COVID-19 the disruptor; Challenges and opportunities in Medical Education

Ayesha Farooq[1], Sabine Rizwan[2], Shayan Farooq Qureshi[3], Uzma Hassan[4]

ABSTRACT

The impact of the disruption of COVID-19 pandemic on medical education is being innovatively tackled by many medical teaching institutes worldwide. While the use of technology has steadily increased in medical teaching and learning over the past decade, in the present unpredictable and uncertain times we are witnessing the exponential, hyper growth in the application of this technology. The objective of this article is to review the role technology is likely to play in a disrupted, post COVID-19 world by a transformative change in our existing practices of medical education leading to new and innovative opportunities.

The literature search methodology involves a systematic online search with PubMed, Google Scholar and other professional electronic medical and technological library sources to review material for this article. The focus was to include post COVID-19, publications from December 2019 to May, 2020. The impact of new and innovative opportunities in the current scenario has been explored through two perspectives; the present use of communication platforms such as LMS, Zoom™, MSTeams™ etc. as tools of distant online learning and assessment in medical universities. Secondly, the future impact of the utilization of emerging, cutting edge technologies of adaptive learning resources comprising Artificial Intelligence in Education (AIEd), Extended reality (XR) and collaborative databases of Open Educational resources (OER) and Open Course Ware (OCW) projects.

As evidence suggests in this review, the coming together of medical teaching and learning with technology in a uniquely enhanced manner during this pandemic has led to historic innovation which is something to look forward to with a positive spirit by both educators and learners.

Key words: COVID-19; Disruption; Medical Education; Emerging Technology; Innovation

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INTRODUCTION

The greatest innovations by mankind have manifested at the heels of the most destructive global crises. Disruptions such as wars, pandemics, economic and geographic disasters, traumatic in terms of speed and impact, result in a paradigm shift at a holistic, global level forcing humanity to alter course in order to survive and settle to a new normal.

As the potentially severe consequences of all "Black Swan" events go, COVID-19 is arguably amongst humanity's worst by any measure; expectation, speed, impact and preparedness. This highly unpredictable event, beyond the realm of normal expectations in the history of science and technology, has led to a partly, though robust, shift in health care provision[1]. Today, lack of preparedness and inadequate response is a testament to our failure to apply available technology to ensure basic human needs; health and security. The severity of this issue led the World Health Organization (WHO) to declare COVID-19 a global emergency in January 2020[2], with WHO COVID-19 Situation Report updates of 15 June, 2020 projecting 7,805,148 confirmed cases of COVID-19, including 431,192 deaths[3,4].

A few months ago, the world of academia bunkered itself against this invisible, elusive enemy; when students and teachers emerge from their lockdowns, a new, unfamiliar world awaits them; change is imminent; more so in the future practice and teaching of medicine. This pandemic is thus creating opportunities to think about new ways of learning and of delivering health care[5].

To better understand and analyze how this disruptor is affecting medical education we conducted a review of material utilizing an online literature search with PubMed and Google

1. Professor of Biochemistry, Al-Nafees Medical College and Hospital, Isra University, Islamabad Campus, Islamabad.
2. Fazaia Medical College, Air University, Islamabad
3. University of Manitoba, Winnipeg, Canada
4. Professor Public Health, NUMS, Rawalpindi

Correspondence:
Ayesha Farooq
Professor of Biochemistry, Al-Nafees Medical College and Hospital, Isra University, Islamabad Campus, Islamabad.
Email: ayeshafarooque@gmail.com

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Scholar, as well as other professional electronic medical and technological library sources including post COVID-19 publications from December 2019 to May, 2020 offering an insight into the ongoing innovative deviations in medical teaching.

Current Context

During the COVID-19 pandemic, the educational environment has taken a severe and unprecedented paradigm shift in medical universities, both nationally and internationally[6], majority having shifted to online teaching since March, 2020. Many have decoded not returning to in-person classes for the remainder of the 2019–2020 academic year including several medical schools across the United States, Canada and other countries[7]. This approach of suspension of all clinical placements and classes during this disruption has been adopted with the hopes of mitigating viral transmission and protecting the already fragile healthcare system[8].

Medical educators worldwide, including Pakistan are pondering on how to return the student back to the classroom post-June, 2020[9,5] as well as devising alternate plans to meet the next set of challenges, as the COVID-19 pandemic continues with its wave.

Challenges for the learner and the educator; technology's role and impact

The palpable panic in the medical community during this pandemic is also accompanied by many challenges. Ferrel and Ryan[10], while investigating the impact of this pandemic on medical education, foresee medical students and faculty questioning the future of their education and their careers. Thus far, since March, 2020, the response across education communities has been increased awareness and proactive, albeit haphazard, adoption of feasible and practical technological solutions including access to technological collaborative platforms. While this approach has navigated this panic in a positive direction from the "fear" phase to the "learning and growth "phase[11], it has also inevitably resulted in compromised protocols, security, quality of delivery and effectiveness of receipt.

In resource poor countries like Pakistan, the decision regarding complete lock-down, social distancing and closure of educational institutes has been very challenging due to socio-economic and other reasons[12]. While analyzing the effect of coronavirus crisis on education, UNESCO International Institute for Higher Education (2020) stress that virtualization that requires stable bandwidth connectivity and high data usage especially impacts the vulnerable socially and economically disadvantaged students[13]. Khan et al[14] address the unpreparedness of Pakistani universities in this regard by retreating that although Pakistan has faced university closures many times in the past decade due to terror attacks and the political scenarios, the sudden shift to digital learning amid the coronavirus crisis has posed challenges to the system as the majority of students are facing problems due to lack of personal computers/laptops and poor internet facilities.

The disruption post COVID-19 has affected not only teaching, but also low and high stake assessments, university examinations and licensing requirements[8]. Although competency based medical education (CBME) requires regular assessments of student achievement, there is now a limited opportunity to observe students or hold traditional face-to-face examinations. Focus is now on e-assessment which requires trained faculty and strategic planning. In such a scenario adaptability and ingenuity is the key. This ingenuity will be essential as educators and students wade through the challenges that lie ahead.

It cannot be predicted yet whether students' native-born to technology adoption will be compromised due to the sudden elimination of the physical aspect of campus, face to face socializing and the overall positive energy of the traditional learning environment; a gradual emotional challenge that is impacting their learning. Meo et al[15], in their descriptive study on impact of COVID-19 quarantine on medical students' mental wellbeing and learning behaviors found that more than forty percent of their study cohort showed a sense of being emotionally detached and dishearted. Evidence suggests that bringing back such learners to the interactive world of the virtual classroom, where connections can be reestablished with peers and teachers, can play an important role in demonstration of attributes of persistence and adaptability by these students[10].

It must also be kept in mind that while students are presumed to be supremely comfortable with technology platforms, educators are typically less comfortable with a primarily technology-driven education process. It is hence, relevant to highlight here that first and foremost, educators must be continuously developed to skillfully align these factors to achieve desired outcomes. Most medical education providers have rapidly scaled up technology infrastructure, digital content, and skills development of faculty, most of whom are not "native born" into technology as the primary platform for lifestyle.

Literature Review

Utilization of tech tools in medical education post COVID-19

According to the World Economic Forum's Global agenda on unlocking technology to deliver education, the COVID-19 pandemic has resulted in educational institutions across the world being compelled to suddenly harness and utilize the suite of available technological tools to create content for remote learning for students in all sectors[16]. Some of these are reviewed below.

Use of Learning Management System (LMS) as a technological resource post COVID -19

The current model of education has been undergoing changes, renovations, and increasing use of the benefiting technological resources such as the Learning Management System (LMS)[10]. Till 2019 many medical universities both globally and locally had not fully utilized the potential of the LMS for varying reasons including the lack of information and communication technology (ICT) support.

Evidence proves that in this era of global transformation of medical education and pedagogy the use of LMS has been proven to improve communication between teachers and students[17]. LMSs offer a number of features that help educators create grading systems, secure content, check attendance, create quizzes and maintain a platform with a lot of helping material that connects students with useful educational resources[18]. Amongst the teaching strategies for online learning communication, one of the most used LMS is the Modular Object-Oriented Dynamic Learning Environment (Moodle)[19, 20].

While investigating the technological advancements in higher education in Pakistan, Memon[21] highlighted that the majority of the Pakistani medical schools, as of 2017 had not integrated IT in medical teaching appearing reluctant in adopting the modern trends in medical education. As per data collected by Memon and Rathore[22], as of July 2017, only two medical schools in Pakistan had actively been using Moodle. Few other studies from Pakistan have attempted to explore this topic in local context; concrete findings are awaited[23,24]. Thus, the Higher Education Commission (HEC) of Pakistan, while proposing in March, 2020 that universities should disseminate information regarding online courses to the students in view of the coronavirus situation in the country[13] faced a paramount challenge. In response many medical universities have rekindled the use of their existent but "dormant" LMS including the Moodle, as an online learning platform for educating students and faculty and as an initiative to promote blended-learning.

Distant online learning post COVID-19

Distant learning is not a new phenomenon in medical education. In their work on the impact of current technology in advancing medical education Moran, Briscoe and Peglow[25], point to the fact that over the last several years globally some medical schools had shifted from traditional forms of 'in-person' lecture-based teaching to other modes, employing online, distance or electronic learning. Post COVID-19 this shift has become the norm; the risk of compromising teaching and learning during the core clinical rotations of medical students, as well as the experiences important for early medical student education, including problem-based learning interactions, skills sessions, anatomy dissections and group learning sessions[10] was too high.

In-person delivery of lectures has been replaced by streaming online lectures using collaborative communication platforms such as Zoom™, MSTeams™, BlueJeans™, and Skype™ etc. Webinars have replaced small group session tutorials, and to encourage interactive behavior through these evolving practices, several additional tools are coming into play such as Zoom breakout rooms and polling using digital devices.

Amongst early adopters, online tools such as videos, podcasts, simple virtual reality, computer simulations and serious games are being introduced to provide a relatively enhanced online learning experience in some hi-tech universities. Online platforms such as websites and blogs offer opportunities for essential clinical skills demonstrations whereby educators can remotely coach students with real time mobile video tools and apps.

Clinical teaching post COVID-19; challenges and the use of tech tools

Medical education regulators have recommended removal of students from direct patient care to avoid further spread of the virus, and to ration precious PPE supplies to front-liners who need them the most. The greatest impact is on advanced level students in the clinical years, who were to be initiated into physical medical encounters with patients: medical training being a hands-on activity, where remote provision of comprehensive education is not feasible[5] as it cannot fully duplicate real-life clinical encounters including ward rounds, interactive patient sessions, taking medical history, hands-on procedures, and other professional communication and clinical skills.

A vast majority of institutions have adopted alternate ways to teach at least some clinical skills remotely. Evidence post COVID-19, suggests that amongst the chaos of this crisis, many innovative remote learning options for clinical teaching have been documented by medical educators around the world. Calhoun KE et al at the University of Washington school of Medicine (UW SOM) Department of Surgery, researched the implementation of extreme pandemic response measures with regards to their widely distributed surgical clerkship experience by developing an innovative virtual clerkship to augment shortened in-person learning time. In this concerted effort, the faculty took challenging decisions with many moving variables and unknowns to include technological resources that will positively impact the distant educational experience of both medical students and faculty[7].

Leveraging the power of crowdsourcing, a tech innovation in the form of a makeshift headgear that holds a cellphone to the foreheads of ICU physicians at Johns Hopkins University School of Medicine, USA to facilitate remote teaching of the management of COVID patients, has offered endless possibilities of virtual, near real-time learning experience, by not only reaching a greater volume of students but also increasing the possibility of catching something significant in a patient's care[5]. Teachers thus remain hopeful to utilize technology to maintain the continuity of clinical teaching despite the constraints of the current teaching environment.

Pre-clinical and Clinical teaching post COVID-19- the local perspective

While in many parts of the world this shift in paradigm has been a mere augmentation of an already smoothly running system, in local medical schools the concept of distance learning, blended-learning and Massive Open Online Courses (MOOCs) has previously not been very popular[26,27]**.** Post COVID-19 several have started to steadily trend through these unchartered waters with basic sciences, pre-clinical and clinical courses being offered in digital format in majority of the medical universities in Pakistan.

Apparently these changes have been more easily achievable than it was predicted especially in those institutes with an already developed online platform as a supportive backbone.

Faculty and student adjustment has been relatively smooth after initial malfunctions and glitches.

Many new digital programs have been launched in the previous months; amongst them pioneer is Pakistan's Aga Khan University Medical College where a six-week online COVID-19 course, providing students with the latest research and evidence on the spread and management of the disease in hospital and community settings has been launched for its undergraduate programme[28].

Tackling assessment using remote learning options in medical education – an e-assessment delivery platform

The current situation has greatly impacted assessment modalities and demands a method of electronic (e)-assessment that is safe, valid, reliable, acceptable, feasible and fair[29]. E-assessment as an innovation has the possibility of enhancing learning and teaching at higher education institutions. Feedback can also be provided using similar platforms. As a result, core knowledge assessment is now being organized in many institutes, locally and globally, using online tools such as discussion forums, LMS, chats and other communication apps.

While reviewing e-assessment in higher education, Martin and Fanus[30] confirmed that e-assessment has the potential to support and even improve student teaching, provided that the assessment tasks are properly designed using tools to assess high order thinking abilities and cognitive domains. In their discussion on 21st century assessment skills, evidence documented by Crisp and Howarth[31,32], concurs that there is more to e-assessment than only MCQs, the most common assessment tool used electronically. Simulation software, Wikis, blogs, self-reviews, peer-reviews, scenario questions, role plays, and observations can all be used in e-assessments for formative and summative assessment purposes[30].

Institutions can decide to use e-assessment facilities that are already built into a learning management system. Merits and demerits of many of these e-assessment tools such as Moodle and Blackboard, or standalone assessment tools such as Test Pilot, Questionmark Perception or A-Tutor have been analysed by Osuji[33] in his work on e-assessment and innovation in higher education. Institutions using LMS such as Moodle have the option to use any of these advanced assessment settings for different question types, including shuffling the items and their options and using sequential or free navigation[34].

This has led to the debate on the reliability of this modality of assessment. In the CAA: International Computer Assisted Assessment Conference held at Zeist, The Netherlands , the proceedings document the use of "online proctoring" by software companies as a part of technology based invigilation options to make online assessments more transparent and authentic for identification of violations by Artificial Intelligence (AI) [35]. Such advance features augment e-assessment reliably.

Open educational resources (OER) and Open Course Ware (OCW) projects

Open educational resources/contents (OERs) enable free and easily accessible education for all and access to knowledge as a public good promoting an open access to scientific information and a culture of participation, collaboration and sharing bringing development of knowledge to society at large. The Horizon 2020 report mentions an inclination towards OERs that are available without restriction, including financial cost, to both educators and students across the world[36,37]. The situation post COVID-19 is highlighting this usage with a worldwide collaborative spirit amongst medical schools to share OERs along with the emerging trend of commercial businesses increasing their engagement with educational institutions.

The first Global OER Forum to investigate the possibility of universal access to high quality education was organized by UNESCO in 2002. The premise of OER was one of many outcomes. The impact of Open Course Ware (OCW), as a free and open digital publication of high quality college and university-level educational materials, on higher education in developing countries was deliberated. The Massachusetts Institute of Technology (MIT), which first announced its OCW project in the spring of 2001, and similar projects of other US universities were presented and discussed throughout the forum[38]. Johnstone[39] stresses the need for development of such initiatives which would allow instructors in less-developed countries to access, materials that would otherwise never be available to them to support their teaching; this collaboration becoming part of a quickly spreading, more general zeitgeist.

Krelja-Kurelovic[40], while proposing the advantages and limitations of usage of OER in less technically advanced countries states that the implementation of OERs in these areas has certain limitations, due to limited resources and support to customize and create them. The cause being that their educational practice is founded on traditional teaching methods with occasional use of digital contents and ICT. An ideal situation would be the maximum utilization of these OERs by developing countries like Pakistan, making it a major step towards advancement of future medical education.

Learning engineering approach

Researchers have highlighted the need to implement "learning engineering" if emerging technologies, such as advanced virtual reality, are applied to the learning process[41]. An interesting viewpoint, in this regard, has been put forward by two medical students, Badwan et al[42], who in collaboration with medical faculty and tech experts, suggested that the craft of learning engineering approach should include design thinking, agile and iterative development, user experience evaluation and the application of learning. They elaborated that design thinking provides a creative and innovate approach which can be widely applied in medical education, from technology intervention projects to curriculum development.

Technology practitioners are very familiar with these approaches and routinely apply them to the solution development exercise; they, nevertheless are new to medical educators who, therefore, face a rather steep learning curve. This will be a costly exercise with, possibly, a need for differently profiled candidates to be discovered amongst educators.

Transformed future scenarios of medical education; emerging cutting edge technologies

Experts deem a return to the pre COVID-19 medical learning approach highly unlikely. Using the events in China and in other Asian countries as a point of reference, UNESCO International Institute for Higher Education in Latin America and the Caribbean (IESALC) prepared a report on the impact analysis, policy responses and recommendations for COVID-19 on higher education. They suggest that the return to face-to-face classes after this disruption will take longer than originally anticipated, with some *expert* voices predicting that it will take a minimum of five years to *return* to complete *pre*-crisis levels of mobility[43]. Emerging technologies will be key elements of a transformed, future form of medical education, one that may well be an improvement over our current format and practice.

We know from evidence that educational technology should be valued in terms of how well the technological process informs and facilitates learning, and the acquisition and maintenance of clinical expertise[44]. In this regard, The Horizon 2020 Teaching and Learning Report prepared by EDUCAUSE™, the largest community of IT leaders committed to advancing higher education and associated technology, recommends that future provision of education rests on two main elements; adaptive learning and extended reality[45,46].

Adaptive e- learning system (AES) and Artificial Intelligence (AIEd) in Medical Education

The first element, AES, consists of offering multiple learning resources, pathways, and just-in-time feedback to students while providing information to teachers to analyze students' absorption and learning experience by delivering tailored, customized learning know-hows that address the unique needs of an individual[47].

AI and learning analytics are the backbone of this iterative process. AI based tools and services have a high potential to support students, faculty members and administrators throughout the student lifecycle by rapid processing and curating of information to enable educators to iteratively improve the process as it facilitates the accurate delivery of the learning modules in specific to the learner's capacity and readiness[48]. Zawacki-Richter et al[49], while documenting the educational approaches, challenges and risks of AIEd, detailed that experts anticipate the usage of this currently emerging technological field to grow by 43% during the period of 2018–2022, thus delivering applications that provide enormous pedagogical opportunities including scaffolding of student learning through AI-based robotic tutors which offer adaptive problem-solving guidance tools for individual, self-regulated learning saving precious time[50].

Extended reality (XR)

The second element, extended reality (XR), blends physical and virtual elements to create a virtual immersive experience (virtual reality or VR)[51], the objective being to replicate real-life experience which can be delivered through devices. An added technology is artificial haptic simulation (telerobotics) which has the potential to add realism to virtual interaction. Culbertson, Schorr and Okamura, in their review of design and control of haptic devices presented their findings proposing that this simulation helps learners complete a task by impacting where the sense of touch is critical such as in remote clinical teaching[52]; areas where clinical learning can be augmented in the digital domain.

The potential of these technology-driven learning experiences in a future medical education scenario is immense.

Outcome

Emerging technologies such as AI for adaptive learning, VR, XR and haptics are key elements of a transformed, future form of medical education, one that may well be an improvement over our current format and practice for both teachers and students. Kurelovic[39] while highlighting the advantages and limitations of usage of OERs in small countries, aptly emphasises that in today's networked society, sharing of digital resource via the Internet, free of any legal, financial or technical barriers, enables unrestricted and accessible education to everyone with access to knowledge as a public good. As a result of this exponential growth of information, the OER movement is becoming more common globally[53].

In this era of globalization and techno innovation medical universities in Pakistan must continue to observe the increased spirit of global collaboration of medical educators to freely create, share and curate learning content. Will it continue and not lose momentum over time; only time will tell.

CONCLUSION

This review presents a pragmatic assessment of the uniquely enhanced contribution of technology as the primary platform for medical teaching and learning, during and after the COVID-19 pandemic. This disruption has provided an opportunity for medical educationist and students to witness the affective and efficient ubiquous development and deployment of innovative digital learning and assessment systems including cutting-edge technologies such as AES, AIEd, VX and XR, that otherwise would have taken decades to be commercialized and utilized.

Recommendations: As evidence suggests, it is near impossible to achieve optimum, effective medical education without face to face activity being undertaken. Hence, an approach needs to be adopted where a medium ground can be achieved with an integrated application and embedment of hybrid learning that leverages advanced technology but also continues with physical learning practices in a secure, controlled environment.

AUTHOR'S CONTRIBUTION

Farooq A: Conceived idea, Designed study, Data analysis, Manuscript writing

Rizwan S: Drafting of the work, Review of material, Manuscript writing

Qureshi SF: Research input and critical analysis of included tech. references, Manuscript writing

Hassan U: Data analysis, Final proofreading

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REFERENCES

1. Wind TR, Rijkeboer M, Andersson G, Riper H. The COVID-19 pandemic: The 'Black Swan' for mental health care and a turning point for e-health. Internet Interv. 2020; 20:1003-17. doi: 10.1016/j.invent.2020.100317
2. Coronavirus disease (COVID-19) pandemic: World Health Organization (WHO) Director-General's opening remarks at the media briefing on COVID-19. WHO; 2020. Website: [https://www.who.int/dg/speeches] Retrieved on 30th March 2020
3. Live World Statistics COVID-19 Worldwide Dashboard. World Health Organization (WHO); 2020 Website: [https://www.covid19.who.int/coronavirus/worlddashboard.pdf] Retrieved on 15th June 2020
4. Coronavirus Disease 2019 (COVID-19) Situation Report-74. World Health Organization (WHO); 2020. Website: [https://www.who.int/docs/default-source/coronaviruse/situation-reports.pdf] Retrieved on 15th June 2020
5. Weiner S. No classrooms, no clinics: Medical education during a pandemic [Internet] AAMC: Medical education Workforce; 2020. Website: [https://www.aamc.org/] Retrieved on 2nd May 2020.
6. Khan R, Jawaid M. Technology Enhanced Assessment (TEA) in COVID- 19 pandemic. Pak J Med Sci. 2020; 36 : 4. doi: https://doi.org/10.12669/pjms.36.COVID19-S4.2795
7. Calhoun KE, Yale LA, Whipple ME, Allen SM, Wood DE, Tatum RP, etal. The impact of COVID-19 on medical student surgical education: Implementing extreme pandemic response measures in a widely distributed surgical clerkship experience. Am J Surg. 2020; 220(1): 44–47.
8. Mian A, Khan S. Medical education during pandemics: a UK perspective. BMC Med. 2020; 8(1):100. doi: 10.1186/s12916-020-01577-y.
9. HEC Announcements, 2020: Why-Online-Education? Higher Education Commission (HEC) Pakistan; 2020 Website:[https://www.hec.gov.pk/english/HECAnnouncements/Pages/] Retrieved on 4th April 2020.
10. Ferrel MN, Ryan JJ. The Impact of COVID-19 on Medical Education. Cureus. 2020; 12(3): 7492. doi:10.7759/cureus.7492
11. Gaëtan M, Lotte G, Stefanie D, Elske S, Iris E. Fear of the coronavirus (COVID-19): Predictors in an online study conducted in March 2020. J Anxiety Disord. 2020; 74: 102258. doi: 10.1016/j.janxdis.2020.102258
12. Sherin A. Coronavirus disease 2019 (covid-19): a challenge of protecting the general population and health-care workers. Khyber Med Univ J. 2020; 12(1):4. doi:10.35845/kmuj.2020.20224.
13. UNESCO's policy statement: COVID-19 and higher education: Today and tomorrow, 2020. UNESCO International Institute for Higher Education in Latin America and the Caribbean (UNESCO IESALC); 2020 Website: [http://www.iesalc.unesco.org/en/wp-content/uploads/] Retrieved on 10th May 2020.
14. Khan AA, Shuriah N, Saif SK. Universities unprepared for switch to remote learning [Internet] University world new: the global window on higher education; 2020. Website: [https://www.universityworldnews.com/pdf] Retrieved on 10th June 2020
15. Meo SA, Abukhalaf D, Alomar A A, Sattar K, Klonoff D. COVID-19 Pandemic: Impact of quarantine on medical students' mental wellbeing and learning behaviors. Pak J Med Sci. 2020; 36(COVID19-S4). doi https://doi.org/10.12669/pjms.36.COVID19-S4.2809
16. Loothra P, Mackenzie S. Four ways COVID-19 could change how we educate future generations. WEF global agenda on education; 2020. Website: [https://www.weforum.org/agenda/] Retrieved on 5th May, 2020.
17. Oliveira PC, Cunha CJCA, Nakayama MK. Learning management systems (LMS) and e-learning management: an integrative review and research agenda. J Syst. Technol. Manag. 2016;13(2):157-180. doi.org/10.4301/S1807-17752016000200001
18. Learning Management Systems: Pakistan needs them for education efficiency, Academia Mag; 2018 Website: [https://academiamag.com/lLMS-pakistan/pdf] Retrieved on 10th June 2020]
19. Junior RC, Medeiros TC, Honório HM, Ana SE, Santos PS. Moodle: Teaching Strategies in Distance Education in Oral Medicine, Educ Res Int, 2017. Website: [https://www.hindawi.com/journals/edri/2017/427914 1/] Retrieved on 16th July 2020
20. Chang HJ, Symkhampha K, Huh KH, Yi WJ, Hoe MS, Lee SS, et al. The development of a learning management system for dental radiology education: A technical report. Imaging Sci Dent. 2017; 47(1): 51-55. doi: 10.5624/isd.2017.47.1.51
21. Memon AR. Research publications and education in Pakistani medical universities: Avoiding predatory journals and improving the quality of research. J Pak Med Assoc. 2017; 67(6): 830-833. doi: https://www.researchgate.net/publication/316739667
22. Memon AR, Rathore FA. Moodle and Online Learning in Pakistani Medical Universities: An opportunity worth exploring in higher education and research. J Pak Med Assoc. 2018; 68(7). 1076-1078. doi: https://pubmed.ncbi.nlm.nih.gov/30317305/
23. Jawaid M, Aly SM. 'E-learning' modalities in the current era of Medical Education in Pakistan. Pak J Med Sci. 2014;30(5):1156-1158. doi:10.12669/pjms.305.4351.
24. Masud S, Ayub A, Mahboob U. Use of massive online open courses as a potential resource to provide continuing medical education in Pakistan. J Coll Physicians Surg Pak. 2016; 26 (2): 160-161. doi: https://pubmed.ncbi.nlm.nih.gov/26876410/

25. Moran J, Briscoe G, Peglow S. Current Technology in Advancing Medical Education: Perspectives for Learning and Providing Care. Acad Psychiatry. 2018; 42(6):796-799. doi: https://doi.org/10.1007/s40596-018-0946-y
26. Shah N, Ashraf H, Anwar F, Khan A, Akhtar H, Abro MA. Status of Postgraduate Training and Continuing Medical Education of Family Physicians in Pakistan. Pak J Med Sci.2012; 28: 4-8. doi:10.1007/s40596-018-0946-y
27. Rizvi NF, Gulzar S, Nicholas W, Nkoroi B. Barriers in adopting blended learning in a Private University of Pakistan and East Africa: faculty members' perspective. Mhealth. 2017; 3: 18. doi: 10.21037/mhealth.2017.04.04
28. Agha Khan University (AKU) introduces COVID-19 online courses for students [Internet] The Agha Khan University Newspage 20 April, 2020; 2020. Website: [https://www.aku.edu/news/Pages/] Retrieved on 6th June, 2020
29. Khan R, Jawaid, M. Technology Enhanced Assessment (TEA) in COVID- 19 Pandemic. Pak J Med Sci. (2020); 36(COVID19-S4) doi.org/10.12669/pjms.36.COVID19-S4.2795
30. Martin A, Fanus T . E-Assessment in Higher Education: A Review. Int J Bus Man Econ Res. 2018; 9(6):1454-14609. doi:https://www.researchgate.net/publication/329775612
31. Crisp G. Assessing 21st century skills. In: editor. Teacher's handbook on e-Assessment: A handbook to support teachers in using e-assessment to improve and evidence student learning and outcomes. San Francisco, California: Creative Commons; 2011:11-12. Website: [https://www.dkit.ie/system/files/TeachersHandbook on e-Assessment//] Retrieved on 10th May, 2020.
32. Howarth P. The opportunities and challenges faced in utilizing e-Based assessment. Educationalrc. 2015. Website:[http://www.educationalrc.org/oldconf/old.pdf]. Retrieved on 11th June, 2020
33. Osuji USA. The use of e-assessments in the Nigerian higher education system. Turkish Online J. Distance Educ. 2012; 13(4):140-152. doi: https://eric.ed.gov/id=EJ1000419
34. Luo L, Cheng X, Wang S, Zhang J, Zhu W, Yangal, etal. Blended learning with Moodle in medical statistics: An assessment of knowledge, attitudes and practices relating to e-learning. BMC Med Educ. 2017; 17(1):170. doi: 10.1186/s12909-017-1009-x
35. Computer Assisted Assessment. Research into E-Assessment. In: Kalz K, Ras E, editors. Communications in Computer and Information Science Volume 439.New York: Springer Link; 2014. Website:[https://link.springer.com/book/10.1007%2F978-3-319-08657-6] Retrieved on 15th July 2020.
36. EDUCAUSE Horizon Report™, 2020. Teaching and Learning Edition. EDUCAUSE Publications; 2020 Mar 2. Website: [https://library.educause.edu/resources/pdf] Retrieved on 7th May ,2020
37. Pounds A, Bostock J. Suitable economic models for Open Educational Resources initiative in aquaculture higher education. Aquacult Int. 2019; 27:1553–63. doi.org/10.1007/s10499-019-00406-1
38. Islam OF, Koybasi GNA, Cagily K. Use of Open Educational Resources: How, Why and Why Not? Int J Teach Learn High Educ. 2016; 28(2): 230-240. doi: https://eric.ed.gov/id=EJ1111136
39. Johnstone S M. Open Educational Resources Serve the World. EDUCAUSE. 2005; 3(4):15-18. Website: [https://er.educause.edu/articles/2005/1/OER- pdf] Retrieved on 10th May, 2020
40. Kurelovic EK. Advantages and limitations of usage of open educational resources in small countries. Int J Sci Educ. 2016; 2(1):136-142.
41. European Union (EU) Horizon Research and Innovation Programme, 2020 [Internet]. The European Asian aquaculture technology and innovation platform (EURASTiP); 2017. Website: [https://ec.europa.eu/programmes/horizon2020/en.pdf] Retrieved on 12th May, 2020
42. Badwan B, Bothara R, Latijnhouwers M, Smithies A, John S. The importance of design thinking in medical education. Med Teach. 2018; 40(4):425-426. doi: 10.1080/0142159X.2017.1399203.
43. UNESCO's policy statement: COVID-19 and higher education: Today and tomorrow, 2020.UNESCO International Institute for Higher Education in Latin America and the Caribbean (UNESCO IESALC); 2020 Website: [www.iesalc.unesco.org/ 2020/04 › COVID-19-.pdf] Retrieved on 10th May, 2020
44. Han H, Resch DS, Kovach RA. Educational technology in medical education. Teach Learn Med. 2013; 25 (1): 39-S43. doi:10.1080/10401334.2013.842914
45. EDUCAUSE Horizon Report ™, 2020: Teaching and Learning Edition. EDUCAUSE Publications; 2020 Mar 2. Website: [https://library.educause.edu/resources/2020-educause-horizon,pdf] Retrieved on 7th May, 2020.
46. Brown A., Green T. Virtual reality: low-cost tools and resources for the classroom. TechTrends. 2016; 60: 517–519. doi: 10.1007/s11528-016
47. Gierke T. Adaptive Learning - Using AI to Enhance the Learning Experience [Internet]. SYSPRO; 2019. Website: [https://www.syspro.com/blog/erp-education/] Retrieved on 8th May, 2020
48. Adamu S, Awwalu J. The role of Artificial Intelligence (AI) in Adaptive e-Learning System (AES) content formation: Risks and opportunities involved. ArXiv. 2019; 1903.00934. Website: [https://arxiv.org/abs/1903.00934] Retrieved on 10th June, 2020
49. Richter ZO, Marín VI, Bond M, Gouverneur F. Systematic review of research on artificial intelligence applications in higher education – where are the educators? Int J Educ Technol High Educ. 2019; 16:39. doi.org/10.1186/s41239-019-0171-0
50. Jones A, Castellano G. Adaptive Robotic Tutors that Support Self-Regulated Learning: A Longer-Term

Investigation with Primary School Children. Int J of Soc Robotics. 2018;10: 357–370. doi.org/10.1007/s12369-017-0458

51. Zweifach SM, Triola MM. Extended Reality in Medical Education: Driving Adoption through Provider-Centered Design. Digit Biomark. 2019; 3(1):14-21. doi: 10.1159/000498923
52. Culbertson H, Schorr SB, Okamura AM. Haptics: The Present and Future of Artificial Touch Sensation. Robot Auton Syst. 2018;1:(1): 385-409. doi: 10.1146/annurev-control-060117-105043
53. Rhoads R, Camacho MS, Lindsey TB, Jennifer LB. The Massive Open Online Course Movement, xMOCs, and Faculty Labor. Rev High Educ. 2015; 38(3):397-424. doi: http://dx.doi.org/10.1353/rhe.2015.0016