International Journal of Engineering Education Vol. 37, No. 6, pp. 1489–1510, 2021
Printed in Great Britain

0949-149X/91 $3.00+0.00

Impact of COVID-19 on Online Education in Developing Countries – An Overview*

AKSHOY RANJAN PAUL[1], ABDULAZIZ ALDIAB[2], SOMNATH CHATTOPADHYAYA[3], ALTAB HOSSAIN[4], ZINAT TASNEEM[5], NAWSHAD HAQUE[6], ANUPAM BASU[7], TASHI GYELTSHEN[8], YANGDON[9], REZA NAKHAIE JAZAR[10] and FIROZ ALAM[11]

[1] Department of Applied Mechanics, Motilal Nehru National Institute of Technology (MNNIT) Allahabad, India. E-mail: arpaul2k@gmail.com

[2,10,11] School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia. E-mail: abdulaziz.aldiab@rmit.edu.au; reza.nakahiejazar@rmit.edu.au; firoz.alam@rmit.edu.au

[3] Department of Mechanical Engineering, Indian Institute of Technology (IIT) Dhanbad, India. E-mail: somuismu@gmail.com

[4] Department of Nuclear Science and Engineering, Military Institute of Science and Technology (MIST), Dhaka, Bangladesh. E-mail: altab76@gmail.com

[5] Department of Mechatronics Engineering, Rajshahi University of Engineering and Technology (RUET), Rajshahi, Bangladesh. E-mail: tasneemzinat@gmail.com

[6] Commonwealth Scientific and Industrial Research Organisation (CSIRO) Melbourne, Australia. E-mail: nawshad.haque@csiro.au

[7] National Institute of Technology (NIT) Durgapur, India. E-mail: anupambas@gmail.com

[8,9] Samtse College of Education, Royal University of Bhutan, Samtse, Bhutan. E-mail: tgyeltshen.sce@rub.edu.bt; yangdon.sce@rub.edu.bt

The COVID-19 lockdown since March 2020 necessitates higher education institutions to deliver education online. Although education institutions in high and higher middle-income countries could relatively easily transition face to face education to online delivery, most higher education institutions in low-income and lower middle-income countries were unable to do it. World-wide, more than half of the world's 1.5 billion students is out of online education activities especially in developing and emerging nations. Hence, the primary objective is to examine the difficulties and challenges experienced by some of those countries in their higher education institutions' transition to online education. The study focuses on internet infrastructure, accessibility, affordability, digital learning management system, academics and students' perspectives and digital knowledge gap related to online education. The study finds that poor or no internet infrastructures/connections, streaming devices, learning management system, inexperience in online education, and socio-economic conditions are the main impedances for slow or no transition to online education in most emerging and developing countries. Some action plans (recommendations) to overcome these challenges are also compiled.

Keywords: Online education; Learning Management System; Internet; emerging/developing countries; eLearning

1. Introduction

The Corona Virus Disease 2019 (COVID-19) has affected everyone and everything by creating crisis in health, economy, education, mobility, sports, and so on. It created unprecedented job losses, unemployment, hunger, poverty, misgovernance, and political instability that our human civilisation never saw from time immemorial. According to the World Bank's estimates, the COVID-19's global impacts are profound and long-lasting. Low income and emerging nations with large populations such as Nepal, India, Pakistan, Bangladesh, Nigeria are at higher risk as they have millions of people below poverty line prior to COVID-19, limited resources, capacity, and technology to deal with the impact of COVID-19. Along with health and economy, the education sector is the most affected. Hundreds of million school and university students (over 300 million in South Asia alone) are locked down at home without having access to education activities since March 2020. For online delivery of education, students and academic staff/faculty members need to have internet infrastructures (including required bandwidth), digital gadgets, learning management system, digital teaching and learning resources and learning evaluation processes (assessment). Furthermore, the urgency to "move online" has created extra workload and stress for faculty members/academic staff struggling to balance their teaching, research, and service/administration obligations as well as work-life balance [1–3]. Academic staff/faculty members are required to prepare and deliver their classes mainly from home with associated practical and technical difficulties, and often without proper technical support [4]. On top, a significant challenge for academic staff/faculty members is the lack of pedagogical content knowledge needed for teaching online and a future educational paradigm [1, 5–9]. Technical and administrative aspects of teaching online including learning resources development,

* Accepted 14 July 2021.

learning management system/platform and digital tools, learning activities, learning evaluation, online help and feedback to students create monumental challenges for the effective delivery of online education especially for emerging and developing nations. Hence, a series of questions about online delivery of education in emerging nations needs to answer. Do the education institutions have internet infrastructures with required bandwidth, do students have internet gadgets (laptop/desktop, tablets, smart phones, etc.) with access to internet, what sort of national internet backbones they have, do they have any learning management systems (platforms) for online delivery? Answers to these research questions are to be investigated in this study for South Asian region especially India, Bangladesh, and Bhutan with a population over 1.5 billion. As scant data is available about online education for the region, the study is primarily based on secondary data available in the public domain. The findings are supplemented by the data obtained through focus group discussions, webinars, online forums, and personal communications with relevant stakeholders. The research approach is based on combined qualitative and quantitative methods. To understand the capability of online education delivery, existing internet infrastructures and network readiness would also be studied.

2. Network Readiness and Online Learning

The network readiness and online delivery of teaching and learning are indispensable, and the latter is highly dependent on the former. The World Economic Forum of the United Nations developed a Network Readiness Index (NRI) to measure the technology readiness of an individual country. Each year, a NRI report is published (in collaboration with INSEAD) as part of the World Economic Forum's annual Global Information Technology Report (GITR) [10]. The NRI consists of four major components: (a) environment for ICT (technology) offered by a given country or community, (b) readiness of the community's key stakeholders (individuals, businesses, and governments) to use ICT, and (c) governance of ICT amongst these stakeholders (trust, regulation, inclusion), and the impact of ICTs on economy, quality of life and the sustainable development goal (SDG) contribution. The twelve major areas of NRI are shown in Fig. 1.

Network readiness is an indicator for the suitability of online education delivery that needs internet bandwidth, wired or wireless connectivity, firewalls, content filtering, and proxy servers. The 2019 NRI report included 121 countries' network readiness based on twelve major areas (criteria) as shown in Fig. 1. A total of 62 indicators under these 12 sub criteria was used to develop a relative weighting scale for the Network Readiness Index. The NRI of selected countries (low income, lower middle income, upper middle income, high income) for 2019 is shown in Fig. 2. As per the World Bank income classification, all countries based on their per capita National Gross Income (GNI) were classified into four groups: Low Income, Lower Middle Income, Upper Middle Income and High Income as shown in Table 1. Figure 2 shows that the network readiness of selected low income, lower middle-income, upper middle income, and high-income countries. The figure illustrates the poor network readiness in low and lower middle-income nations. The average network readiness for a high-income country is over 2.5 times greater than that of a low-income country. The weighting scores against all twelve criteria under Technology, People, Governance, and Impact for five South Asian countries (Bangladesh, India, Pakistan, Nepal, and Sri Lanka), one each from South East Asia (Singapore), Africa (South Africa) and South America (Brazil) are shown in Table 2 to illustrate where which country scores better and where attention is needed.

Under the "Technology" criteria and its sub criteria "Access", there are seven weighting areas are considered to rank the individual country.

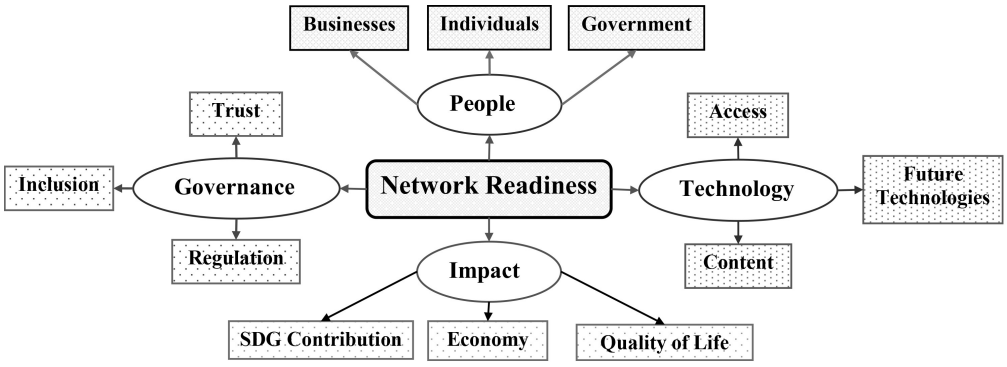

Fig. 1. NRI's twelve major areas, adapted from [10].

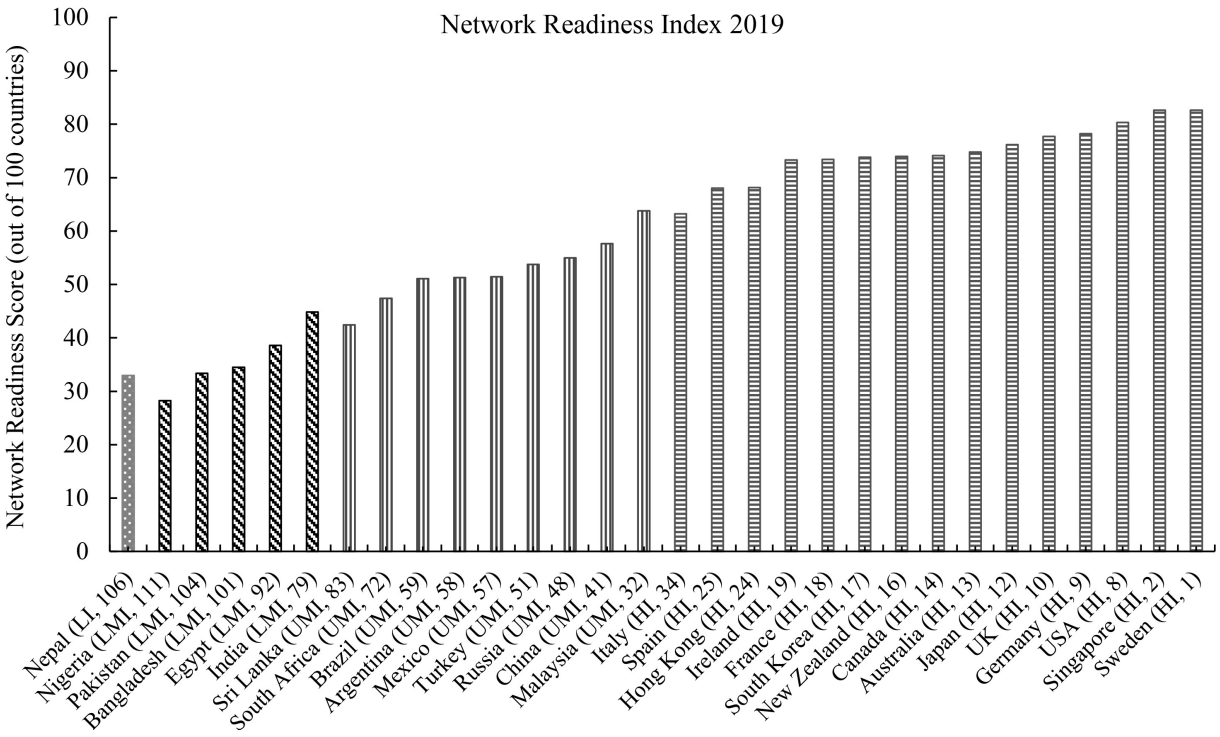

Fig. 2. Network readiness indices for selected countries in 2019, adapted from [10].

Table 1. The World Bank thresholds for income classification 2020, adapted from [11]

	Income Group	Gross National Income (GNI) per capita for 2021 based on 2019 income in US dollar
1	Low Income (LI)	1,035 or less
2	Lower Middle Income (LMI)	1,036–4,045
3	Upper Middle Income (UMI)	4,046–12,535
4	High Income (HI)	12,536 or more

These weighting areas are mobile tariffs, handset price, household internet access, 4G mobile network coverage, fixed broadband subscription, international internet bandwidth, and internet access to schools. All low income and lower middle-income countries are performing poorly in three vital areas: household internet access, fixed broadband subscription and internet access to schools compared to upper middle income and high-income nations (see Fig. 3). For online learning, eLearning and the reduction of digital divide are fundamentally dependent on these three areas. Bangladesh- a lower middle-income country scored less than 1 out of 100 for the household internet access where India, Pakistan and Nepal scored 20, 16, 12 respectively compared to 98 by Singapore and 87 by Australia.

The US based Lumina Foundation investigated the COVID-19 impact on global higher education from March to September 2020 [12]. The study was based on (a) global scanning and analysis of policy documents, research articles, and verifiable news pieces), (b) interviews with university top managements, academic staff/faculty members and stu-

Table 2. Score matrix of selected countries, adapted from [10]

	Technology			People			Governance			Impact			Score	Rank
	Access	Content	Future Technologies	Individuals	Businesses	Government	Trust	Regulations	Inclusion	Economy	Quality of Life	SDG Contributions		
Nepal	31.53	28.05	18.85	26.83	14.57	31.72	49.85	47.05	47.68	6.33	54.85	38.25	32.96	106
Pakistan	41.91	25.96	29.49	12.59	21.47	29.15	41.34	52.61	36.14	11.31	54.16	44.42	33.38	104
Bangladesh	37.41	18.03	27.57	22.15	9.99	43.26	37.17	43.31	62.87	6.09	62.41	43.45	34.48	101
Sri Lanka	52.59	38.94	29.85	35.66	14.52	34.90	49.42	52.01	62.55	7.94	57.41	73.22	42.42	83
India	59.14	32.97	36.16	28.35	22.60	56.67	61.89	64.61	64.49	19.37	52.39	39.11	44.81	79
South Africa	61.33	48.92	33.39	42.95	23.22	47.44	69.07	61.96	68.81	17.28	28.71	65.42	44.59	72
Brazil	60.11	47.85	22.22	51.83	32.02	60.21	61.69	54.81	71.86	22.17	51.21	76.85	51.07	59
China	77.36	35.37	50.66	57.77	54.85	49.06	60.83	67.52	67.92	34.90	66.22	69.06	57.63	41
Australia	88.71	76.48	46.92	73.43	62.92	78.62	86.80	88.69	81.56	37.07	83.85	92.60	74.80	13
Singapore	89.69	71.48	74.19	73.20	64.47	82.97	85.56	90.83	88.19	82.22	86.28	96.49	82.13	2

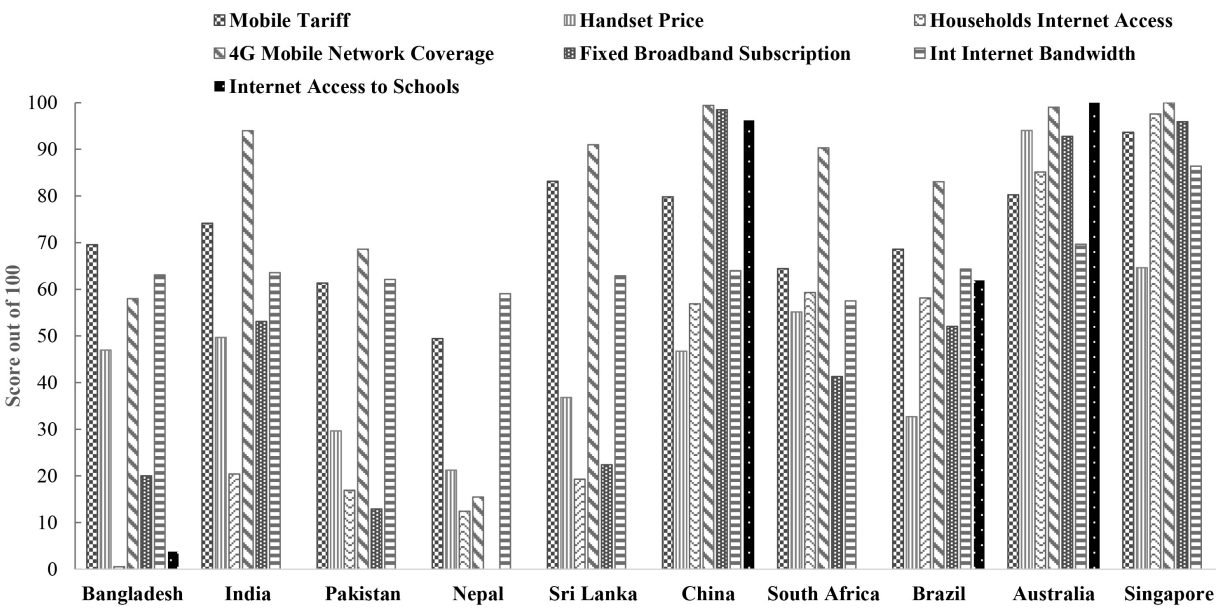

Fig. 3. First Sub Pillar: scores for Access for selected countries in 2019, adapted from [10].

dents in 20 countries across all continents, and (c) advice received from higher education policy-makers and researchers around the world. The study revealed that COVID-19 has affected rich and poor countries equally but its disastrous effect on students from developing countries' socio-economic disadvantaged groups (e.g., low-income students, girls, women, minority people, and students with special needs) is far greater than the average student population in developed (high income) and upper middle-income countries. Students in low-income nations face greater difficulties due to acute resource and capacity constraints. The opportunities for online learning are almost nil in rural, tribal, and remote areas in emerging and developing nations. The study also reported that countries with limited internet access and low broadband capacity, higher education institutions are struggling to launch quality online education as they lack resources, experienced teaching staff (faculty members), and institutional capacity. The challenges/difficulties faced by higher education institutions in high, middle, and low-income countries are shown in Figs. 4 and 5.

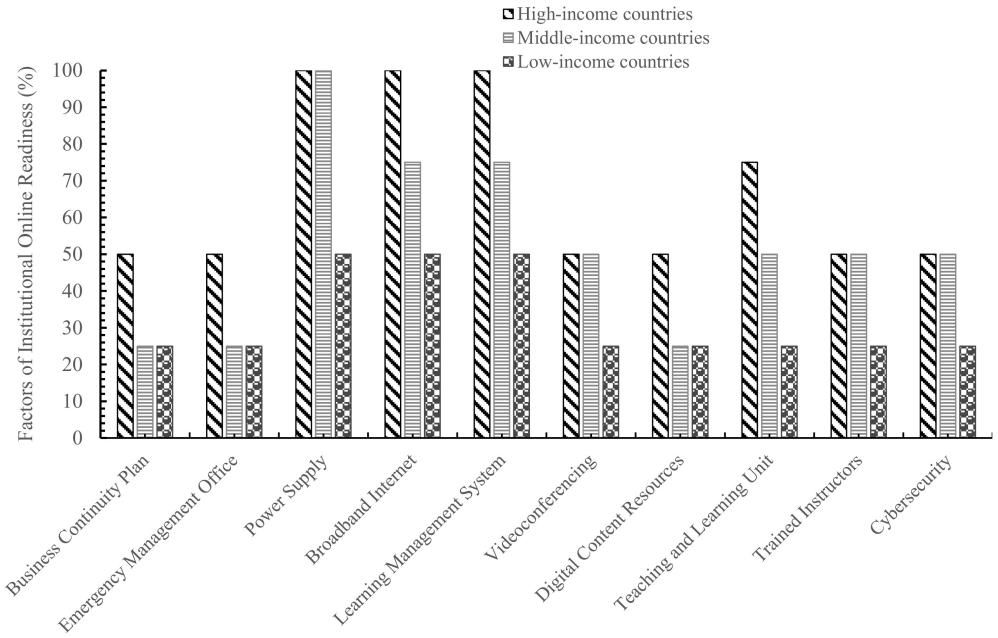

Fig. 4. Factors affecting education institutional online readiness, adapted from [12].

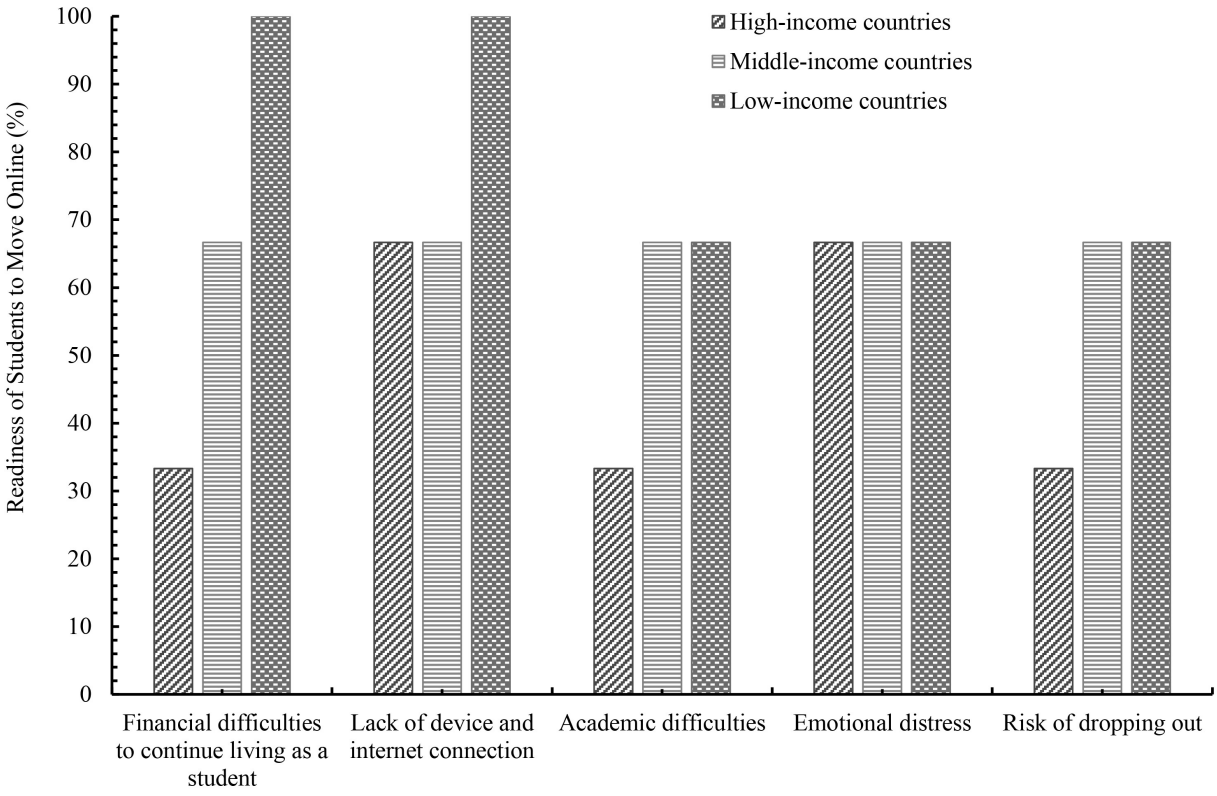

Fig. 5. Readiness of students to move online education, adapted from [12].

3. Online Teaching and Learning in South Asia and Australia

3.1 Internet Infrastructures and Online Education in India

India is world's second largest populous country (over 1.3 billion) after China. It has second largest student population. In 2018, there were over 36 million students in Indian higher education institutions compared to 42 million students in China [13]. There were four million students enrolled in postgraduate (mainly in master's) programs. According to the Ministry of Higher Education and the University Grants Commission (UGC), India has 821 universities (49 Central Universities, 367 State Universities, 123 Deemed Universities and 282 Private Universities), 24 Indian Institutes of Technology (IITs), 31 National Institutes of Technology (NITs), 25 Indian Institutes of Information Technology (IIITs), 15 All India Institutes of Medical Sciences (AIIMSs), 7 Indian Institutes of Science Education and Research (IISERs), and 20 Indian Institute of Management (IIMs). Furthermore, India has more than 20,000 colleges and 4,282 Engineering and Technical Institutes approved by All India Council for Technical Education (AICTE). There are tens of thousands Government Degree Colleges and Private Degree Colleges delivering higher education under universities and institutions. Collectively 51,649 universities, institutes and degree colleges deliver higher education in India.

India has 3 major interstate data transfer Internet backbones in its 29 states and union territories: (a) RailTel Corporation India's National Long Distance (NLD 1), (b) Power Grid Corporation of India Ltd (PGCIL)'s National Long Distance (NLD 2) and (c) Bharat Sanchar Nigam Ltd (BSNL)'s National Long Distance (NLD 3) as shown in Fig. 6. The Internet penetration and accessibility vary notably across the nation. The 2018 network readiness for all 29 states is shown in Fig. 7. As shown in the figure, the network readiness in the large part of central and eastern India is quite inadequate. This disparity in network readiness affects the online delivery of education, which has direct impact on education institutions, academic staff/faculty members and students.

To provide high speed internet services to education institutions, research organisations, libraries, laboratories, healthcare, and agricultural institutions, the government of India created National Knowledge Network (NKN) in 2010. The network started with 2.5 Gbps bandwidth capacity and progressively reached to 10 Gbps between Mumbai, Bengaluru, Chennai, Hyderabad, New Delhi, Kolkata, and Guwahati. The network was

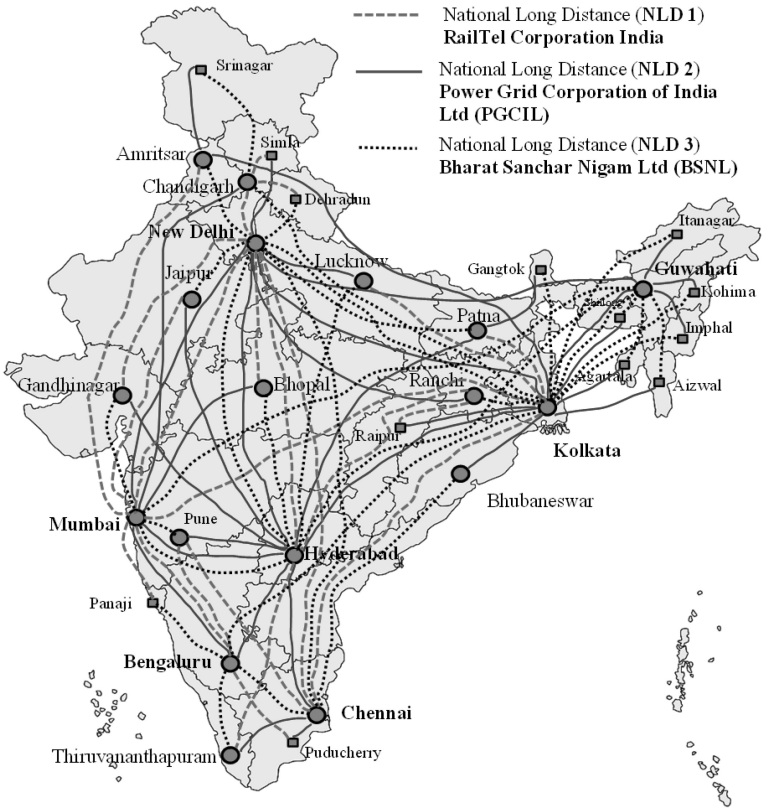

Fig. 6. Interstate data transfer backbones in India, adapted from [14].

Fig. 7. Network readiness 2018 in India, adapted from [15–16].

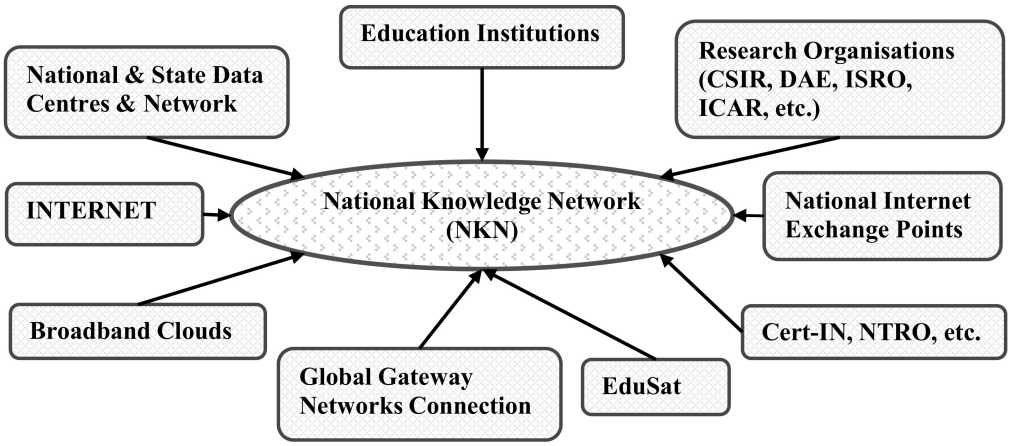

Fig. 8. Features of National Knowledge Network (NKN), adapted from [14].

further expanded through 26 semi-major locations (mainly other state capitals) with multiple of 2.5/10 Gbps. The distribution layer connected to the semi-major network using multiple links at speeds of 2.5/10 Gbps. The end users at district level are connected at a maximum speed of 1 Gbps. The NKN will expand the bandwidth progressively to 40/100 Gbps at major cities in the future. The NKN is connected to Asia's Trans Eurasia Information Network (TEIN 3), Europe's GEANT, and GLORIAD network via a China and Russia consortium from Mumbai using two 10 Gbps (2 x 10 Gbps) undersea cables for communication with the global research and education communities. It is also connected to Bangladesh Research and Education Network (BdREN), Nepal Research and Education Network (NREN), Bhutan's Research and Education Network (DrukREN), Sri Lankan Education and Research Network (LEARN), Afghan Research and Education Network (AfgREN) via Bharat Sanchar Nigam Limited (BSNL)'s link. The AfgREN is connected to NKN via Satellite link. Currently Maldives' Research and Education Network is under construction via undersea cables from Chennai. Within India, the NKN uses main backbones of RailTel, Power Grid Company India Ltd (PGCIL) and BSNL. The major features of NKN are shown in Fig. 8.

India started developing eLearning tools, systems, and platforms since 2006 when Indira Gandhi National Open University started E-Gyankosh, a national digital repository of learning resources. Since 2006, India's developed eLearning tools/platforms for schools, colleges and universities as shown in Table 3.

To minimise the impact of COVID-19 lockdown, the UGC India instructed higher education institutions to deliver at least 25% of the course components via online. However, most higher education institutions face difficulties to deliver online education. A joint survey conducted by all 24 elite Indian Institutes of Technologies (IITs) among their 11,890 students and 840 academic staff/faculty members during 5–25 May 2020 has revealed an eye-opening truth and ground reality about online education in India [17]. Students and faculty members/academic staff were asked about internet connectivity (wired broadband, mobile internet–3G/4G), streaming devices (laptop/desktop computers/smartphones), online teaching mode (synchronous/asynchronous, interactive/non-interactive), online assessment, digital course delivery, laboratory practices, and preparation for online teaching. As shown in Fig. 9, over 80% of surveyed IIT students did not have stable internet accesses/connections (via 3G/4G mobile and/or wired broadband) and nearly 40% students could not afford computing and streaming devices, vital for online learning. The survey also revealed that nearly 46% courses delivered online did not have any online learning assessment.

The courses with physical laboratory components mostly delivered without any laboratory activities. Less than 5% such courses had simple online simulations. Most courses delivered in asynchronous mode without live student interaction. Nearly two-third (75%) faculty members/academic staff had no prior experience in online course delivery. Most academic staff were attempted to deliver their face to face class content to online without customising the contents and pedagogy for online mode delivery.

3.2 Internet Infrastructures and Online Education in Bangladesh

Bangladesh for its 165 million population, currently has 52 public universities (including 8 engineering and technology universities, 14 science and technology universities, 6 agricultural universities, 5 medical universities and 19 general universities) with a total yearly enrolment over 150,000 students.

Table 3. Indian developed eLearning tools and platforms

	Indian developed eLearning systems	Targeted application areas
1	Diksha developed by National Council of Educational Research & Training (NCERT), Ministry of Education.	DIKSHA platform for school education. Teachers can plan lessons, activities. Students can download lessons and do practice exercises. Parents can follow classroom activities of students.
2	E-Pathshala developed jointly by Ministry of Education (former MHRD) and NCERT.	E-Pathshala is a repository for dissemination educational e-resources including textbooks, audio, video, periodicals, and other digital resources among school students.
3	Study Webs of Active-Learning for Young Aspiring Minds (SWAYAM) developed by Ministry of Education & All India Council for Technical Education (AICTE).	It is an Indian Massive Open Online Course (MOOC) platform for university and senior high school (Y11-12) students.
4	National Repository of Open Educational Resources (NROER) developed by Coimbatore Institute of Engineering and Technology (CIET) & NCERT.	It is a repository of videos, images, audio, documents, and interactive materials for school education (primary, secondary, and senior secondary classes).
5	National Academic Depository (NAD) developed by Ministry of Education and University Grants Commission (UGC).	It is a digital database for storage, retrieval, authentication and verification of academic awards given by (a) Central Universities, (b) Central Higher Educational Institutions and Institutions, (c) Deemed to be Universities, (d) State Universities, (e) Private Universities, (f) Institutions approved by the Ministry of Skill Development and Entrepreneurship (MSDE), (g) Central Board of Secondary Education (CBSE), and (h) State Education Boards.
6	National Digital Library of India developed by Ministry of Education.	It is a framework of virtual repository of educational resources (books, audio books/lectures, video lectures, lecture presentations/notes, simulations, question papers, solutions, etc.) for primary to postgraduate levels including technology, social science, literature, law, medical, etc. It is located at IIT Kharagpur.
7	Virtual Labs, developed by Ministry of Education .	It is a consortium of 12 IITs aiming to promote virtual experiments through internet using amalgamated physical experimental resources. Its main server is located at IIT Bombay.

Furthermore, there are 107 private universities with yearly intake over 300,000 students. For undergraduate medical education, the country has 116 medical colleges with a total annual intake of 11,000 students (48 public medical colleges with yearly intake 5,000 and 68 private medical colleges with annual intake 6,000). Additionally, 35 dental colleges/units have annual intake capacity of 2,000 (9 public dental colleges/units with 550 and 26 private dental colleges with around 1,450 annual intake).

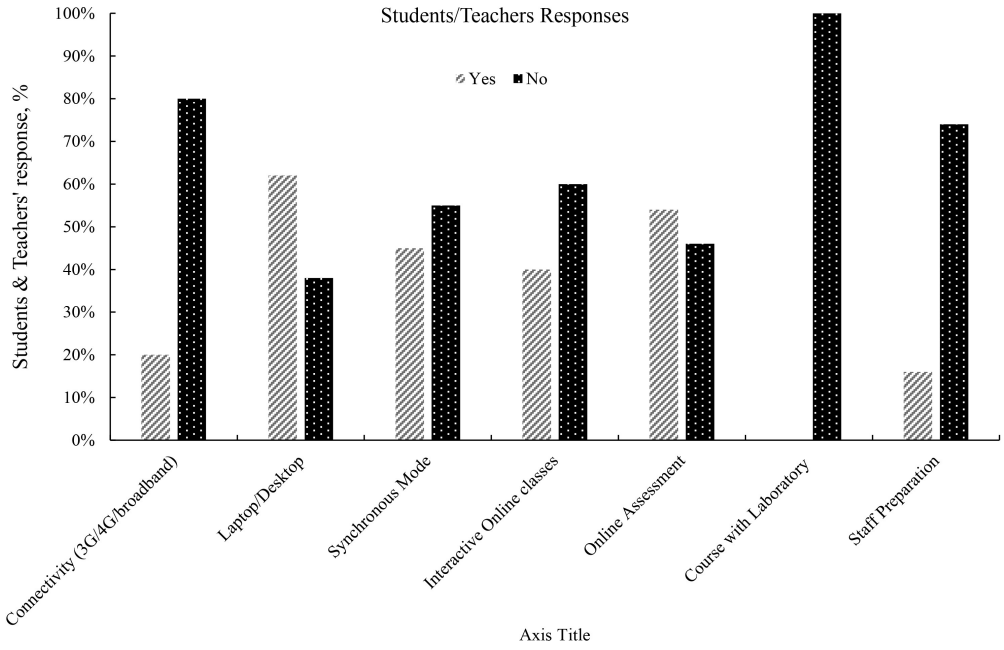

Fig. 9. Students/faculty members' responses to internet infrastructures and online education delivery, adapted from [17].

Additionally, the country's 5 bachelor's degree engineering colleges, 7 textile engineering colleges and five marine academies have approximately 4,000 yearly intake capacity [18, 19]. For diploma level engineering and technical education, there are 114 public technical institutes (49 polytechnics and 65 vocational institutes) with annual enrolment capacity of 60,000. The private sector has nearly 200 technical and vocational institutions. Bangladesh planned to increase technical and vocational enrolment from existing 15–20% to 30% by 2030 following the examples of China, Singapore, and South Korea. To achieve this objective, Bangladesh has started building 389 technical schools and colleges across the country (at least one such institution in every rural Upazila/Subdistrict where presently there is no technical school and college. Bangladesh has 492 Upazila as of December 2020 [18, 20].

Bangladesh alike many other developing countries lags behind in up taking technology aided education delivery. Despite having connected to intercontinental submarine global data transfer super-highways including dedicated international academic and research network (via Asia's TIEN 3, Europe's GEANT) and terrestrial cable connections with India's NKN, the eLearning/online education delivery infrastructures within higher and technical education institutions have not been well developed. Bangladesh has two submarine global data transfer gateways: (a) SEA-ME-WE4 established in 2006 through Cox's Bazar with 300 Gbps capacity and b) SEA-ME-WE5 established in 2017 through Kuakata (Patuakhali) with 1,500 Gbps capacity. Furthermore, the country has three dedicated terrestrial cable connections with India via Jashore (Jessore) – Kolkata, Cumilla (Comilla) – Agartala and Kurigram – Coach Behar corridors. As of October 2020, Bangladesh consumed approximately 1,700 Gbps bandwidth compared to 970 Gbps in 2019 and 300 Gbps in 2016. State owned Bangladesh Submarine Cable Company Ltd (BSCCL) alone supplied approximately 1,100 Gbps through its two undersea connections and the remaining bandwidth (~600 Gbps) was imported through 3 terrestrial connections from India by six private companies. State owned Bangladesh Telecommunications Company Ltd (BTCL) has developed nation-wide fibre optic network with high-capacity routers and switches up to union (shire) level. It provides internet data services to educational institutions through Leased Line Internet (LLI) at a highly subsidised rate [21–26]. As of 30 November 2020, Bangladesh has 110.6 million internet subscribers including 101.9 million mobile and 8.7 million wired broadband subscribers [21].

In 2009, the University Grants Commission (UGC) Bangladesh with the support of Ministry of Education and the World Bank started developing Bangladesh Research and Education Network (BdREN) to provide high performance data communications network and connectivity to higher education and research institutions across the country. The BdREN is a non-profit publicly owned internet infrastructure managed jointly by the University Grants Commission (UGC), public universities and research organisations [26].With its multi-gigabit capability, the BdREN aims to connect all universities, research institutions, medical colleges, libraries, laboratories, healthcare and agricultural institutions across the country and to support geographically dispersed academics, medical professionals, scientists and researchers with reliable access to high-end computing, simulation tools and datasets. The BdREN backbone is based on the state-owned Power Grid Company Ltd (PGCL) Bangladesh which has country-wide distributed Optical Ground Wire (OPGW) network, through Indefeasible Right of Use (IRU) agreement signed between UGC Bangladesh and PGCL Bangladesh. According to the Institute of Electrical and Electronics Engineers (IEEE) standard, the OPGW is also known as the optical fibre composite overhead ground wire used in overhead high voltage transmission power lines. Such wires combine the functions of grounding and communications. The BdREN and its core functions are shown in Figs. 10 and 11.

The BdREN uses over 3,600 km long Dense Wavelength Division Multiplexing (DWDM) based data transmission network which so far connected to 41 public, 45 private, 2 international universities and 32 research institutions. Its data transfer bandwidth has increased to 8 Gbps in 2020 from just 0.005 Gbps in 2010. The allocated BdREN's maximum bandwidth for each public university is 1 Gbps [26].

Most undergraduate students at public universities in Bangladesh do not have personalised email account from their respective institutions. Furthermore, most institutions do not have either in-house developed or commercially developed Learning Management System (LMS). This makes much harder to implement and manage online education delivery. Some universities are using ad hoc systems which are not fully evaluated and/or implemented for secured use within the university. The prolong lockdown due to COVID-19 pandemic, the UGC Bangladesh instructed universities to deliver online education. Most private universities with their limited internet infrastructures have started to deliver some courses online as their students' economic conditions are generally better than most students in public universities. Additionally, stu-

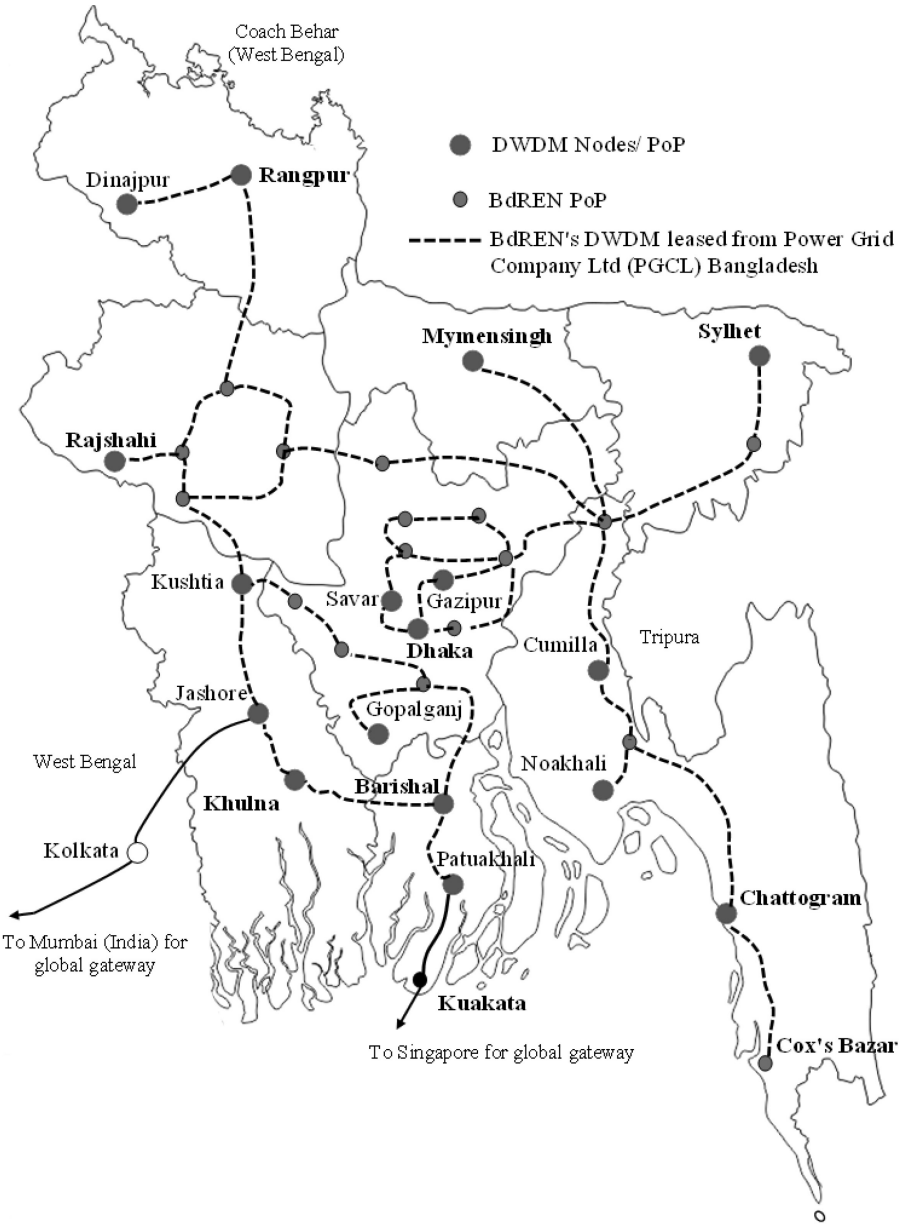

Fig. 10. BdREN infrastructures that connect institutions across Bangladesh, adapted from [26].

dents at private universities were reluctant to pay tuition fees if no classes are delivered. However, the situation is quite different for public universities. Only a small number of public and most private universities are delivering online education using Zoom, Google Classroom, Google Meet, WhatsApp, Facebook live, Microsoft Teams, Instagram, etc. with limited capacities as these apps are not as comprehensive as Blackboard, Moodle, Canvas and D2L for university level online education delivery.

The ICT Division of the Ministry of Posts, Telecommunications, and Information Technology in association with the Ministry of Education has developed a "Virtual Classroom" platform in June 2020 [27]. The main purpose of the platform is to assist higher education institutions for developing their own profiles through which they can deliver courses (live or recorded lectures, tutorials, other synchronous and asynchronous activities. So far, 35 education institutions (universities, colleges, schools) have connected to this "Virtual Classroom" platform. However, the usefulness of the "Virtual Classroom" outside the BdREN is in doubt. Instead of investing resources for "Virtual Classroom" apps, the ICT Division could strengthen and extend the bandwidth of BdREN, which could serve education institutions much more effectively. As per the plan, scope, vision, activities, governance, and ownership, the

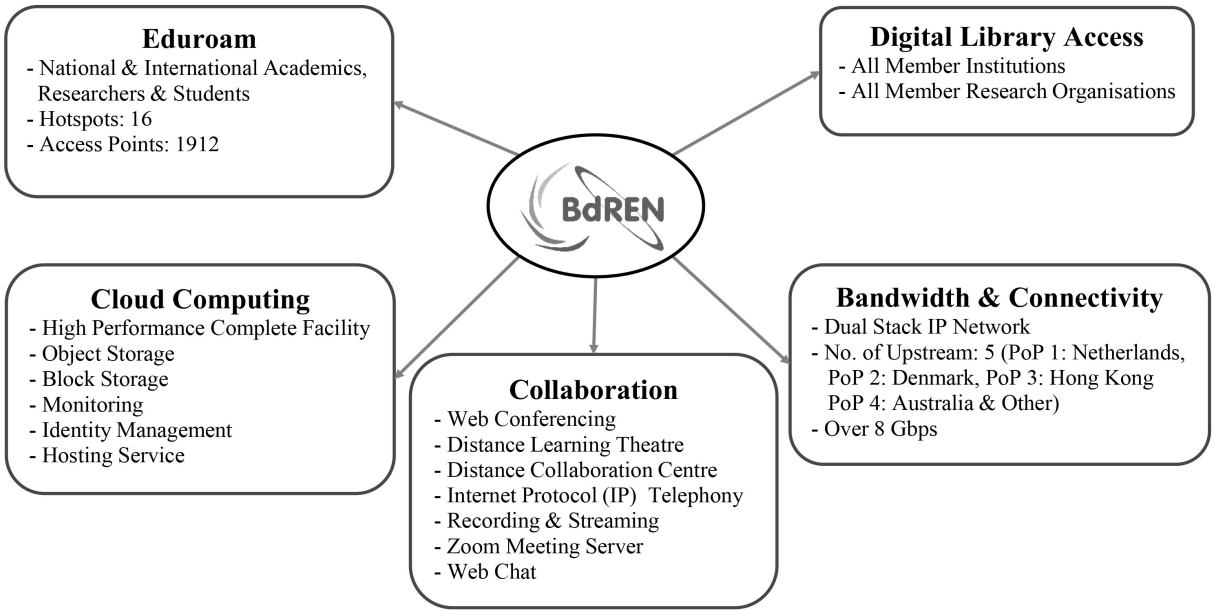

Fig. 11. Core functions of BdREN, adapted from [26].

BdREN is very much like the Australian Academic and Research Network (AARNet). The AARNet is one of most successful superhighway internet systems serving education institutions that any country can take pride and emulate.

The COVID-19 lockdown forced all education institutions in Bangladesh to stop face to face education delivery since 17 March 2020. Public university students vacated their campuses and most students left for their native towns and villages. As mentioned earlier, a small number of public universities and most private universities started delivering online education. To understand the impact of these limited online education activities on students, a survey was conducted among 2,038 students from 42 public and private universities across the country by Islam et al. [28]. The student sample included science, engineering, arts, humanities, social sciences, business studies, and other disciplines. Students were selected randomly, and they were asked eight questions related to internet gadgets, access to internet, their location, university affiliation, perception of online classes, and online education assessment. Their responses are shown in Fig. 12. As illustrated in the figure, nearly 60% students did not have access to internet and 45% students did not have internet gadgets (laptop/desktop/tablets, smartphones) despite 65% of respondents were in towns and cities during the conduction of survey. Around 87% students stated

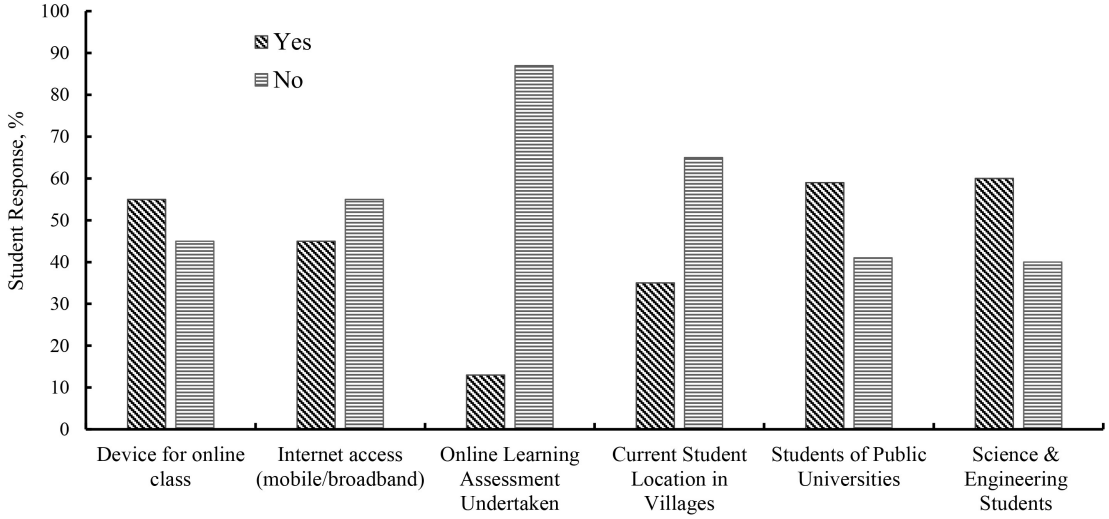

Fig. 12. Students responses to internet infrastructures and online education delivery, adapted from [28].

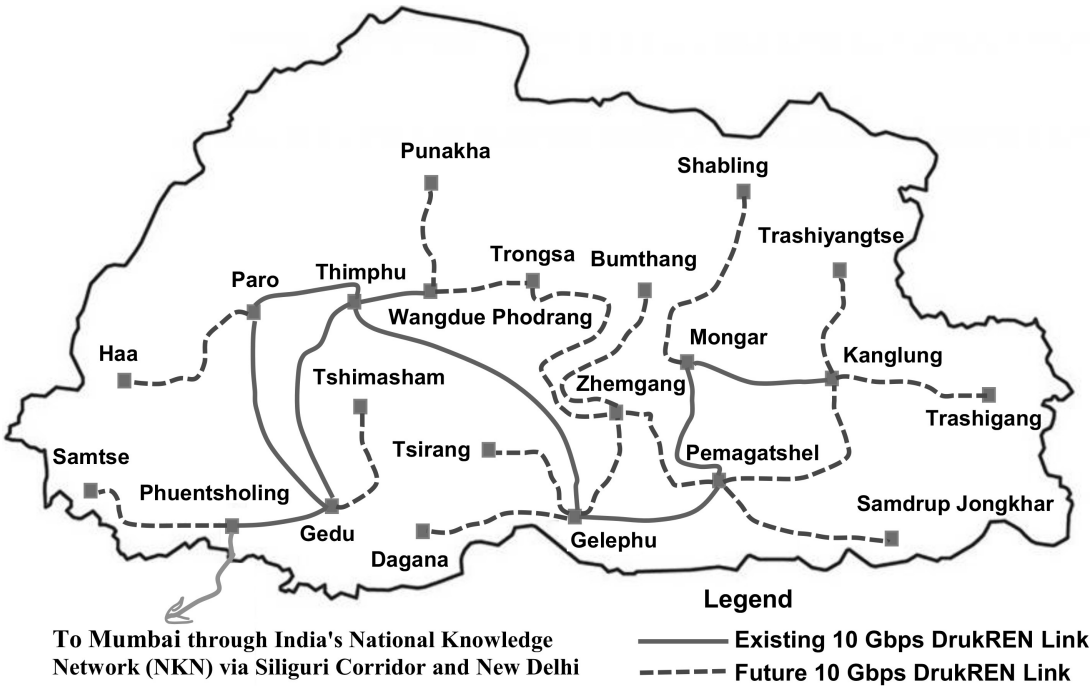

Fig. 13. DrukREN's existing and proposed 10 Gbps nation-wide links, adapted from DrukREN [33].

that they did not have any online assessment for their online classes/lessons, only 13% students mentioned that they had some sort of online assessments.

Another survey conducted by the UGC Bangladesh among 19,000 students in May 2020 reported that approximately 80% students possessed smartphones but not all are suitable for online education [29]. Having smart phones do not necessarily ensure students' affordability of mobile data for online education. An average data required for one class (less than 40 minutes) is around 0.5 GB. Hence a student attending three to four classes per day requires nearly 1.5 to 2.0 GB data which is beyond the reach of over 90% students in Bangladesh. The data requirement amount and the cost are very similar for mobile internets in India and Bhutan. As most students stay in rural areas and small towns during COVID-19 lockdown, no reliable mobile internet is available there. If available in selected areas, the average download speed for mobile internet ranges from 0.6 to 0.8 Mbps (daytime) and maximum 2 Mbps (at night) compared to the global average 34.8 Mbps in 2020 [30–32].

3.3 Internet Infrastructures and Online Education in Bhutan

The Himalayan kingdom of Bhutan is a tiny country with around 0.8 million inhabitants in South Asia. As per Bhutan Telecommunications and Broadband Policy 2014, sixteen out of twenty districts have power transmission Optical Ground Wire (OPGW) and the remaining four districts are connected through All-Dielectric Self-Supporting (ADSS) (gewog) cables at distribution and high voltage power transmission lines. Currently Bhutan has two international gateways: one from Phuentsholing (South West border town) by Bhutan Telecom and other from Gelephu (South Central town) by Tashi Cell both of which fibre optic lines pass through Indian narrow Siliguri corridor to join Chennai and Mumbai submarine intercontinental landing stations. The total bandwidth of these two gateways is around 10 Gbps (Bhutan Telecom Ltd – 6 Gbps, Tashi InfoCom Private Ltd – 3.0 Gbps and Nano – 0.2 Gbps). The two gateways terminate in London via Mumbai and Singapore via Chennai, respectively. As these two gateways pass through a 20 km wide Siliguri corridor, Bhutan needs to have its International Internet Backbone Redundancy at least 100 km apart from these two mainlines. Bhutan wants to get 3rd international gateway from Bangladesh via India connecting to either Cox's Bazar or Kuakata (Patuakhali) intercontinental gateways shortening nearly 2,500 km overland distance from Chennai or Mumbai. Upon completion, Bhutan's international bandwidth capacity would be increased to 20 Gbps from existing 10 Gbps. The research and education network of Bhutan "DrukREN" is shown in Fig. 13.

Bhutan's three universities (Royal University of Bhutan, Medical University and Monastic University) cater to the need of higher education for

around 11,000 students. Like other higher education institutions in South Asia, the Bhutanese universities stopped delivering face to face education since 19 March 2020. All students left university campuses and affiliated colleges for their hometowns and villages. Despite the stoppage of face to face class activities, partial online education delivery was started using Moodle, Zoom, Big Blue Button, Google Classroom, Google Meet, H5P, telegram, group chats, and Skype. However, the initiative faces significant constraints in delivering online education in Bhutan. According to the Royal University of Bhutan Response Plan for COVID-19 [34], despite the institution's good-will assistance to students with data charges to facilitate online learning, students could not avail the online education opportunity due to poor internet connectivity in rural areas and small towns or no connectivity at all. There is also challenge of disparity in access. Even if the limited mobile internet is available, many students cannot afford it. Moreover, majority of students do not possess laptop/desktop computers or quality smartphones to avail the opportunity for online education. Some students are engaged in farming activities to assist their parents/family members in their villages and are fully disengaged from the online education.

3.4 Internet Infrastructures and Online Education in Australia

With around 25.7 million people, Australia has 42 universities (40 public, one catholic and one private). All Australian universities and research organisations are well connected through an ultra high-speed network with the public internet. This network is called Australian Academic and Research Network (AARNet) that connects education and research institutions and organisations with the global research and education network community and resources via multiple 10 and 100 gigabit per second (Gbps) links. Each Australian university is connected to AARNet with 100 Gbps bandwidth. The network was designed to meet the needs of data-intensive research in science, engineering, and humanities. The AARNet was developed with low latency, low contention and with sufficient headroom capacity to support bursts of intense use. These key features distinguish the AARNet from other research and education networks. The AARNet is a not-for-profit National Research and Education Network (NREN) owned by the Australian universities and Commonwealth Scientific and Industrial Research Organisation (CSIRO) for the greater good of Australia and its citizens. It is widely regarded as the founder of the internet in Australia in 1989. The Australia wide AARNet is shown in Fig. 14.

The AARNet connects over two million users (researchers, academics/faculty members, students, administration, and general staff) at institutions across Australia to commercial internet, their peers nationally and globally, various cloud services and specialist online resources. In addition to Australian universities and CSIRO, the AARNet also provides internet services to research institutes, hospitals, vocational education, and training institutes (TAFEs), schools, galleries, libraries, archives, and museums. The AARNet owns and has access to fibre optic links across Australia through major metropolitan cities. It interconnects Australian research and education institutions directly with foreign universities using global national research and education networks without using commercial internet. The AARNet has multiple networks (100, 10, 1 Gbps) with a total bandwidth 245 Gbps with North America's INTERNET 2, 100 Gbps network to Asia's TEIN 3 and Europe's GEANT via Singapore. The AARNet has another 100 Gbps network connecting Asia's TEIN 3 and Europe's GEANT via Hong Kong. AARNet's international gateways are shown in Fig. 15. It has collaboration services with CloudStor, Zoom and Panopto enabling the delivery of education and seamless data access [34]. Australian population is well served by commercial internet infrastructures. Every household in Australia has either wired ADSL2+ broadband and/or National Broadband Network (NBN). Over 98% of Australia's population is covered with 4G mobile internet networks with average download speed 50 Mbps in metropolitan cities [31]. However, download speed on personal devices could be less than 50% of it.

The expansion and development of mobile network (considered to be the future backbone for online education) are much faster in developed nations than emerging and developing countries. The mobile internet speed now exceeds the fixed line broadband internet speeds in many countries. The mobile (cellular) network started from generation one (1G) in early 1980s with analogue signal (voice only), 2G from early 1990s with digital signal (voice, text, conference call, call hold and roaming), 3G from early 2000s (voice, text, photo sharing, video streaming, video calls, data, internet), 4G from end of 2010 (with all features as 3G but much faster speeds and greater capabilities for multimedia tasks), 5G from 2018/2019 with all features as 4G but with much faster speeds. Specific standards, frequencies, download speeds related to each "G" are shown in Fig. 16. To use basic internet for social media, email, surfing and listening to music, a minimum of 1 Mbps download speed is required. For watching standard definition (SD)

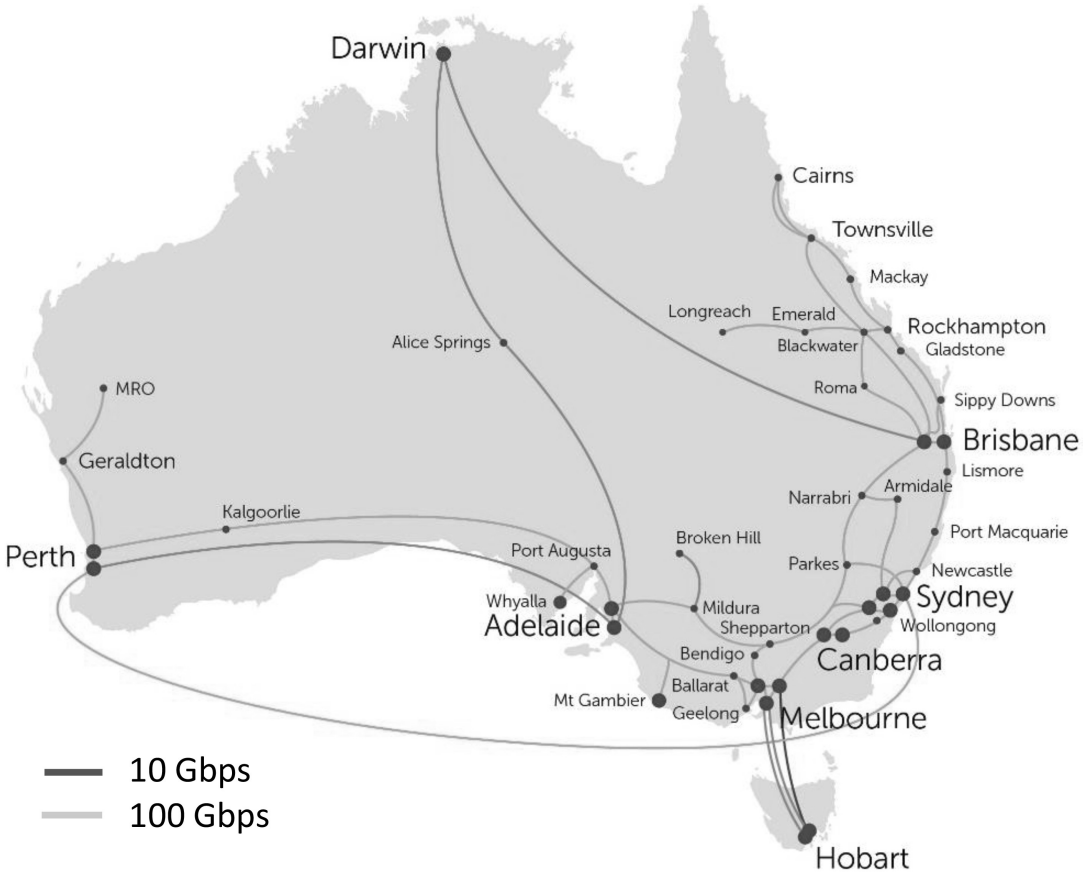

Fig. 14. Australian Academic and Research Network (AARNet), adapted from [34].

videos on YouTube, 2 Mbps, for High definition (HD) video streaming, 5 Mbps, and for high quality images, cloud services, playing online games, watching 4K TV or very HD movies, a speed of 10 Mbps is required. Therefore, for delivering online education with visual aids, graphics display, and high-resolution multimedia, more than 2 Mbps mobile internet download speed is required.

To deliver online education effectively, well-structured, and well-designed Learning Management System (LMS) is essential for education institutions [35–39]. LMS is used to design, develop, deliver courses (and programs) along with course assessment/evaluation, grade management, student participation and engagement, etc. Class timetable is mostly automated and lecture theatres enable to record lectures in real time using lecture capture software. The recorded lecture is then automatically posted to the course shell in LMS. Only enrolled students for the course have access to the recorded lectures, learning materials/resources in LMS. For all course-management activities, teaching staff communicate with students through LMS platform as it sends all communications to individual student using institutional email address and keeps a record of all communications between students and teaching staff. The LMS can be used to create professional structured course content. The teaching staff can add text, images, tables, links, interactive assessment (tests, quizzes, examinations, etc.) slideshows, recorded lectures, tutorials, lab demonstrations, live delivery of lectures, tutorial classes, etc.

The regulated access helps teaching staff controlling and managing the educational content, track study progress and engage student with contact tools. LMS can enable teaching staff to create customized tests for students, accessible and submitted online. It allows designing assessment with multiple question types including one/multi-line answer, multiple choice answer, drag-and-drop order, essay, true or false/yes or no, fill in the gaps, upload answer and offline tasks [35–39].

The LMS allows giving feedback to students and obtaining feedback from students. Teaching staff can create discussion groups to increase student interaction in the course and get live or anonymous students' feedback on course deliberation. Students' feedback is vital for teaching staff to improve their work, identify what to add or remove from their courses, where students feel more comfortable, what makes them be more included, etc. [35–

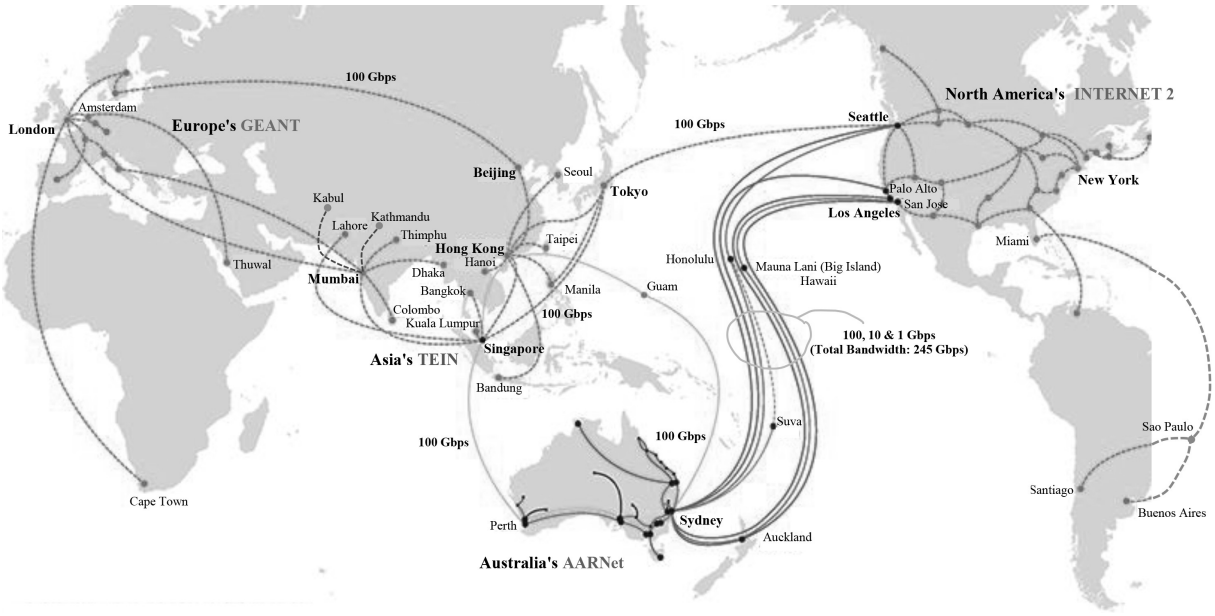

Fig. 15. International Academic and Research Network, adapted from [34].

39]. Major benefits and issues associated with LMS are shown in Table 4.

Higher education institutions in developed countries including Australia, New Zealand, USA, Canada, UK, and Ireland created capability to deliver online education (courses/programs) partially or fully over a decade ago. Furthermore, most higher education institutions are using commercial or open-sourced Learning Management Systems (LMSs) for online and off-campus education. There are three major LMSs used in Australia, Canada, New Zealand, UK, and USA. These LMSs are Blackboard, Moodle and Canvas as shown in Fig. 17. Blackboard is commercially developed platform, Moodle and Canvas are open-source platforms. In the US, 34% higher education institutions use Canvas, followed by Blackboard 28%, Moodle 18%, D2L 10% and other 8%. In Canada,

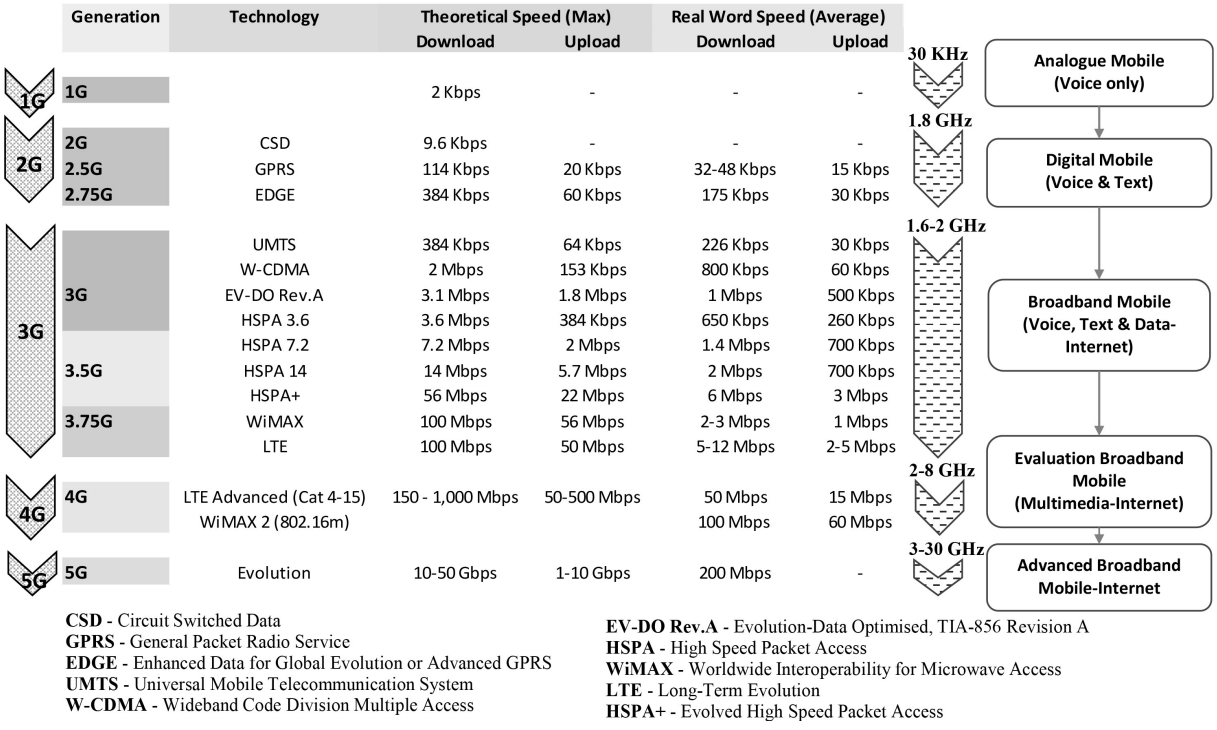

Fig. 16. Mobile network from 1st generation to 5th Generation with bandwidth capacity, adapted from [32, 40].

Table 4. Major benefits and issues of LMS adoption

Advantages	Difficulties
• *Interoperability* – an LMS supports content in all popular formats including text, video, audio, social media links, etc. • *Accessibility* – enrolled students and course faculty members/ academic staff can access to materials anytime, from everywhere. Academics/faculty members can modify the content, and enrolled students can see the updated learning materials/resources. • *Evaluation Adaptability* – the evaluation of students is easier, track student attendance, conduct online quizzes, tests, examinations (including upload worked out answers, etc. • *Reusability* – enrolled students and academics/faculty members can re-use the material every time they need. • *Flexibility and Maintenance Ability* – enrolled students can engage in learning activities collaboratively by setting up discussion groups within LMS thereby facilitating assisted learning and teaching. • *Compliance and Copyright* – LMS software helps education institutions and teaching staff keeping up to date with compliance regulations and copyright issues.	• *High Speed Internet Access* – implementing LMS requires a well-built technology infrastructure and internet bandwidth within educational institutions and externally connected with high-speed public internet infrastructures. Students, institutions, and academics/faculty members- all need to have reliable and required internet bandwidth for effective access. • *Commitment* – faculty members/academic staff need to be motivated to adapt their curricula from traditional face to face delivery to fully online mode delivery and/or supplementing face to face delivery. • *Delivery Style* – presenting learning module in only one style can make it difficult to accommodate different learning styles that required for online/eLearning education delivery. • User Helpline – any LMS introduction needs comprehensive support and in-person training. Without such support, it is extremely difficult to motivate academic staff/faculty members to use LMS effectively.

over 51% higher education institutions use Moodle, followed by D2L 30%, Blackboard 11%, Canvas 4% and other 2%. Moodle is the dominating LMS in the UK (48%), Australia (37%) and New Zealand (38%) [35–38]. However, Blackboard is also popular in New Zealand (38%), Australia (38%), and the Middle East (for example Saudi Arabia 89%). Globally, Moodle has over 50% market share in Europe, South America, and Oceania [35–38]. Blackboard and Canvas were developed in the USA by Blackboard Inc. and Instructure, respectively. Moodle developed by Martin Dougiamas, an Australian Computer Scientist. Moodle and Canvas are both open source LMS. There are annual subscription fees for Blackboard and support and maintenance fees for Canvas and Moodle. The yearly subscription amount is kept undisclosed as the LMS company negotiates price with individual university separately. Therefore, teaming up with several universities may ensure lower annual subscription through collective bargain if a group of universities decide to use Blackboard, Canvas or Moodle LMS. The Moodle was written in PHP and distributed under the GNU General Public License. It was developed on pedagogical principles for blended learning, distance education, flipped classroom and other e-learning in schools and universities.

Since 22 March 2020, all Australian universities stopped face to face education delivery due to COVID-19 pandemic lockdown. Academics/ faculty members as well as students were not allowed to come to the university campuses. As a result, with a short notice (in some cases less than two days), academics/faculty members were required to move their face to face education delivery to fully online delivery via university's LMS. Teaching staff were required to adapt lectures, tutorials, laboratory practices, etc.) for online mode delivery. However, this quick transition did not create huge disruption as most teaching staff were familiar with LMSs which they were using for partial or full online course delivery. Like other universities in Australia, RMIT University (one of Australia's largest public universities with over 80,000 students including 20,000 students in offshore campuses) also transitioned to fully online education delivery since the beginning of COVID-19 lockdown in March 2020. It switched to Canvas from Blackboard in 2018. Familiarisation with Canvas was undertaken in an orderly manner and all teaching staff were coached and trained to create individual course shell and use it for face to face and online course delivery. This helped teaching staff switching to online mode with minimal or no disruption at RMIT University. Teaching staff at other Australian universities have undergone through similar coaching and transitional processes. A course shell with the key course/subject/ module/unit functionalities in Canvas LMS is shown in Fig. 18.

4. Discussion

The COVID-19 pandemic has affected more than 1.5 billion school and university students across the planet since March 2020. In India alone, there are 250 million students affected by the COVID-19 lockdown, 80% of which fall in the economically weaker section (EWS) category and are struggling to attend limited online classes due to lack of resources. Over 30% students do not possess gadgets (devices) and infrastructure to pursue online learning. Similar situations are prevalent in other South Asian and emerging nations. Online teaching and learning where teaching staff and students are separated by distance require information and communications technology (ICT), stable and fast

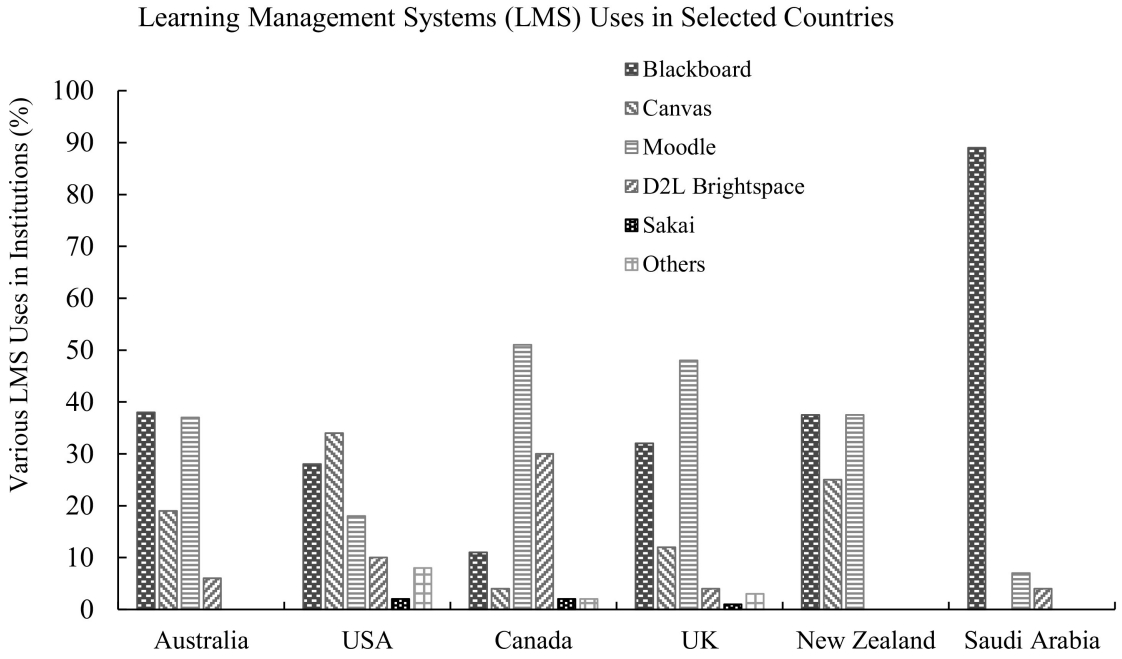

Fig. 17. Common LMS platforms.

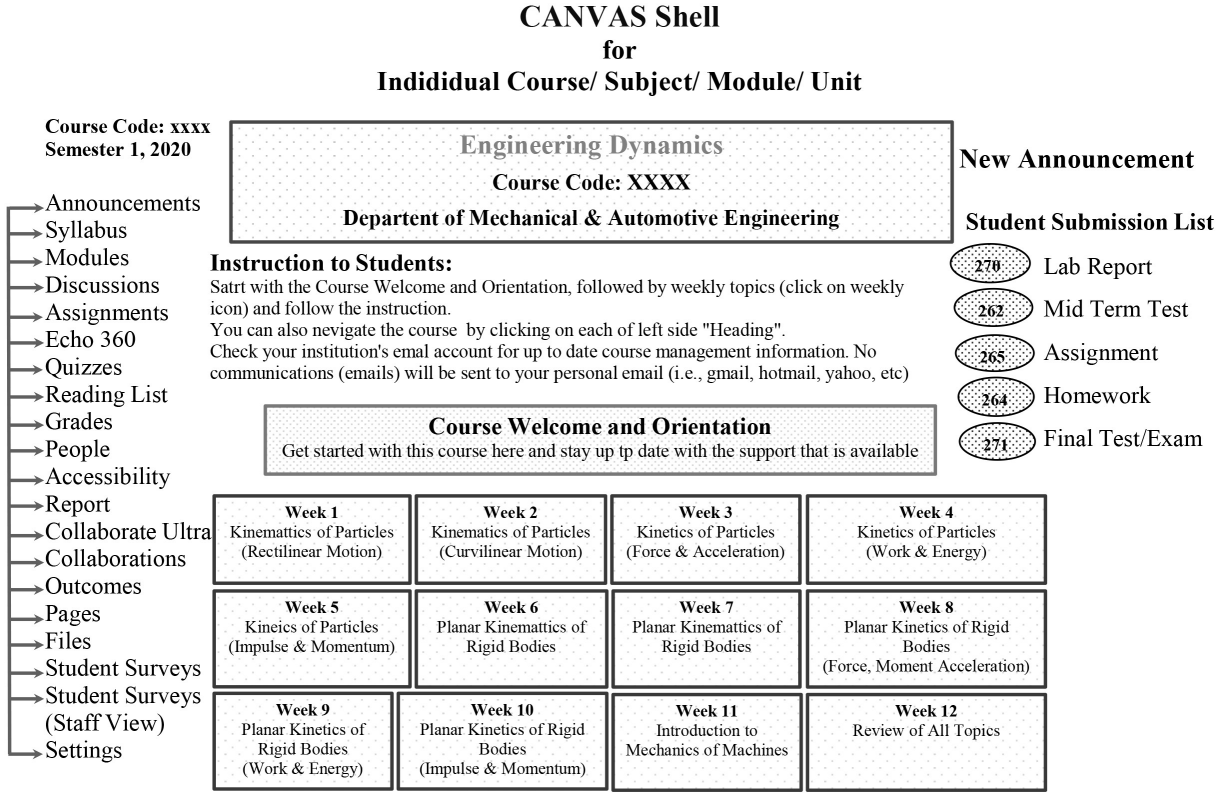

Fig. 18. A typical course shell in Canvas.

internet connection, digital learning resources, online pedagogy, and equitable access. Despite the difficulties, online delivery of teaching and learning has numerous advantages thanks to no physical boundaries (from any location, any time, and learners' own pace) [37–39, 41]. It is cost-effective, student comfort zone enabled learning, and transparent teaching and learning activities if undertaken through Learning Management System (LMS). As there is no structured LMS for online education delivery in developing and emerging nations including South Asia, teaching staff are

using video calling and messaging apps such as Zoom, Microsoft Teams, Google Classroom, Google Meet, WhatsApp, and Google drive for their online course delivery. Teaching staff are required to use numerous apps as no single app could cater the whole gamut of online delivery activities. A student requires around 3 to 4 GB mobile data daily for attending on average four online classes of one-hour duration each, the cost of which is beyond the reach of most students. According to Open Signal report [31], the average download speed for mobile internet is 7.3 Mbps in South Asia compared to 67.6 Mbps in Australia. Our own sample speed tests in large cities showed the download speed is significantly lower than 7.3 Mbps. The download speed in regional and smaller cities/towns for the mobile internet is less than 2 Mbps. In rural areas, the situation is significantly worse. In Bangladesh, there are only 8.7 million subscribers of land based broadband internet subscriber for 165 million people. Where there is no land based high speed broadband internet network, people generally rely on mobile internet. As shown in Fig. 18, mobile networks in South Asia mainly offer 3G connections which have severe bandwidth limitation. Major cities like New Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad in India, Dhaka, Chattogram, Khulna and Sylhet in Bangladesh, Colombo in Sri Lanka, Lahore, Islamabad and Karachi in Pakistan, and Kathmandu in Nepal have so called 4G mobile network without true minimum average 50 Mbps download speed. The true 4G mobile network (50–100 Mbps download speed) is a dream for most people in South Asia as nearly 70% population still do not have reliable 3G mobile network (0.226–12.0 Mbps download speed) beyond major cities. Furthermore, the difficulties with the download speed mobile network need to be considered. For example, the speed depends on (a) *Mobile Network* (base station data speed, capacity of base station – the number of users that base station can handle at any time, backhaul capabilities of base station – connection speed between tower and network, carrier's frequency channel bandwidth, wider the channel bandwidth, higher the data to send, for example, standard channel bandwidths that Australia's mobile networks used are 10 MHz, 15 MHz and 20MHz for 4G), (b) *Environment* (terrain between user and base station – buildings and structures, trees, terrains, hills, water, etc, reduce the signal strength, similarly weather conditions – wind, rain, snow, etc. also lower the signal strength), (c) *Users* (number of devices connected to base station at any one time - more the number using internet the sluggish data speed, distance between base station and user – more the distance slower the speed, signal level on the users device – lower the signal slower the speed, and signal quality received by users device – lower the quality of signal slower the speed); and (d) *User Hardware/Mobile Set* (types of mobile device are used – data speeds supported, strength of MIMO antenna support, amplifier power, etc.) [40].

Despite having immense benefits, online education in emerging nations especially in South Asia remains a distant dream. There are no true internet infrastructures for comprehensive online education delivery. Furthermore, socio-economic divide has made internet gadget gaps as majority students do not have either computing and streaming devices or no internet accesses and no capacity to pay for the accesses. Whatever the limited infrastructures are available they do not have adequate internet bandwidth for online interactive education delivery. For example, every higher education institution in Australia has a minimum of 100 Gbps dedicated bandwidth compared to 1 Gbps or less bandwidth that some elite higher education institutions have in India, Bangladesh, or Bhutan.

India's elite IITs and NITs are delivering courses online with mixed success. It may cause digital knowledge divide among their students. Most higher education institutions (except private institutions) in Bangladesh and Bhutan are refrained from delivering online education due to insufficient internet infrastructures and affordability of computing and streaming devices, limited and/or lack of internet accesses. In Australia and other high-income countries, all higher education institutions and schools have been delivering their teaching and learning activities fully online using in-house built or commercial LMSs since the outbreak of COVID-19 without skipping a single day. In contrast, most government and government aided universities and schools remain closed since March 2020 in emerging nations. As there is no end of COVID-19 mayhem in the short term, the only viable alternative for education institutions in emerging and developing nations is to deliver education online. To make the online education delivery more equitable, affordable, and viable for all education stakeholders (students, academic staff/faculty members, management, and government), some recommendations along with action plans are furnished in Table 5.

5. Conclusions

Online delivery of education is irreversible and sooner the education institutions embrace it better for all. The COVID-19 has profound impact on education delivery of every institution in every country. It accelerated the education transition to online from traditional face to face delivery. It has

Table 5. Recommendations and action plans

Element of Online Education	Suggested Actions
Infrastructure	• Higher education institutions must have tens of giga byte dedicated internet bandwidth infrastructures for internal and external internet traffic. Without such infrastructure, no effective online education delivery is possible. • Students and academics outside of the institution premises need to have high speed internet access. Where there is no land based broadband network available, there must be true 4G and/or 5G mobile network. • Education institutions, government, and telecommunication company need to work hand in hand to develop and maintain high speed internet infrastructures (land based and mobile) for the greater benefit of students, academic staff, administration, education institutions and the nation. • All education institutions must be connected to the national research and education network which in turn would be connected to global intercontinental networks TEIN (Asia), GEANT (Europe), INTERNET 2 (North America), AARNET (Australia) and other regional and continental research and education networks.
Management and Administrative Support	• Authorities must ensure adequate funding, guidance, oversight, and support in removing all barriers for online delivery of courses/programs. • Administrative support must begin with the home institution by fostering a synergistic environment conducive to innovative online education delivery that significantly differ from traditional face to face education by actively encouraging, engaging, and rewarding academic staff/faculty members and support staff.
Selection, Development, Utilisation and Ongoing Maintenance of LMS	• Selection of appropriate Learning Management System (LMS) is critical for successful and effective online education delivery. • Some well-developed commercial or open source LMSs such as Blackboard, Moodle, Canvas, Desire2Learn (D2L) can be utilised as each of these LMSs has unique and common features (e.g., flexible, ease of access, ability to sophisticated multimedia and technologies) very useful for comprehensive online delivery. • In-house built LMS with required features can also be used as an alternative to commercial or open source LMSs. • Regardless of commercial, open source or in-house built LMS, a structured and well-designed LMS is vital for successful, productive, efficient, and sustainable online teaching and learning.
Online Course Design, Delivery (objectives, digital and pedagogical contents, learning resources and delivery, learning activities, assessment, and feedback)	• Online delivery (synchronous or asynchronous) must have well-designed course and program along with well-structured and high-quality digital resources, pedagogical delivery of contents, learning activities, assessment/evaluation, and closed loop feedback mechanism. • Although the modes of online and face to face delivery are not the same, both delivery modes must have undifferentiated learning outcome. Hands on laboratory practices must be supplemented with video lab demonstration and sample data for preparing laboratory report, virtual laboratories, and remotely controlled/operated labs. Exposure to hands on laboratory practices is vital for all core engineering and science courses and programs [42].
Support for Students, Academics/Faculty Members	• Along with pedagogical support, socio-economically disadvantaged students need to have financial aid for acquiring digital gadgets (desktop, laptop, smart phones) and data services including access to reduced cost high speed internet. • Lost cost gadgets (android operating smartphones with bulk purchased prepaid mobile data sim card) either locally manufactured/assembled or imported can be given to socio-economically disadvantaged students free of charge to enable them engaging in online education. • Academic staff/faculty members need technical and transitional support for delivering courses from face to face to online mode delivery. Supports are critical in digitisation of learning content/resources and selection of digital tools for delivering engaging learning contents and activities. • In absence of LMS platform, teaching staff should continue using existing tools/systems (e.g., Google Classroom, Google Meet, Microsoft Teams, Zoom, WhatsApp, YouTube Live, Good Drive, etc.).
Focus on Blended Learning	• COVID-19 has profound impact on every aspect of life, especially on education. Online delivery of education will remain as one of the centre parts in overall education delivery in all countries (high income, medium income, and low income). • Course and program need to be designed for both online and face to face mode delivery. There should be no longer a split between online and face-to-face teaching, instead ''everything is blended''. Infrastructures, resources, pedagogical mindset, and support systems must be continuously improved, reviewed, and corrective measures undertaken.

created favourable perception about online education especially in emerging nations where generally online education is berated and subjected to harsh regulatory compliances and disregards.

The online transition requires adaptation of curriculum, course content, course materials/ resources, pedagogy, learning activities, assessment, feedback and responses to compliances, urgency, and student needs. The COVID-19 transition clearly showed that online delivery could not be a simple recording of traditional face to face lectures or class activities posted to the LMS or non LMS platforms such as Zoom, Microsoft Teams, Google Classroom, Google Meet or WhatsApp. Online education delivery requires highest-level pedagogical mastery for actively engaging students in learning activities and assessing their learning outcomes.

The COVID-19 has exposed the infrastructural weakness and impedance for online education delivery in emerging and developing countries. For effective online delivery, ICTs, robust internet infrastructures, and equitable access for all are indispensable. Furthermore, coordinated effort and investment are required for building online education delivery capability. The institution management, policymakers and the government must work together for developing high speed research and education network (like Australia's AARNet) that can serve institutions (universities, polytechnics, colleges, schools) and research organisations nationally and internationally connecting to global research and education network independent of commercial internet networks.

For effective online education delivery, dedicated Learning Management System (LMS) platform (commercial, open source or in-house built) is a must as it allows managing every aspect of course activities including delivery plan, learning resources compilation, learning activities with synchronous or asynchronous lecture recording, assessment, and closed loop feedback. Through LMS, accountability and transparency of stakeholders (teaching staff, students and course related other staff) and track record of their activities can be monitored and ensured.

Ensuring equitable participation of all students regardless of their socio-economic status in online education, the digital division and knowledge gap significantly be reduced or eliminated. In developing nations, mobile internet will be dominating due to land based broadband internet infrastructure constraints. Moreover, true 4G and 5G mobile networks will offer higher internet speeds than land based wired broadband internet. Therefore, the COVID-19 initiated online education delivery and traditional face to face delivery can be blended, customised for the greater benefits of students, teaching staff and the institution. Internet devices (laptop, smart phones, and internet access) must be provided to socio-economically disadvantaged students for ensuring equity and equality.

References

1. C. Rapanta, B. Botturi, P. Goodyear and L. Guàrdia, Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity, *Postdigital Science and Education*, **1**(1), pp. 132–145, 2020.
2. D. Houston, L. H. Meyer and S. Paewai, Academic staff workloads and job satisfaction: expectations and values in academe, *Journal of Higher Education Policy and Management*, **28**(1), pp. 17–30, 2006.
3. S. Houlden and G. Veletsianos, Coronavirus pushes universities to switch to online classes – but are they ready, The Conversation, https://theconversation.com/coronaviruspushes-universities-to-switch-to-online-classes-but-arethey-ready-132728, Accessed 12 September 2020.
4. C. Hodges, S. Moore, B. Lockee, T. Trust and A. Bond, The difference between emergency remote teaching and online learning, *Educause Review*, https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning, Accessed 10 August 2020.
5. L. Shulman, Knowledge and teaching: foundations of the new reform, *Harvard Educational Review*, **57**, pp. 1–22, 1987.
6. C. Angeli and N. Valanides, Preservice elementary teachers as information and communication technology designers: an instructional-systems design model based on an expanded view of pedagogical content knowledge, *Journal of Computer Assisted Learning*, **21**(4), pp. 292–302, 2005.
7. Y. Kali, P. Goodyear and L. Markauskaite, Researching design practices and design cognition: contexts, experiences and pedagogical knowledge-in-pieces, *Learning, Media and Technology*, **36**(2), pp. 129–149, 2011.
8. Y. H. Ching, Y. C. Hsu and S. Baldwin, Becoming an online teacher: an analysis of prospective online instructors' reflections, *Journal of Interactive Learning Research*, **29**(2), pp. 145–168, 2018.
9. A. D. Lantada, Engineering Education 5.0: Continuously Evolving Engineering Education, *International Journal of Engineering Education*, **36**(6), pp. 1814–1832, 2020.
10. S. Dutta and B. Lanvin, B. (2019), The Network Readiness Index 2019: Towards a Future-Ready Society, Portulans Institute, Washington D.C., pp. 1–308, 2019.
11. The World Bank Country and Lending Groups, https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups, Accessed 3 January 2021.
12. J. Salmi, COVID's Lessons for Global Higher Education, https://www.luminafoundation.org/wp-content/uploads/2020/11/covids-lessons-for-global-higher-education.pdf, Accessed 5 January 2021.
13. Y. Sharma, India in "initial stages" of higher education massification, University World News, https://www.universityworldnews.com/post.php?story=20191128104421724, Accessed 10 August 2020.
14. National Knowledge Network (NKN), Delhi, http://nkn.gov.in/documents/NKN_Brochure.pdf, Accessed 17 July 2020.
15. R. Choudhary, COVID-19 Pandemic: Impact and strategies for education sector in India, https://government.economictimes.indiatimes.com/news/education/covid-19-pandemic-impact-and-strategies-for-education-sector-in-india/75173099, Accessed 16 April 2020.
16. Map Chart, https://mapchart.net/india.html, Accessed 15 July 2020.
17. Pan-IIT Survey on Online Education – A Report, Pan IIT Group, https://arxiv.org/ftp/arxiv/papers/2007/2007.03613.pdf, Accessed 29 October 2020.
18. Bangladesh Bureau of Educational Information and Statistics-BANBEIS, http://www.banbeis.gov.bd/, Accessed 30 November 2020.
19. H. Chowdhury and F. Alam, Engineering Education in Bangladesh – an indicator of economic development, *European Journal of Engineering Education*, **37**(2), pp. 217–228, 2012.

20. H. Uzzaman, Establishing Technical Schools and Colleges in 329 Upazila, 26 April, Daily Jugantor, https://www.jugantor.com/todays-paper/last-page/170932, Accessed 24 June 2020.
21. Bangladesh Telecommunication Regulatory Commission (BTRC), http://www.btrc.gov.bd/content/internet-subscribers-bangladesh-november-2020, Accessed 7 January 2021.
22. Bangladesh Telecommunications Company Ltd (BTCL), http://btcl.gov.bd/, Accessed 26 June 2020.
23. V. O'Grady, Bangladesh reports internet usage growth, Developing Telecoms, https://www.developingtelecoms.com/telecom-technology/optical-fixed-networks/9378-bangladesh-reports-internet-usage-growth.html, Accessed 26 June 2020.
24. G. M. Rahman, Finding a better way to use surplus bandwidth, The New Age, 2 May, http://www.newagebd.net/article/66175/finding-a-better-way-to-use-surplus-bandwidth, Accessed 26 June 2020.
25. Bangladesh Research and Education Network (BdREN), https://www.bdren.net.bd/, Accessed 3 July 2020.
26. Bangla Tribune, https://www.banglatribune.com/others/news/640273/, Accessed 23 September 2020.
27. Virtual Classroom Apps Bangladesh, http://demo.virtualclass.gov.bd/, Accessed 26 June 2020.
28. M. S. Islam, M. Amin, M. Salman and K. M. Tanvir, Online classes for university students in Bangladesh during the Covid-19 pandemic- is it feasible? The Business Standard, https://tbsnews.net/thoughts/online-classes-university-students-bangladesh-during-covid-19-pandemic-it-feasible-87454, Accessed 23 September 2020.
29. M. Wadud, Delayed online teaching in pandemic widens education gap, University World News, https://www.universityworldnews.com/post.php?story=20200722154017758, Accessed 23 September 2020.
30. Internet users in Bangladesh double in last five years, The Financial Express, https://thefinancialexpress.com.bd/trade/internet-users-in-bangladesh-double-in-last-five-years-1602834123, Accessed 7 January 2021.
31. Australia Mobile Network Experience Report, Opensignal Ltd, https://www.opensignal.com/reports/2020/04/australia/mobile-network-experience, Accessed 11 January 2021.
32. The economic impact of 5G – Ensure regulation and keep pace of innovation, International Telecommunications Union -ITU, https://www.itu.int/en/ITU-D/Regulatory-Market/Documents/Events2018/RED-AFR_BF/Ses5.0_5G_Ssemboga.pdf, Accessed 23 September 2020.
33. Druk Research and Education Network (DrukREN), https://drukren.bt/network/, Accessed 5 January 2021.
34. Royal University of Bhutan (RUB) Response Plan for COVID-19, https://www.rub.edu.bt/images/rub/Key-Documents/Response-Plan/RUB-Response-Plan-for-COVID-19.pdf, Accessed 20 March 2020.
35. Australian Academic and Research Network (AARNet), https://www.aarnet.edu.au/network-and-services/the-network, Accessed 30 December 2020.
36. J. Schoonenboom, Using an adapted, task-level technology acceptance model to explain why instructors in higher education intend to use some learning management system tools more than others, *Computers & Education*, **71**, pp. 247–256, 2014.
37. Edutechnica, 8th Annual LMS Data Update, https://edutechnica.com/tag/market-share/, Accessed 1 January 2021.
38. P. Hill, State of Higher Ed LMS Market for US and Canada: Mid-Year 2020 Edition, Phil on Ed Tech, https://philonedtech.com/state-of-higher-ed-lms-market-for-us-and-canada-mid-year-2020-edition/, Accessed 30 December 2020.
39. F. Alam and A. Kootsookos, Accreditation of Engineering Education and Global Mobility, CRC Press, London, p. 228, 2021.
40. F. Alam, R. Hadgraft and Q. Alam, eLearning – Challenges and Opportunities, in: Using Technology Tools to Innovate Assessment, Reporting, and Teaching Practices in Engineering Education, (ed. Alam F), IGI Global, New York, p. 409, 2014.
41. Mobile Network Guide Australia, https://www.mobilenetworkguide.com.au/mobile_data_speeds.html, Accessed 11 January 2021.
42. F. Alam, R. Hadgraft and A. Subic, Technology Enhanced Laboratory Experiments in Learning and Teaching, in: Using Technology Tools to Innovate Assessment, Reporting, and Teaching Practices in Engineering Education, (ed. Alam F), IGI Global, New York, p. 409, 2014.
43. F. Alam, E. Dilla, A. Subic and J. Tu, A three-step teaching and learning method in laboratory experiments for a thermal fluid course, *World Transactions of Engineering and Technology Education*, **6**(1), pp. 13–18, 2007.

Akshoy Ranjan Paul, PhD is an Associate Professor at the Department of Applied Mechanics, Motilal Nehru National Institute of Technology (MNNIT) Allahabad, India and is involved in teaching and research for 20 years in the areas of fluid mechanics, green energy, and educational technology. Dr. Paul has over 135 publications as book chapters, journal articles and peer reviewed conference papers.

Abdulaziz Aldiab is a Lecturer at Imam Abdulrahman Bin Faisal University (formerly University of Dammam), Saudi Arabia. Currently he is a PhD research scholar in the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia. He has Bachelor and Master's degrees in Computer and Information Technology (ICT). His research interest includes eLearning, virtual laboratories and Learning Management System (LMS).

Somnath Chattopadhyaya, PhD is an Associate Professor at the Department of Mechanical Engineering, Indian Institute of Technology (IIT)/Indian School of Mines (ISM) Dhanbad, India. He has obtained his Bachelor, Master and PhD degrees in Manufacturing and Production Engineering. He has over 100 publications (books, book chapters, journal articles and peer reviewed conference papers). His research interest includes 3D printing, mining equipment and engineering education pedagogy.

Altab Hossain, PhD is an Associate Professor at the Department of Nuclear Science and Engineering, Military Institute of Science and Technology (MIST), Bangladesh. He is also an Associate Editor of MIST International Journal of Science & Technology (MIJST). He has over 100 publications as book, book chapters, journal articles and peer reviewed conference papers. He has strong interest in education technology and online education.

Zinat Tasneem is an Assistant Professor at the Department of Mechatronics Engineering, Rajshahi University of Engineering and Technology, Bangladesh. She has completed her BSc and MSc in Electrical and Electronic Engineering from the same institution. Her research interests include wind turbine aerodynamics, power electronics in renewable energy technology and control system, technology assisted pedagogy and online education.

Nawshad Haque, PhD is a Senior Scientist at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Melbourne, Australia researching on hydrogen and renewable energy. Dr Haque received his PhD from the University of Sydney in 2002. He is an Adjunct Academic at Monash University, Swinburne University and RMIT University, Australia. He has over 100 publications and has strong interest in education technology.

Anupam Basu, PhD is Director NIT Durgapur, India and Professor, Department of Computer Science & Engineering, IIT Kharagpur, is an active researcher in the areas of Cognitive and Intelligent Systems, Embedded Systems and Language Processing, He leads a number of projects for Technology Enabled Education. He is an Alexander von Humboldt Fellow and a Fellow of the Indian National Academy of Engineering and has won several awards and honours.

Tashi Gyeltshen, PhD is an Assistant Professor at Samtse College of Education, Royal University of Bhutan. He received his PhD in education. Over sixteen years offering programs at undergraduate and postgraduate levels, he supervised MEd dissertations and BEd research projects. He has research publications at both national and international levels. He has strong research interest in eLearning and distance education.

Yangdon, PhD is a lecturer at Samtse College of Education, Royal University of Bhutan. She received her PhD in education. Dr Yangdon has teaching experience in schools and tertiary colleges. She teaches English language and undertakes educational research. She is a keen researcher with a passion to advocate positive social changes and best-informed practices in educational settings.

Reza Nakhaie Jazar, PhD is a Professor at the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University. He is an expert in nonlinear dynamics and applied mathematics. He has worked in several universities worldwide, and through his research, he has formulated many theorems, and discoveries. He has authored 17 books all among the most prestigious publications in their fields.

Firoz Alam, PhD is a Professor at the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia. He received his bachelor's degree combined with master's degree in Aeronautical Engineering and PhD in road vehicle aerodynamics. He has over 250 publications (books, book chapters, journal articles and peer reviewed conference papers). His research interest includes eLearning, virtual laboratories, and transnational education.