March 2020) (37)

According to the results presented in Figure 5, the total number of cases are increasing worldwide. The total cured ratio is better than death statistics, still, more analysis may provide the factors that affect it. According to the report presented by WHO China, COVID-19 fatality rate varies with age, sex and comorbidities. In this report, 55,924 confirmed cases of COVID-19 were analyzed and effect of age, sex and comorbidities were presented as shown in figures below

According to the WHO-China report as presented in Figure 6, age is an important factor for resistance against COVID-19. The people with age group above 80 are more vulnerable to COVID-19 and fatality ratio is high among this group. On the other hand, fatality ratio is zero for the children below 9 years. This shows that older population is prone to COVID-19.

Figure 7 shows the fatality statistics of COVID-19 w.r.t. gender. According to Figure 8, fatality ratio in males is high as compared to females. Similarly, the fatality statistics w.r.t. comorbidities is presented in Figure 8, according to which the victims of COVID-19 who are already suffering from pre-existing medical conditions are more vulnerable to COVID-19 as compared to those who have no pre-existing medical condition. From these comorbidities, the fatality from COVID-19 is high among patients with cardiovascular diseases (39). Similarly, patients with diabetic problems, chronic respiratory disease, hypertension and cancer patients are also more vulnerable to COVID-19 as compared to the normal persons having none of these diseases.

## 2.2 Impact of COVID-19 on Education

COVID-19 is a global issue, and a lot of efforts are going on to stop the wide spread of this life-threatening virus. In this regard, some key measures that are taken by the majority of the world governments include social distancing and self-isolation. Although this social distancing and self-isolation have impacted almost every field of life, however; one of its major impacts is on Educational system that has far-reaching societal and economic consequences. According to UNESCO, about 100 countries have implemented closure of educational institutions nationwide that is impacting almost 90% of the world population. Figure 9 shows the staggering impact of COVID-19 on education in the last two months

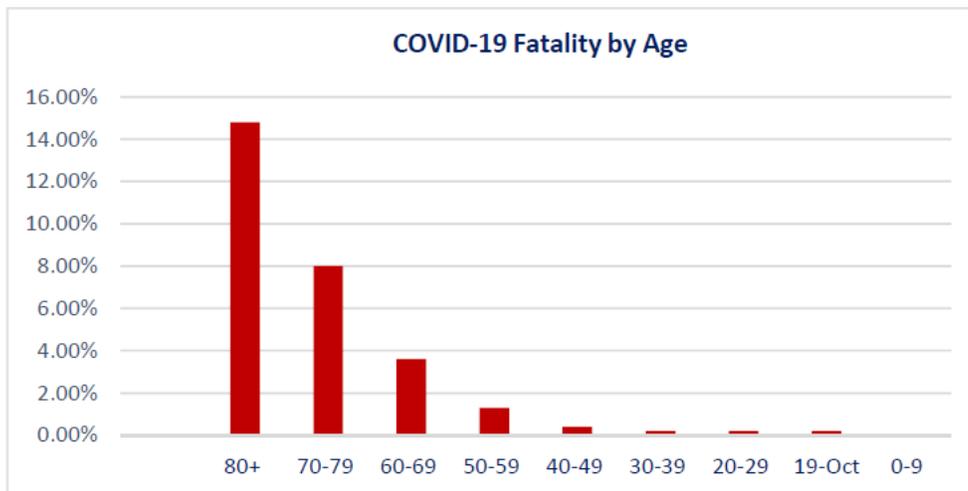


Fig 6. COVID-19 fatality percentage by age<sup>(38)</sup>

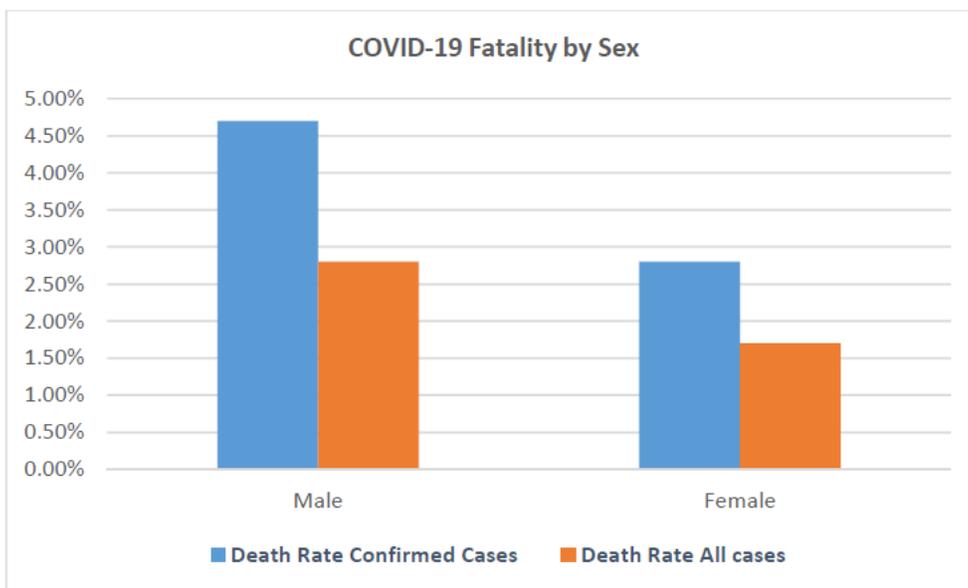


Fig 7. COVID-10 fatality percentage w.r.t Sex<sup>(38)</sup>

Another report was presented by Statista on 4th March 2020. According to this report, millions of children were affected by school closure all over the world. Figure 9 provides the statistics of these children across various countries of the world. The closure of educational institutes not only disrupts interactive teaching facilities for students around the world, but rather assessment also couldn't be done on proper time, and a lot of assessments have been cancelled or postponed. Internal assessment is the only source to showcase child's progress to their parents. The loss of this progress information may have long-term consequences as parents are not able to recognize potential difficulties faced by their children. A lot of specialty certificate examinations have also been cancelled. The graph of Figure 10 provides the statistics of school closure in various countries of the world as per 4th March 2020

According to the recent report published by UNESCO, the number of learners that are affected by school closure reached 1,543,446,152, which is almost 90% of total learners. Figure 11 provides worldwide statistics about school closure locally and country-wide. Localized closure means closing educational institutes at the city/state/province level while Total closure means

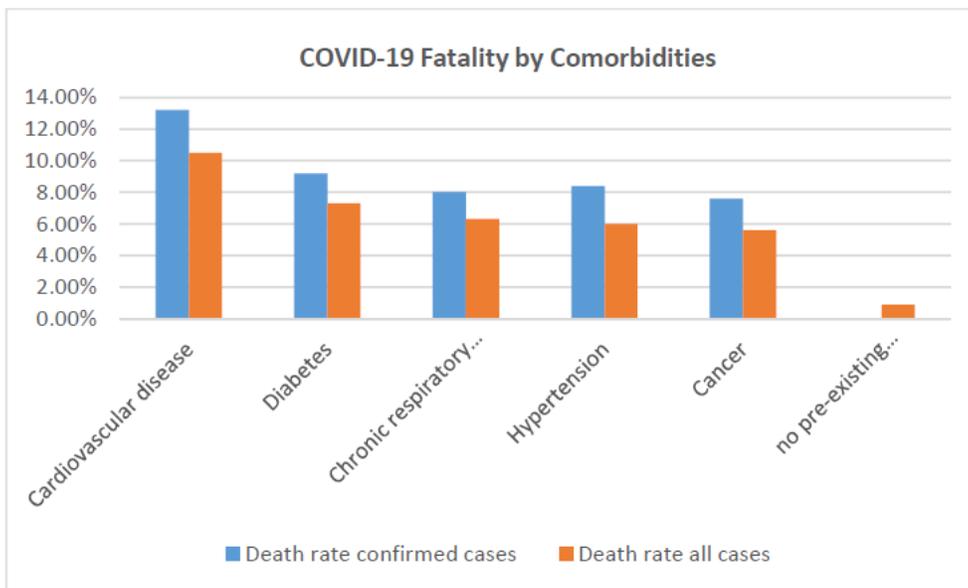


Fig 8. COVID-19 fatality statistics w.r.t comorbidities<sup>(38)</sup>

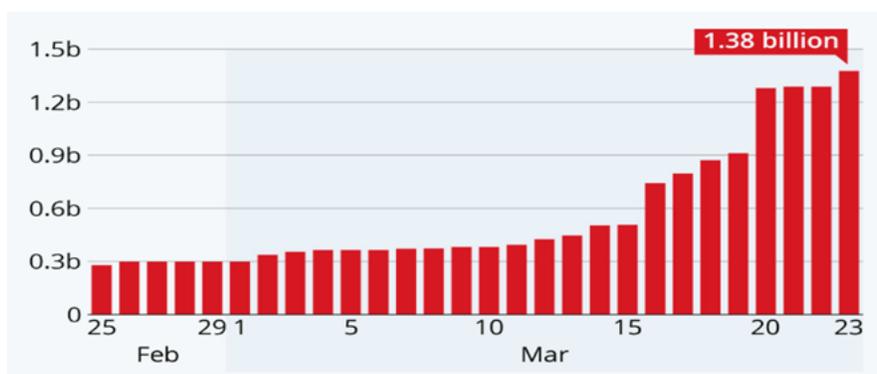


Fig 9. Learners impacted by school closure worldwide (25 Feb-23 March 2020)<sup>(40)</sup>

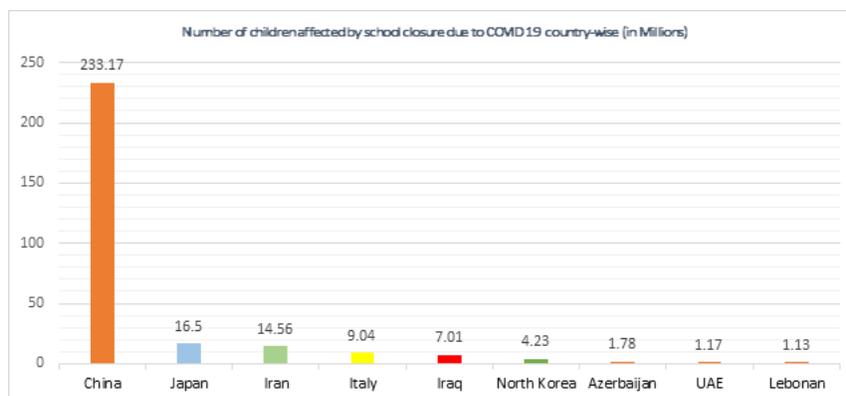


Fig 10. Number of learners affected by COVID-19 worldwide (4 March 2020)<sup>(41)</sup>

the closure of the school at a localized level and nation-wide. According to Figure 11, the number of school closures is increasing every week. These statistics include the number of learners at pre-primary, primary, secondary and tertiary education levels<sup>(42)</sup>.

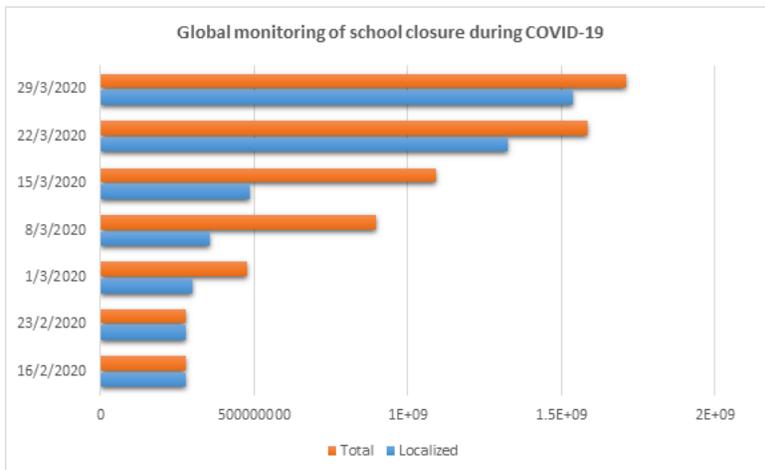


Fig 11. Global closure of schools during COVID-19

### 2.3 Raise the need for E-Learning

Education plays a vital role in the development of any country; therefore, the natural disaster such as COVID-19 may affect it but cannot stop it completely, especially in the current era of technology. Many educational institutions around the world are already shifted towards EL mode of education and others are working on it. UNESCO and other well-known organizations recommend EL mode of education to overcome the adverse consequences of education disruptions. However; reliable internet access, especially in rural areas, lack of technology awareness and access are key challenges towards this end. Despite the limitations involved in EL, a lot of institutions around the world are shifting towards it, and a key benefit associated with this paradigm shift is increasing teachers’ confidence in technology and EL platforms<sup>(43–45)</sup>. EL platforms are already available in many institutions around the world, such as the blackboard system. It is the leading provider of EL solutions and is serving more than 16000 clients across 90 countries and is reaching more than 100 million users. A lot of limited free tools are also available for the developing countries and the institutions which are lack in having proper EL platform. These tools include Microsoft teams, Team viewer, Trello, eFront, LoveMyskool, etc. However, currently, there is a need for quick adaption to rapidly changing circumstances, preparedness and willingness to collaborate<sup>(46)</sup>.

One of the key challenges that are faced by almost all individuals involved in education is the selection of suitable tools for EL and the knowledge about existing tools. Figure 12 depicts a detailed taxonomy of existing online learning tools, which are further classified into 8 main categories, namely; Digital learning management systems (DLMS), Massive Open Online Course Platforms (MOOCP), Self-directed learning content (SDLC), Mobile reading applications (MRA), Collaboration platforms that support live-video communication (CPLVC), Tools for teachers to create digital learning content(TCDLC), External repositories of distance learning solutions (ERDLS), Systems built for use on basic mobile phones(SBM) and Systems with strong offline functionality (SSOF)<sup>(47)</sup>.

There exist a lot of tools to support distance learning as shown in the taxonomy of Figure 12, however, our main focus in this paper is on EL which means an interactive learning to process that is an alternate of a traditional classroom for students<sup>(48)</sup>. Table 1 provides an overview about existing EL tools that are commonly being used by educational institutions during COVID-19 along with the key features associated with them. This will help educational practitioners in better selection of tools

Table 1 provides the common EL tools that are used to support the learning process especially during COVID-19 where the traditional classroom has become a dream in major parts of the world. The data of Table 1 will help in choosing a suitable tool according to the institutional requirements.

### 2.4. Security and privacy issues in EL

The rapid adaption of the EL paradigm due to COVID-19 has raised many issues. One of the key issues that need to be addressed is security, as EL systems collect sensitive data of students that can be misused, these systems need to protect the contents and

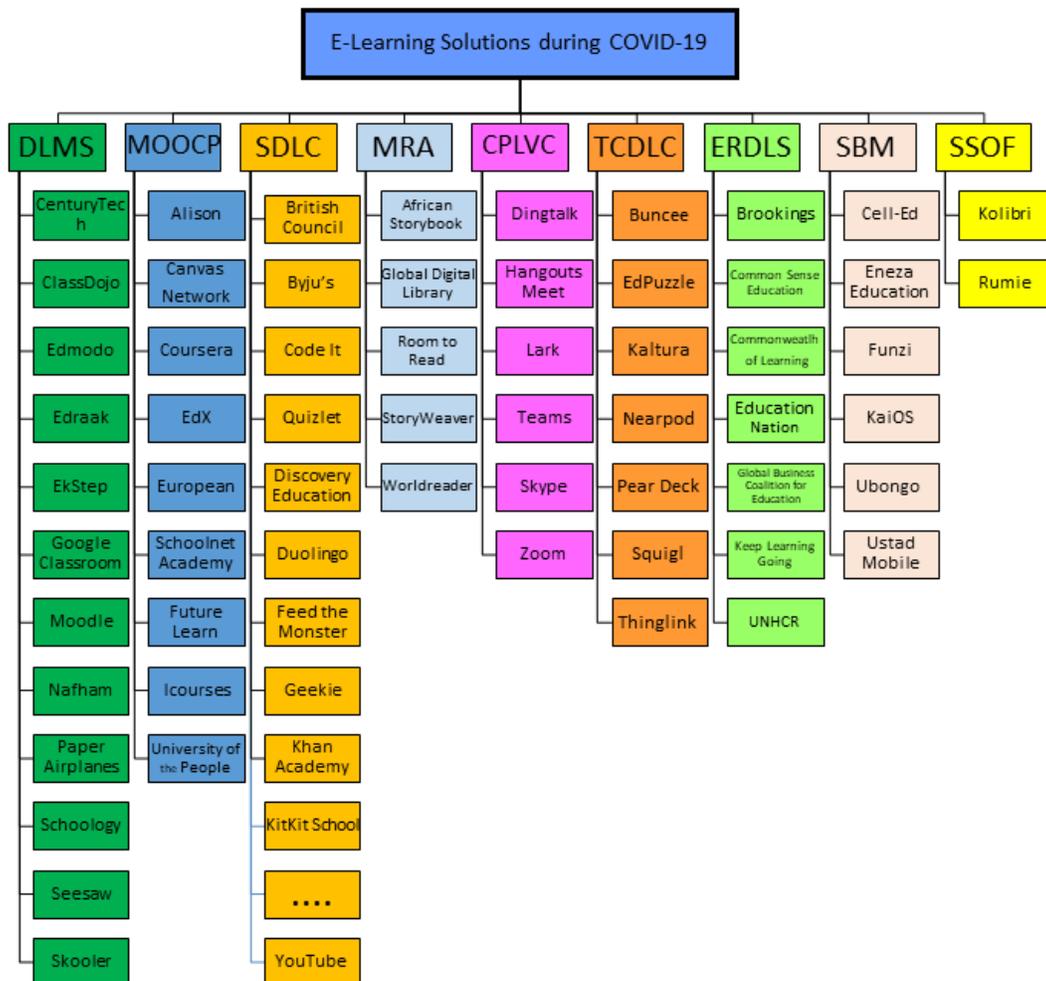


Fig 12. Taxonomy of e-learning solution by UNESCO

personal data of students from intruders. To address this gap, the traditional centralized EL platform is not enough due to the limitations of limited transparency, low scalability, single point of failure and more vulnerable to security threats. Therefore, peer-to-peer EL platforms are better as they can easily accommodate the rapidly growing number of users<sup>(49,50)</sup>. A key reason for security threats in the EL platform is that more attention is given towards course development and delivery. While minor consideration is given to security and privacy threats. Some open-source EL platforms have tried to address the security issue by releasing different versions; still, this approach is not sufficient for providing end-to-end security and it has become a broader issue<sup>(51,52)</sup>

Although some of the Open-source E-learning platforms have realized the importance of security, and they have been improving it by releasing different versions continually, meeting the increasingly strict security requirements needs more explorations and efforts. Existing security solutions in EL are usually classified into the following three categories, namely: Password, ID card, and Biometric/face recognition. Out of these three methods, the first two methods are vulnerable to losses or forgetful-

**Table 1.** Comparison of existing e-Learning tools

Tools	Availability free*/paid	Video conferencing	Content sharing	Mobile support	Comments / feedbacks	Supported assesments
Blackboard	paid	yes	yes	yes	yes	Assignments Surveys Quizzes(MCQs, True/false, Fill in the blanks, short questions, Essays, file response, Colum matching)
Nearpod	Paid	Yes	Yes	Yes	Yes	Assignments Polls Quizzes (open-ended questions, fill in the blanks, draw its)
Microsoft teams	Free*/paid	Yes	Yes	Yes	Yes	No
Zoom	Free*/paid	Yes	Yes	Yes	Yes	No
Team viewer	Free*/paid	Yes	Yes	Yes	Yes	No
Google class-room	Free	Yes	Yes	Yes	Yes	Assignments Quiz assignments using Google
Skooler	Paid	Yes	Yes	Yes	Yes	Assignments Quizzes
Schoology	Free*/Paid	Yes	Yes	Yes	Yes	Assignments Quizzes
ClassDojo	Free	Yes	Yes	Yes	Yes	No
Moodle	Free	Yes	Yes	Yes	Yes	Assignments Quizzes
Desire2Learn	Paid	Yes	Yes	Yes	Yes	Assignments Quizzes
Canvas	Free	Yes	Yes	Yes	Yes	Assignments Quizzes

ness. The biometric method is somehow more secure than the previous two methods; still, it has its shortcomings. Apart from access control, encryption is also an important concern in EL platforms. Encryption is very important for keeping the confidentiality, authenticity, and integrity of educational resources and students’ data. Therefore, the developers of the EL platform needs to develop a secure encryption system to protect both learners and EL providers<sup>(53)</sup>.

Privacy and security issues linked to online applications could be effectively addressed using Blockchain. It is widely been used in various sensitive applications such as banking, business transactions and nowadays in education as well<sup>(49,54)</sup>. It is not a new technology rather a rearrangement of existing technologies deployed in a better way. Some examples of Blockchain use in education include blockcerts and Ethereum apps. Blockcerts is a mobile app that was developed for securing educational credentials using Blockchain technologies. Ethereum is a system that was developed to allow a secure transaction using smart contracts<sup>(55)</sup>. These apps are used in many other fields other than education. A Blockchain is a decentralized approach in which information is distributed on various nodes; therefore, it is difficult to hack it<sup>(54,56)</sup>.

### 3 Proposed Framework

The above discussion shows that EL is the only supplement that can cope with the loss of school closure due to COVID-19. However, security is one of the main issues in existing EL systems that need to be addressed. In this section, we propose a Blockchain-enabled framework that will address the issue of security and will help the EL system designer in better understanding for the development of secure EL platforms. Our proposed framework is based on 5 layers as shown in Figure 13: Layer 1 is the cloud layer that serves as a hosting layer. Due to an abundant number of users involved in EL, especially during COVID-19, the cloud is the only solution where EL providers can host their software. The benefits of using the cloud for hosting EL software is to provide fast and round the clock availability of data to its intended users. Cloud has its security mechanisms; therefore tracking the data is difficult as compared to storing it on a local server. EL data is a big data which include multi-

media streaming, using the cloud service will solve the limitation of bandwidth as well<sup>(57)</sup>. Cloud computing is very useful for academic institutions that are having a shortage of budget and want to host their EL platform effectively. These institutions can't afford to buy computers, pay licensing costs, and other supporting elements such as power, servers, cooling system, network devices, maintenance team, etc. Therefore, cloud computing is an ideal situation. In EL with cloud computing, the user only needs a cell phone or computer with internet access to use the EL platform from anywhere<sup>(58)</sup>. The second layer is the Blockchain layer: this is the most important layer which serves as a secure platform between EL applications and the cloud. The major security breaches occur when EL applications access data from the cloud; therefore Blockchain is an ideal solution for maintaining security<sup>(59)</sup>. It allows secure transactions and transfers of data at a low cost. To ensure security, cryptographic proof of identity is used for user authentication. Each network participant owns a private key that is assigned to the transaction made and this key acts as a personal digital signature. If there is any illegal modification in the record, the signature becomes invalid, and the peer network will be notified about it. Hence, early detection of security breaches is also possible with Blockchain. The third layer is the EL system that serves as a platform through which user and administrator access learning contents. Layer 4 includes key users of EL system which comprise of teachers, students, educational institutions etc. The number of EL users have tremendously increased after COVID-19 and lot of security breaches have been reported on a daily basis. Therefore Blockchain enabled security mechanism is best suitable for overcoming the security breaches and solving the rapidly increasing demand of EL in the current critical situation.

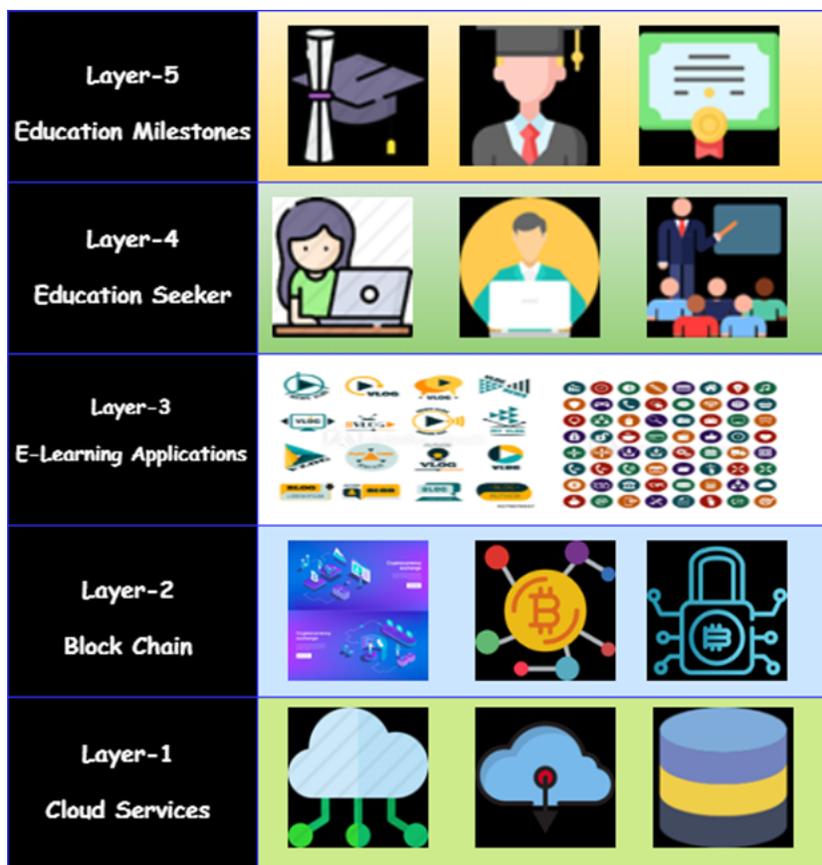


Fig 13. Blockchain-based EL framework

The 5th layer of the proposed framework is milestones of an education system that might be passing out the students so that they could serve their nations. In today's critical situation where there is a huge demand for professionals especially in the field of medicine, scientific research, Information technology, economy, etc. managing the education system effectively and without delay is very important. EL has an important role to play in combating COVID-19 by removing delays in education and preparing good professionals on time. The proposed scheme will help the EL practitioners and researchers to address the problem of EL security so that the maximum benefits of EL could be utilized.

## 4 Discussion

Education is the most important sector of modern economies which prepares the individuals for working effectively in a society. Indirectly, all other fields are somehow dependent on it. A good education provides good professionals who contribute immensely to the society. All the developed countries have reached their milestones through proper education and hard work. To improve the educational system, modern societies are using the blend of face-to-face education with EL. Recently, the widespread COVID-19 epidemic has highly effected the education sector of almost all the countries. Billions of educational institutes around the world are closed due to lock-down strategy adapted for overcoming COVID-19. In such a situation, students' career is on the risk and society will face the delay in getting good professionals on time if the education process continue to be affected. In such situations, EL is the best solution that provides an online interactive learning environment for the students. COVID-19 is a global issue, and we all need to play our part for the smooth running of economies. EL is not the new phenomena; a lot of educational institutions in the world are using it from past two decades. However, the dominant mode of education all over the world was face-to-face interaction where the learner attends the school and appears to the classes and assessment physically. Currently, due to COVID-19, this mode of education is not possible, and paradigm is shifted to EL. The whole world was not expecting this quick paradigm shift, and they were not fully prepared for it. Although there exist a lot of EL platforms to assist the teachers and students in continuing their education. However, the availability of course contents was more valued while designing these systems and the security aspect was neglected. Due to which a lot of security breaches in EL systems are reported daily.

EL system keeps the personal information of students and a lot of heterogeneous data is generated daily. Therefore, the proper implementation of the security mechanism in the EL system is indispensable. To assist the EL learners and practitioners, it is necessary to make them familiar with existing EL systems and also guide them about how to ensure the security of EL system contents. To address these gaps, this paper provides a list of commonly used distance learning solutions that can be used during the current COVID-19 situation. We have also provided a comparison of some commonly used tools based on the important features. This will help the EL practitioners to choose the best solution according to their needs. Further, we have provided a 5-layered framework based on Blockchain. This framework will help the EL system developers in implementing proper security mechanisms while designing EL solutions.

## 5 Conclusion

The widespread COVID-19 epidemic has affected the educational system worldwide. Currently, billions of students are out of school due to this current health threat. According to UNESCO, over 100 countries of the world have announced school closure. In such a situation, the educational system is shifted to the EL platform in which interactive learning is provided to students using the internet. However, there are a lot of challenges associated with it, such as the facility of internet- connected devices, especially in rural areas, the problem of bandwidth, loss of connection, etc. However, two key challenges need to be addressed to supplement the current education system. Firstly, the learning providers are not aware of the existing solutions; therefore, they are not able to choose a suitable solution according to their needs. Secondly; the EL system involves personal information of the students that need to be secured from unauthorized access. To address these issues, this paper first provides a taxonomy of existing distance learning solutions that might be used in the current situation. Next, we have provided a comparison of commonly used EL solutions based on key features that are required in the educational system. This research proposed a secure EL framework using the Blockchain. The proposed Blockchain-based layered architecture for implementing security in existing EL solutions. In the future, we are planning to test the proposed framework by implementing it in a real-life EL system.

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