




# Role of Internet of Things and Cloud Computing in Education System: A Review

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**Abstract.** The current outbreak of the coronavirus (COVID19) pandemic has affected education across the world. To meet the current challenges posed by COVID19, educational institutions (schools, colleges and universities) need to be more efficient in providing quality educational services virtually. Cloud computing and Internet of things (IOT) are such technologies that accomplishes this. In this work, we review the recent works related to the cloud technology and IOT in education system and explores its various benefits and challenges. Furthermore, this article examines recent work on the potential scope of IoT in the Education Sector.

**Keywords:** Cloud computing · Virtual learning · Internet of Things · Online teaching · Virtual classes · Smart device

## 1 Introduction

The international quarantine imposed since December 2019 due to the coronavirus pandemic has put pressure on us to reconsider the idea of e-learning [1]. Cloud computing is a must-have within the academic process, and it is widely employed in enterprises. For individuals in every aspect of the process of mastery, cloud technology makes training a true and enjoyable pleasure. With the help of smart devices, students can now communicate with each other or with teachers and experience the flexibility of learning. The offerings of cloud computing have advanced the results of an institution's study and have allowed professors and college students to access this modern technology as well as receive additional blessings. Over time the educational system has changed and at the same time is no longer limited to blackboard classrooms and textbooks. Training in the cutting edge landscape of cloud computing has emerged as an advantage for the commercial enterprise, while all and sundry are trying their hardest to combat the virus posed by COVID-19 [18]. From preserving scholarly data to storing information, from online training systems to advanced study analysis, it has completely revolutionized teaching-learning training. Students, professors, and instructors can now enjoy cloud-primarily based totally training's accessibility and convenience. The Internet of Things connects processes, people, data, and devices, making it easier for education stakeholders to convert data acquired from portable devices and sensors into useful information

and to take meaningful steps taken in response to that facts [2]. It is crucial to consider the influence of IoT adoption in order to understand the problems and benefits of Internet of Things in Education, especially as IoT is still in its early stages in the education system. The Internet of Things provides numerous advantages, including: the development of intelligent interactive classes; the ability to customize dynamic models in which Students are active learners process; the encouragement of imagination; as well as real-time monitoring of students’ cognitive processing. The COVID19 epidemic has put a strain on both research and the use of new technology in education. Higher interest in this study issue is indicated by an increase in the number of publications on the use of IoT in education, while contemporary educational practices are a factual evidence of such interest. Nevertheless, due to the fact that those possibilities are limitless within a cloud pack- age and educational process, this research focuses on providing the recent progress related to the cloud technology and IOT in education system along with its benefits and challenges.

**1.1 Cloud Computing and Education**

Cloud computing is a method of delivering a variety of services via virtual machines that are placed on top of a big pool of actual equipment in the cloud [3]. Services are stored in laboriously scalable information in visible form centers fashionable the cloud and accessed via the internet by some connected scheme. In the dispersed cloud environment, we have a lot of compute power and storage capacities. Some applications of cloud technologies in education are depicted in Table 1.

**Table 1.** Examples of the application of cloud technologies in education

Google Classroom [4]	Google Classroom is a cloud-primarily based totally gaining knowledge of control machine this is a part of the Google Apps for Education suite of products. Students can use Google Classroom on PCs, tablets, and cell-phones
Blackboard [5]	Education, mobility, communication, and trade software program, in addition to associated services, are furnished via way of means of Blackboard to customers together with instructional institutions, enterprises, and authorities agencies. In January 2014, round 17,000 faculties and businesses in a hundred nations had been the use of its software program and services
Knowledge Matters [6]	Knowledge Matters is a major virtualized online firm that teaches important business principles to college and high school students through interactive web, game-like business simulations
Coursera [7]	The most well-known educational site, in my opinion. Anyone can study a wide range of subjects on Coursera. There isn’t a single student in the United States, Canada, Thailand, Russia, or Ukraine who isn’t aware of Coursera’s opportunity to gain valuable knowledge

*(continued)*

**Table 1.** (continued)

Microsoft Education Centre [8]	The Microsoft Education Centre turned into supposed to permit college students to retain studying irrespective of their circumstances. They make on- line studying viable and offer the best training to each and every student
Classflow [9]	Classflow is an interactive screen-based course delivery program that runs in the cloud. They offer customers unlimited access to lessons and learning tools without a subscription

## 1.2 IOT Enabled Education Environment

The Internet of Things is changing the way we live by transforming every product becoming an intelligent entity. All of this is correct in the teaching institution, where a veritable cycle of power is intelligently carried from Smart University, Smart Classroom, Smart Learning, Smart Learning and Smart Teaching to Smart Analysis (Table 2).

**Table 2.** Smart education

Smart Education	The purpose of smart education is to educate students with the skills and expertise they need to succeed in today's market. Smart education's success is dependent on sensing devices, an IoT infrastructure, communication linkages, and user apps. The IoT integration in the classroom institution would conclusion in higher educational quality since students will learn quickly and teachers will be prepared to carry forward their educational duties more efficiently [10]
Smart University	A smart university combines cutting-edge hardware and software, cutting-edge concepts, education techniques based on trendy, learning tactics, and smart teaching and smart classrooms equipped with cutting-edge technology [11]. A smart university has access to a diverse range of worldwide materials, an interactive teaching environment that can be examined inside the network, and learning that is flexible to data acquired. Many institutions have IoT devices such as temperature control devices, security cameras, electricity, heating systems, and building access devices
Smart Classroom	A smart classroom is a location where students can access educational activities utilizing electronic equipment such as internet-connected gadgets, digital screens and video projectors [12]. Beginning in 2012, a smart class is built on automated communication devices, mobile learning and mobile technologies, which use cameras, facial recognition algorithms, video projectors, sensors, and extra modules to keep track of many characteristics of the natural environments. When machines are linked to the Internet of Things, they form a smart class that allows access to knowledge from everywhere and at any time. A smart class offers numerous advantages, including greater information communication, flexibility, interactive learning, educational content exchange, and improved thinking capacities

(continued)

**Table 2.** (continued)

Smart Teaching	The manner in which information is transmitted via electronic devices can differ greatly from traditional teaching approaches. The material is always accessible, and Learning is adaptable, allowing you to stay up to date on the most recent advancements. The Internet of Things may provide access to the actual world, which might make teaching difficult because it must be adjusted and adapted to meet the needs of students with various impairments. Teaching methods must also be modified to accommodate students with disabilities
Smart Learning	Smart learning is a learning approach that makes use of electronic gadgets. According to [13], smart learning is a procedure that assists students in learning by focusing on the subject as well as the students themselves. This technology's intelligence, adaptability, and efficacy are dependent on the ICT infrastructure. The usage of Internet of things e-learning apps is critical for establishing a virtual classroom and a competitive learning process, both worldwide and locally. Because Students have access to every library or lab throughout the universe to collect data, conduct experiments, and send assignment or for self-evaluation and be assigned, the Internet of Things fosters online self-teaching
Smart Assessment	Smart assessment [14] goes beyond the traditional methods by adding other types of evaluation, such as interviews and focus groups. To make an accurate assessment, we must consider the effects of modern technology on how we work. The evaluation process then evolves as we engage inside an ever-expanding IoT ecosystem. To capture student behavior in online learning assessments, new learning systems must have the appropriate technologies. The Internet of Things instruments are available for use in assess the student's concentration, which is critical in assessing their education. It is feasible to design adaptive exams that are adjusted to the student's responses to questions and are presented in the student's preferred learning style. This type of examination would allow us to delve into the students' knowledge, how they understand and apply it, as well as their learning styles and skills. The usage of simulations during educational activities is an important component of smart assessment and can also be utilized as a learning approach

## 2 Literature Review

### 2.1 Cloud Computing in Education

In recent years, cloud computing implementations have attracted attention in several areas, including higher education in emerging markets. In this section we present a review of the adoption of cloud computing on education. Moodle was investigated [15] as a case of cellular cloud gaining knowledge of structures in better learning. Posted in [16] an overview on the use of mobile cloud computing (MCC) within the instructional field, which summarized the demanding conditions and troubles that MCC requires to gain knowledge of structures, as well as privacy, interoperability arise because of. The cognitive load on college students due to exceptional operating platforms, information integrity, community availability and community speed, and large learning materials and courses. Cloud computing (CC) in education was evaluated from the perspective of teaching staff and IT professionals in Saudi Arabia [17]. [19] The authors studied characteristics influencing adoption by collecting data from a mobile cloud learning environment from Blackboard users at the University of Leeds in the United Kingdom

using a structured questionnaire. [20] The authors examined their country's potential to transition to remote mastering and reviewed structures that have been used in schooling and supported by government access, as well as modern online conversation structures. Those who are advanced with the help of using Microsoft Teams. [21] The authors noted China's revelations about the duration of the covid-19 lockdown with continued learning. Authors described technical support for instructors and knowing help for college students. [22] The authors examined the risks of using an automated machine and provided a web multi-element authentication test method. The authors [23] summarized the conditions of seeking to achieve the amazing distance of knowing and e-checking from the thoughts of professors and college students in Arab universities. Universities, schools and various educational institutions are important for the standard development of a country.

[24] Used the ambiguous AHP to take a look at the determinants of CC adoption in better Indian educational institutions. The maximum important factors decided to be relative profit, IT demand and security. [25] Using a SEM approach, the authors evaluated cloud computing-based education in Saudi Arabia and influenced characteristics such as reliability, social impact, information quality and ease of use. Tuan suggested that it would be more accurate to assess teacher research productivity using an integrated multi-criteria decision-making approach (MCDM). To do this, the researchers used the hybrid AHPTOPSIS technology. Due to the suspension of on-campus classes, a large jump in student ranks, monodemic content, and the content offered, and the material provided, e-mastering structures have grown at an exponential rate [26, 27]. The cloud era is now being used by many educational institutions, and it is very clear [28] that it has a shiny destiny.

In addition, due to the fact that there is a single database for all customers in the cloud, cyber security modifications can be analyzed and made quickly [29]. [30], as it was designed to allow customers to collaborate from anywhere at any time. It can reach out to more students outside the general study room and meet their needs. Due to better calls to keep education afloat, establishments are paying additional interest on a mix of cloud generation and e-learning. Almost all educational institutions saw it as a viable and suitable e-learning option. Nevertheless, the lack of study may also provide a theoretical framework on which to build a technology. On the other hand, the potential inherent in the cloud approach can also be highlighted as a major advantage in the development of an analytical framework and one-hit training techniques [31]. However, in the literature, common features of the cloud are associated with social participation and collaborative learning activities [32].

## 2.2 IOT in Education

The term "Internet of Things" (IoT) refers to state-of-the-art technology that connects all intelligent objects in a network without the need for human intervention. This is indeed a new study focus that would have recently discovered an important and compelling research base in a wide range of academic and industrial disciplines [33]. According to Walcott [34], many governments are implementing the latest digital defense strategies in the fight against COVID 19. During this time, digital technology and innovation gradually became the focus of mankind. The economic demands of COVID19 strongly drive the

deployment and creation of new digital technologies at a particular pace and scale. Population surveillance, response assessment, incident detection and touch tracking is one of the digital tools used to facilitate the international public health impact of COVID 19, with a focus on public participation and data mobility. According to Islam [35], the integration of IoT with advanced technology could be a major step forward in efforts to combat new epidemics. The potential of the Internet of Things will have a significant impact on the ability of Western countries to achieve the SDGs (Sustainable Development Goals). In environments where Internet-of-Things-enabled devices and applications are used, it is essential to implement specified protocols, patient monitoring and primary identification procedures, to reduce the chances of spreading the coronavirus.

According to Jawed [36], the Internet of Things can send and receive both information and physical goods (IoT). Intelligent hospital equipment and concepts were controlled via wireless and wired Internet. Various medical diagnostics, instruments, advanced imaging equipment, artificial intelligence and sensors are essential for the implementation of IoT in the medical field. Intelligent technologies can collect and share data to carry out essential tasks in our daily lives. The application will pave the way for entertainment systems, automobiles, connected healthcare and smart cities. These advances have increased both the quality of life and the efficiency of industries and societies, both new and old. This technology is flourishing in health surveillance during the COVID 19 pandemic. According to Nasajpur et al. [37] Innovation has retained most of the information about COVID19 patients inside the data center to ensure adequate attention, and that could be more helpful. Internet of Things (IoT) combines all-digital, computing technologies and mechanicals to transmit data over the web without human intervention. In this dire scenario, many people die of late and incorrect medical information. The Internet of Things is taking over every day human activities and changing health problems. Sensors are used to quickly notify the system of health issues [38]. The successful operation of medical institutions requires proper equipment. During the COVID-19 pandemic, the use of the Internet of Things improves patient care. Smart medical devices are connected via smart connectors to deliver important medical data to doctors. These devices use the Internet of Things to successfully track real-time data, saving lives from a variety of health problems. The Internet of Things (IoT) has great potential to analyze and leverage impactful activities including after-services [36]. De Rauer and Radanlive [39, 40] focused on ethical IoT design updates and IoT design, but did not discuss the implications of the coupled and multiple risks of IoT system-themes. They concluded that before new ICT systems are incorporated, production facilities should be coupled with an ethical assessment of cyber threats. They enable governments, health experts, and medical organizations to build a framework to provide guidance in this article [41] as the introduction of IoT into the vaccination supply chain increases risk. [42] Applications of the Internet of Things include contact tracing devices, wearable health monitors, thermal cameras, temperature sensors and package tracking to help fight disease by providing critical data needed for the safe delivery of COVID19 vaccines. In this COVID situation, IoT has helped to make automated activities in warehouses and supply chains more resilient to encourage social distancing and secure remote access to industrial machines.

By studying the potential of IoT in the socio-economic development areas of Bangladesh, Parvez et al. [43] Created a conceptual framework model, and the model

showed that Bangladesh needed to develop a set of policies for IoT deployment to implement a national strategy on the Internet of Things. Miyazi et al. [44] The IoT, introduced in Bangladesh, reveals technical challenges, financial challenges, security, privacy issues and device reliability, along with opportunities such as occupational safety, mHealth, traffic safety, service management and environmental monitoring. Sarkar et al. [45] Highlighting the future prospects and problems of some of the most promising IoT applications. As per the literature review on IoT applications in Bangladesh, no such in-depth work has been found on the current scenario of employing IoT in various industries during COVID-19. As a result, a conceptual model of the impact of Inter-Net of Things applications across multiple industries was created during the pandemic. During the pandemic, this study looks at the barriers and benefits of adopting IoT services across multiple sectors, and the findings will help organizations respond and adapt to IoT services more quickly, giving them a competitive advantage.

### 3 Discussion and Conclusion

In India, cloud computing adaptation in higher education is an under-studied area and the literature does not document systematic studies. We studied in this article how cloud computing can be used in educational contexts. Due to the COVID-19 pandemic which has prompted many schools, colleges and establishments to supply online training, it has become mandatory. According to the analysis' overview, using cloud services in E-learning is a good option since it allows teachers to take use of cloud adaptability, flexibility, and security to reflect the primary framework of E-learning education accessible from anywhere, at any time, and on any device. We can fully use the prospects presented by an efficient learning environment with specialized information that is easily adaptable to today's educational paradigm. Integrating an elearning system into the cloud has several advantages, including increased storage, computing, network connectivity and prioritize software and hardware cost savings. On the other hand, it offers a more diverse range of educational programs at a lower license cost. The replacement rate for student computers is lower due to the extended machine life. These savings add up to a reduction in IT personnel costs associated with computer lab maintenance and software updates. Today's e-learning services and systems are all about personalizing learning and learning for each user. As a result of this technology, students receive generic e-learning that is not tailored to their specific needs. In most modern systems, interaction between professors and students is essential for improving the quality of each student's learning experience. When evaluating the scale of a problem, there are many things to consider. In response to customer concerns about security and privacy, cloud service providers have made major investments in cloud infrastructure and platforms. Furthermore, country limits are necessary since some countries require data to be maintained within their borders, making data storage remotely or outside of the country illegal. As per current research, academics have a wealth of data at their disposal to aid in building cloud-based elearning frameworks and implementations. A quantitative assessment of the impact of switching to a cloud e-learning environment on several factors such as access speed, educational quality, and return will be conducted in the future. The adoption of IoT in universities may be influenced by education policy in terms of administrative support

and change mindset. There is a need to examine the advantages and disadvantages of Internet of Things in depth. Information and communication technology (ICT), a society that places a high value on acquiring knowledge, and the current pandemic have all contributed to an increase in the amount of pressure on the education system to adopt ICT and make education more intelligent. There is also a need to explore machine learning algorithms [46–50] in cloud based analysis of education systems for tasks such as student monitoring, student lecture engagement, etc.

## References

1. Dias, S.B., Hadjileontiadou, S.J., Diniz, J., Hadjileontiadis, L.J.: DeepLMS: a deep learning predictive model for supporting online learning in the Covid-19 era. *Sci. Rep.* **10**(1), 1–17 (2020)
2. Bagheri, M., Movahed, S.H.: The Effect of the Internet of Things (IoT) on Education Business Model, in *Proc.*, pp. 435–441. SITIS, Naples, Italy (2016)
3. Gong, C., Liu, J., Zhang, Q., Chen, H., Gong, Z.: The characteristics of cloud computing. In: 2010 39th International Conference on Parallel Processing Workshops, pp. 275–279. IEEE (2010)
4. <https://classroom.google.com/>. Accessed 26 May 2022
5. <https://www.blackboard.com/en-apac>. Accessed 26 May 2022
6. <https://knowledgematters.com/>. Accessed 26 May 2022
7. <https://www.coursera.org/>. Accessed 26 May 2022
8. <https://education.microsoft.com/en-us>. Accessed 26 May 2022
9. <https://classflow.com/>. Accessed 26 May 2022
10. Mohanty, D.: Smart learning using IoT. *Int. Res. J. Eng. Tech.* **6**(6), 1032–1037 (2019)
11. Uskov, V.L., Bakken, J.P., Howlett, R.J., Jain, L.C. (eds.): SEEL 2017. SIST, vol. 70. Springer, Cham (2018). <https://doi.org/10.1007/978-3-319-59454-5>
12. Pai, S.S., et al.: IOT application in education. *Int. J. Adv. Res. Ideas Innovations Technol.* **2**(6), 20–24 (2017)
13. Gwak, D.: The meaning and predict of smart learning. In: *Proceedings of the Smart Learning Korea* (2010)
14. Aljohany, D.A., Mohamed, R., Saleh, M.: ASSA: adaptive E-learning smart students assessment model. *Int. J. Adv. Comput. Sci. Appl.* **9**(7), 128–136 (2018)
15. Wang, M., Chen, Y., Khan, M.J.: Mobile cloud learning for higher education: a case study of moodle in the cloud. *Int. Rev. Res. Open Distrib. Learn.* **15**(2), 254–267 (2014)
16. Sarode, N., Bakal, J.W.: A review on use of mobile cloud system in educational sector. In: 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS), pp. 715–720. IEEE (2020)
17. Almutairi, M.M.: A review of cloud computing in education in Saudi Arabia. *Int. J. Inform. Technol.* **12**(4), 1385–1391 (2020). <https://doi.org/10.1007/s41870-020-00452-6>
18. Kumar, V.: A review on deep learning based diagnosis of COVID-19 from X-ray and CT images. In: 2022 International Mobile and Embedded Technology Conference (MECON), pp. 547–552. IEEE (2022)
19. Sultana, J.: Determining the factors that affect the uses of mobile cloud learning (MCL) platform blackboard—a modification of the UTAUT model. *Educ. Inform. Technol.* **25**(1), 223–238 (2020). <https://doi.org/10.1007/s10639-019-09969-1>
20. Basilaia, G., Kvavadze, D.: Transition to online education in schools during a SARS-CoV-2 coronavirus (COVID-19) pandemic in Georgia. *Pedagogical Research* **5**, 4 (2020)



21. Huang, R.H., Liu, D.J., Tlili, A., Yang, J.F., Wang, H.H.: Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak, pp. 1–54. Smart Learning Institute of Beijing Normal University, Beijing (2020)
22. Mallik, S., Halder, S., Saha, P., Mukherjee, S.: Multi-factor authentication-based E-exam management system (EEMS). In: Bhattacharjee, D., Kole, D.K., Dey, N., Basu, S., Plewczynski, D. (eds.) Proceedings of International Conference on Frontiers in Computing and Systems. AISC, vol. 1255, pp. 711–720. Springer, Singapore (2021). [https://doi.org/10.1007/978-981-15-7834-2\\_66](https://doi.org/10.1007/978-981-15-7834-2_66)
23. Bashitialshaaer, R., Alhendawi, M., Lassoued, Z.: Obstacle comparisons to achieving distance learning and applying electronic exams during COVID19 pandemic. *Symmetry* **13**(1), 99 (2021)
24. Sharma, M., Gupta, R., Acharya, P.: Factors influencing cloud computing adoption for higher educational institutes in India: a fuzzy AHP approach. *Int. J. Inf. Technol. Manage.* **19**(2–3), 126–150 (2020)
25. Naveed, Q.N., Alam, M.M., Qahmash, A.I., Quadri, K.M.: Exploring the determinants of service quality of cloud E-learning system for active system usage. *Appl. Sci.* **11**(9), 4176 (2021)
26. Khan, R.M.I., Radzuan, N., Farooqi, S., Shahbaz, M., Khan, M.: Learners' perceptions on whatsapp integration as a learning tool to develop EFL spoken vocabulary. *Int. J. Lang. Educ.* **5**(2), 1–14 (2021)
27. Khan, R.M.I., Shahbaz, M., Kumar, T., Khan, I.: Investigating reading challenges faced by EFL learners at elementary level. *Register J.* **13**(2), 277–292 (2020)
28. Khan, I., Ibrahim, A.H., Kassim, A., Khan, R.M.I.: Exploring the EFL learners' attitudes towards the integration of active reading software in learning reading comprehension at tertiary level. *MIER J. Educ. Stud. Trends Pract.*, 248–266 (2020)
29. Bhardwaj, A., Goundar, S.: A framework to define the relationship between cyber security and cloud performance. *Comput. Fraud & Secur.* **2019**(2), 12–19 (2019)
30. Kaisara, G., Bwalya, K.J.: Investigating the e-learning challenges faced by students during COVID-19 in Namibia. *Int. J. High. Educ.* **10**(1), 308–318 (2021)
31. Park, J.H., Park, J.H.: Blockchain security in cloud computing: use cases, challenges, and solutions. *Symmetry* **9**(8), 164 (2017)
32. Marinescu, D.C.: *Cloud Computing: Theory and Practice*. Morgan Kaufmann (2017)
33. Mohammed, T., Jean-Yves, C., Peter, B., Christophe, R.: Petrogenesis of the post-collisional Bled M'Dena volcanic ring complex in Reguibat Rise (western Eglab shield, Algeria). *J. Afr. Earth Sci.* **166**, 102250 (2020)
34. Walcott, D.A.: How the fourth industrial revolution can help us beat COVID-19. In: World Economic Forum (2020). <https://www.weforum.org/agenda/2020/05/how-the-fourth-industrialrevolution-can-help-us-handle-the-threat-of-covid-19>
35. Islam, A., Anum, K., Dwidienawati, D., Wahab, S., Abdul, L.A.: Building a post COVID-19 configuration between Internet of Things (IoT) and sustainable development goals (SDGs) for developing countries. *J. Arts Soc. Sci.* **4**(1), 45–58 (2020)
36. Javaid, M., Khan, I.H.: Internet of Things (IoT) enabled healthcare helps to take the challenges of COVID-19 pandemic. *J. Oral Biol. Craniofac. Res.* **11**(2), 209–214 (2021)
37. Nasajpour, M., Pouriyeh, S., Parizi, R.M., Dorodchi, M., Valero, M., Arabnia, H.R.: Internet of Things for current COVID-19 and future pandemics: an exploratory study. *J Healthcare Inf Res.* **1**, 40 (2020)
38. Fahrni, S., Jansen, C., John, M., Kasah, T., Körber, B., Mohr, N.: *Coronavirus: Industrial IoT in Challenging Times*. McKinsey & Company, New York (2020)

39. Radanliev, P., De Roure, D.: Alternative mental health therapies in prolonged lockdowns: narratives from Covid-19. *Heal. Technol.* **11**(5), 1101–1107 (2021). <https://doi.org/10.1007/s12553-021-00581-3>
40. Radanliev, P., De Roure, D.: Epistemological and bibliometric analysis of ethics and shared responsibility—health policy and IoT systems. *Sustainability.* **13**(15), 8355 (2021)
41. Radanliev, P., De Roure, D., Ani, U., Carvalho, G.: The ethics of shared Covid-19 risks: an epistemological framework for ethical health technology assessment of risk in vaccine supply chain infrastructures. *Heal. Technol.* **11**(5), 1083–1091 (2021). <https://doi.org/10.1007/s12553-021-00565-3>
42. Forum, W.E.: State of the Connected World (2020). [http://www3.weforum.org/docs/WEF\\_The\\_State\\_of\\_the\\_Connected\\_World\\_2020.pdf](http://www3.weforum.org/docs/WEF_The_State_of_the_Connected_World_2020.pdf)
43. Parvez, N., Chowdhury, T.H., Urmi, S.S., Taher, K.A.: Prospects of Internet of Things for Bangladesh. In: 2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD), pp. 481–485 (2021)
44. Miazzi, M.N.S., Erasmus, Z., Razzaque, M.A., Zennaro, M., Bagula, A.: Enabling the Internet of Things in developing countries: opportunities and challenges. In: 2016 5th International Conference on Informatics, Electronics and Vision (ICIEV), pp. 564–569. IEEE (2016)
45. Sarker, S., Roy, K., Afroz, F., Pathan, A.-S.: On the opportunities, applications, and challenges of internet of things. In: Khan, M.A., Quasim, M.T., Algarni, F., Alharthi, A. (eds.) *Decentralised Internet of Things*. SBD, vol. 71, pp. 231–254. Springer, Cham (2020). [https://doi.org/10.1007/978-3-030-38677-1\\_11](https://doi.org/10.1007/978-3-030-38677-1_11)
46. Kumar, V., et al.: Hybrid spatiotemporal contrastive representation learning for content-based surgical video retrieval. *Electronics* **11**, 1353 (2022)
47. Kumar, V., Tripathi, V., Pant, B.: Learning unsupervised visual representations using 3d convolutional autoencoder with temporal contrastive modeling for video retrieval. *Int. J. Math. Eng. Manag. Sci.* **7**(2), 272–287 (2022)
48. Kumar, V., Tripathi, V., Pant, B.: Enhancing unsupervised video representation learning by temporal contrastive modelling using 2d CNN. In: 5th IAPR International Conference on Computer Vision & Image Processing (CVIP 2021)
49. Kumar, V., Tripathi, V., Pant, B.: Unsupervised learning of visual representations via rotation and future frame prediction for video retrieval. In: Singh, M., Tyagi, V., Gupta, P.K., Flusser, J., Ören, T., Sonawane, V.R. (eds.) *ICACDS 2021*. CCIS, vol. 1440, pp. 701–710. Springer, Cham (2021). [https://doi.org/10.1007/978-3-030-81462-5\\_61](https://doi.org/10.1007/978-3-030-81462-5_61)
50. Kumar, V., Tripathi, V., Pant, B.: Exploring the strengths of neural codes for video retrieval. In: Tomar, A., Malik, H., Kumar, P., Iqbal, A. (eds.) *Machine Learning, Advances in Computing, Renewable Energy and Communication*. LNEE, vol. 768, pp. 519–531. Springer, Singapore (2022). [https://doi.org/10.1007/978-981-16-2354-7\\_46](https://doi.org/10.1007/978-981-16-2354-7_46)