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The Review of Mobile Applications and Wireless Technologies in Sustaining K-12 Schools during COVID-19

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Abstract

Mobile-learning (M-Learning) is no longer a futuristic concept in E-learning. The disruptions induced by the mandatory social distancing norms amidst the COVID-19 pandemic has brought it to the centre stage as it facilitates seamless delivery of education to mobile-users on the go. The ever increasing penetration of low-cost smartphones and remarkable advancement in wireless communication technologies has made M-learning ubiquitous and affordable. This paper highlights the roles that mass-adoption of mobile phone devices have played in sustaining K-12 schools. We review the impact that latest developments in communication technology and the deployment of LTE-WiFi coexistence, 5G, and Wi-Fi6 networks will have on M-learning applications. Further, we highlight the challenges that need to be addressed so that the higher penetration of mobile phones and deployment of wireless network technologies can be optimally harnessed for an improved M-learning experience.

Keywords: Mobile Applications, K-12, M-learning, COVID-19, Pandemic, LTE-WiFi Coexistence, 5G, 802.11ax, Wi-Fi6, Education

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1. Introduction

In March 2020, multiple schools closed down at the outbreak of the pandemic. Since then, 1,198,364,965 learners i.e. 68.4% of overall enrolled learners have been affected [1]. Remote learning had never been an option for the K-12 education sector, but in the prevailing scenario where many schools went virtual, it was the only option to ensure synchronous or asynchronous schooling. These shutdowns have shifted the debate from 'if to use Ed-tech' to 'how to use Ed-tech'. Consequently, mobile phones have taken the stage as the panacea for many K-12 schools. Even though many school buildings remain closed, learning continued; expanded and aided by mobile phones, mobile phone applications and associated network technologies.

Most mobile applications require robust and seamless network connectivity, which has been made possible by spectacular advancements in wireless communication paradigms, primarily Wi-Fi and cellular technologies. IEEE 802.11ax or Wi-Fi 6 is the upcoming Wi-Fi standard that will support dense and ultra-dense WLANs phenomenally improving the end-user bandwidth and quality of services (QoS) [2].

Even more vital are the currently deployed and upcoming cellular technologies such as Long Term Evolution Advanced (LTE-A) and 5G as cellular providers are more ubiquitous and have a deeper penetration [3]. These are specifically applicable to the remote and impoverished sections of the society where access to education was hit worse by the pandemic. Ed-tech applications will solely rely on cellular services to provide learning to students in these regions.

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Another upcoming technological framework is LTE-WiFi coexistence which paves the way for optimal spectrum utilisation by the two wireless technologies in the 5 GHz spectrum. In areas where both technologies are available to Ed-tech applications, we can leverage the coexistence standards for optimal user-experience and affordable data costs. The two prominent LTE-WiFi coexistence frameworks are LTE-Unlicensed (LTE-U) and LTE-Licensed Assisted Access (LTE-LAA) [4]. Major industry players have already begun deploying the LAA networks in several major cities of the world, and Ed-tech applications will benefit from their proliferation.

In this work, we review the capability and potential of mobile phone applications in sustaining schools during the COVID-19 pandemic and other similar circumstances in light of the recent advancements in network technology.

The rest of the paper is arranged as follows. Section 2 highlights the recent developments in wireless and cellular technologies followed by Section 3, where we present a review of the reach of mobile phone applications. Section 4 shows the state-of-the-art technology in Mobile learning (M-learning) and Section 5 takes the discussion further by highlighting the role of M-learning in a virtual school environment. Section 6 outlines and compares the physical requirements for Ed-tech applications. Finally, Section 7 discusses the way-forward by highlighting the reasonable expectations of teachers and students from network technologies and Ed-tech applications.

2. A Review of Wireless Network Technologies

The growing use of Ed-tech and M-learning applications on the web, smartphones, and tablets has led to a surge in mobile multimedia streaming. As a result, mobile data consumption foresees to cross 77 exabytes by 2022. The integration of Ed-tech and M-learning with Augmented and Virtual Reality (AR/VR) technologies had expected a phenomenal yet gradual surge in the end-user data demand for mobile data. However, the COVID-19 induced pandemic and the subsequent lockdowns and quarantines have enormously accelerated the adoption and use of Ed-tech and M-learning applications.

Cellular providers are meeting this unprecedented and unexpected rise in data-demand by innovative solutions such as multi-input multi-output (MIMO), new wireless technologies (LTE-A, 5G, Wi-Fi 6), and new network paradigms such as LTE-WiFi coexistence networks [2].

Wireless spectrum is a limited and expensive resource and, cellular carriers usually operate in the licensed domain. As Ed-tech and M-learning applications see increased adoption, the licensed format may not suffice in catering to the data-demands of mobile virtual schools. A solution in that direction is enhanced spectrum usage by allowing multiple wireless technologies to coexist in the unlicensed 5GHZ band where 5000 MHz of the spectrum is open to all communication [4].

However, we can expect the 5 GHz unlicensed band capacity to saturate due to the rapid deployment of LTE-WiFi coexistence networks. Consequently, the Federal Communications Commission has sanctioned 1200 MHz for unlicensed operation in the 6GHz spectrum as well [4]. This sanction bodes well for M-learning applications as it can offer seamless online access to school education to students in suburban and remote areas under government-imposed quarantines or lockdowns due to the pandemic.

To improve end-user QoS experience, network providers have also resorted to consistent network densification through the higher deployment of small cells. As a consequence, major urban centers now have dense and ultra-dense networks with intra-cell distances of less than 10 meters [2]. These pave the way for M-learning applications to leverage AR/VR technologies, as dense networks offer high data-rates and low latencies [2].

5G will offer the next generation of cellular services. The most exciting and relevant to Ed-tech and M-learning applications is the Multi-access edge computing or Mobile edge computing (MEC) [5]. MEC will allow 5G services and content to move closer to the end-user, eventually. These services will substantially facilitate M-learning application performance. Also, the high network capacity and low-latency to the edge will allow M-learning applications to create virtual classrooms through VR/AR technology [5].

Next, we discuss the increasing penetration of smartphone applications.

3. The Reach of Mobile Phone Apps

While there were 7.5 billion mobile subscriptions in 2016, the unique number of subscribers was 5.2 billion. (This discrepancy is owing to conditions of multiple device ownership, inactive subscriptions or optimisation of subscriptions [6]. In the second quarter of 2020, the total mobile subscriptions rose to 7.9 billion and that of unique subscribers to 6.0 billion. [6]. The global mobile data usage will grow roughly fourfold by the year 2025 with the penetration rate for mobile internet rising from 49 percent to a promising, 65 percent [7]. Figure 1 illustrates this comparison of growth in various regions across the globe.

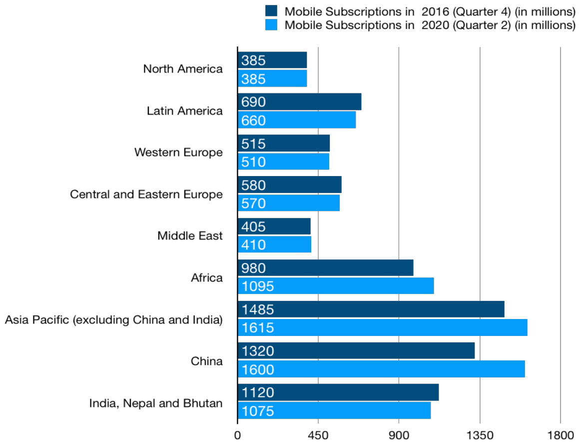

Figure 1. A region wise comparison of mobile subscriptions

The launch of Apple App and the Google Play stores in 2008 unfolded a new era of the app economy. A mobile phone application (app) is a self-contained program constructed for a mobile device [8]. Since then, the app economy has thrived and, the European app economy accounts for about a third of the revenues in the international market [9]. (Figure 2)

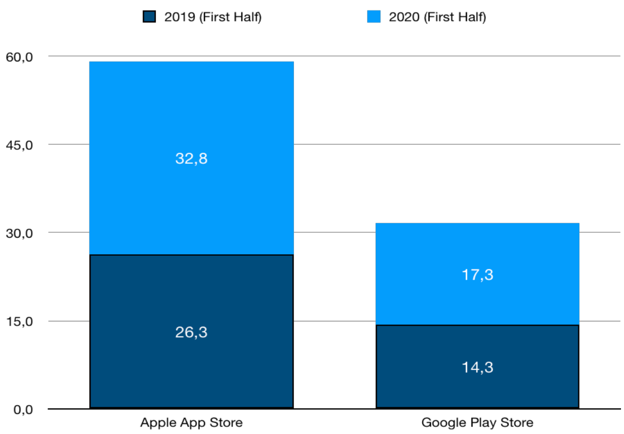

Figure 2. A comparison of the revenues of the Apple App Store and Google Play Store in 2019-2020 (Tower; 2020)

By 2024, the number of mobile apps is expected to expand by a remarkable 31 percent [10]. Mobile applications leverage wireless network technology

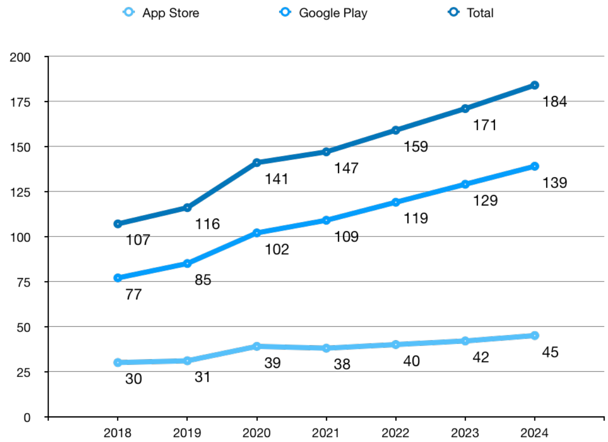

Figure 3. Mobile app downloads worldwide from 2018-2024, by store (in billions)

Many nationwide surveys and NGO reports show that students from families with nominal incomes rely on mobile phones for internet access and hence staying connected with virtual schools. Mobile phones seize a larger market share worldwide, 50 percent more than compared to desktops and tablets together (Figure. 3) [11]. Data from as early as 2008 show that the penetration of mobile devices has become substantially higher than the penetration of computers on the globe [12].

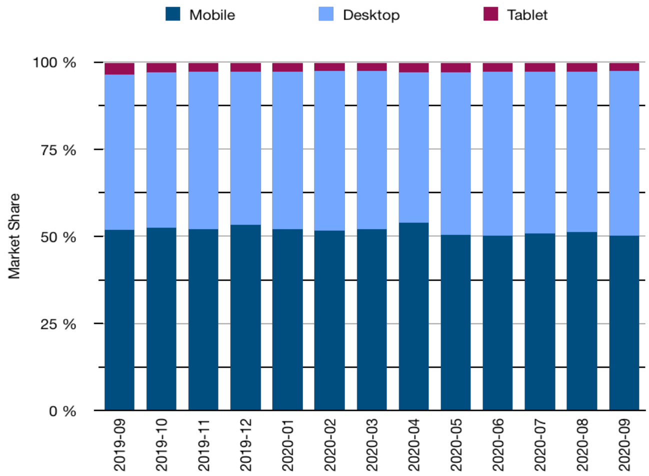

Figure 4. Desktop vs Mobile vs Tablet Market share Worldwide (Sep 2019-2020)

Mobile phones have become so ubiquitous that they are often the primary means of communication and information dissemination in the remotest areas and in extreme scenarios such as natural disasters [13, 14].

Therefore, a nexus analysis of these sources has positioned mobile phones in the spotlight of the

Educational Technology (Ed-tech) landscape. Since most learners use mobile phones to port to school, virtual learning in this case can justly be addressed as mobile learning (M-learning). We can credit this significant position of a mobile phone to its size, affordability and connectivity [15, 16].

Mobile phones provide learners flexibility, in the sense that learners can undertake educational activities beyond the confinements of a physical location. Motivated students can learn from e-resources such as textbooks, publications, web pages, scholarly articles and other opportunities that stand just a click away. With enhanced functionality in a phone, it has never been more convenient to reach objects or places, virtually.

M-learning comes from the possibility of a portable device that is small enough to grip and can comfortably fit into pockets. This relative ease makes it a user-friendly alternative to access learning in comparison with other larger gadgets and therefore the prime choice for many learners

4. The Rise of M-learning

In the earlier narratives of M-learning, it is interpreted as a system to access information using phones and the internet [17]. But with the colossal advancement of mobile based technologies the description can be upgraded to qualify the prevailing approach i.e. it is a learning construct that requires stakeholders to use their portable devices to acquire experiences by accessing, generating and managing information, and this can be done individually or collaboratively.

M-learning, being deemed the future of education, has been a swiftly evolving area [18, 19]. M-learning is closely linked with blended learning, ubiquitous learning, collaborative learning, distance learning, game-based learning, gamification and language learning [20]. This revelation accentuates the impact of M-learning on all these modes and fields of learning.

Mobile phones have the competence to provide a learning environment that is ubiquitous, pervasive and ambient [21]. Anecdotal evidence reveals that many learners have attended virtual school from places other than their homes using a mobile phone. Initially, mobile learning was considered a part E-learning however, the recent advancements in wireless technologies and mobile devices have led to the formulation of methods and norms to address mobile learning on its own. So, mobile learning exists as a thoroughly established niche in itself. With the outbreak of the pandemic, this space has become higher in demand now.

Phones may seem like an incredibly convenient way to attend virtual classes, but for many students from the weaker socio-economic segments of the community it is the sole alternative. Affordability and convenience make it a leading choice for learners.

5. Role of M-learning in a School setup

The Ed-tech loosely comprises three sectors; the hardware like the screens, tablets, touchpad, stylus etc., the systems like the Student Management Systems (SMS), Learning Management System LMS and the Training Management Systems (TMS) and last, the technology such as analytics, gamification, augmented reality, VR's and so on and all of these have an important role to play. In 2015, the office of Educational Technology invited software developers, startups, and entrepreneurs to create technology that would support teaching & learning in the following ten area;

1. Improving mastery of academic skills
2. Developing skills to promote lifelong learning
3. Increasing family engagement
4. Planning for future education opportunities
5. Designing effective assessments
6. Improving educator professional development
7. Improving educator productivity
8. Making learning accessible to all students
9. Closing opportunity gaps
10. Closing achievement gaps [22]

So even though Ed-tech had created its own niche a long while ago, the COVID -19 closure has made it more desirable for investors. Ed-tech financing is on record for a great year. Stimulated by several mega investments, the market has surpassed 2019, with over 4.8 Billion US Dollars raised in 2020 (as of August) [23,24].

All schools require structure to operate and minimize conflict. LMSs have presented a breakthrough path in this setting. An LMS is a platform that connects all stakeholders; the students, the parent and the school, both teachers and administrative staff. This platform carries the following roles; cataloguing the learning material at each level, storing assessment criteria, evaluation and feedback, and monitoring success growth [25, 26].

Canva, Schoology, Blackboard, ManageBac etc. are LMS that are thoroughly usable by phone apps and were the choice of many schools during the pandemic to create a structure within the virtual school. Figures 3 a, b, c, d and e display the teachers view and Figures 4 a, b, c and d shows the student views of the ManageBac app, an LMS widely used in many international schools. There is a wide range of features available through the phone app that are helpful to both students and teachers alike.

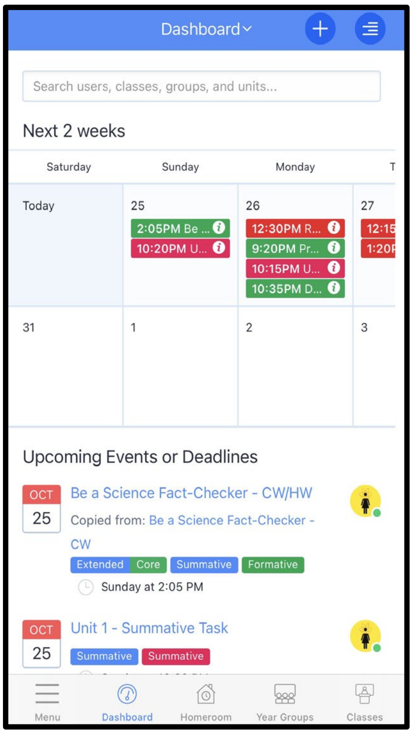

Figure 3a. The Dashboard

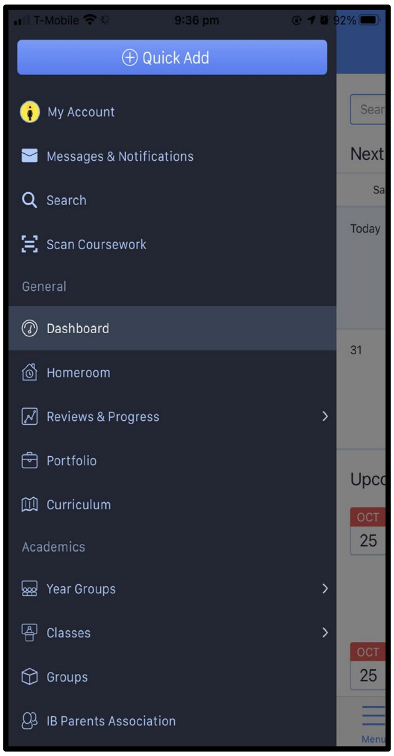

Fig 3b. The Menu Panel

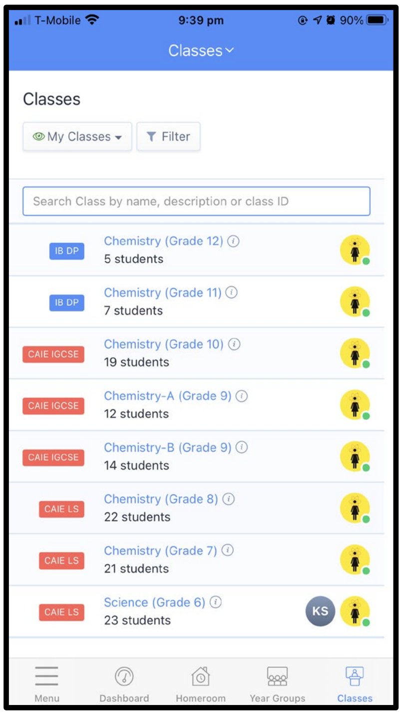

Figure 3c. Teachers view of assigned classes

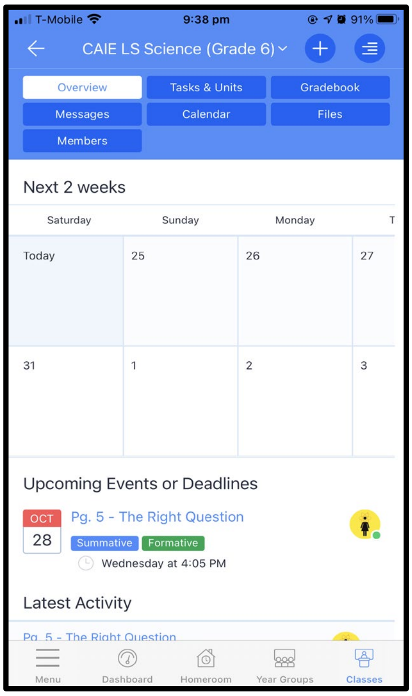

Figure 3d. Individual class view

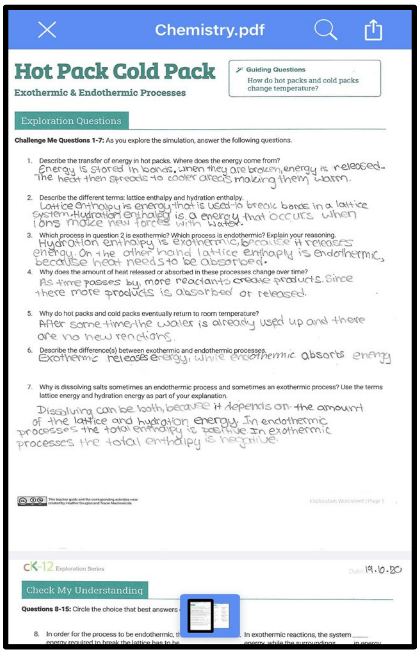

Figure 3e. A view of the students submission (teachers view)

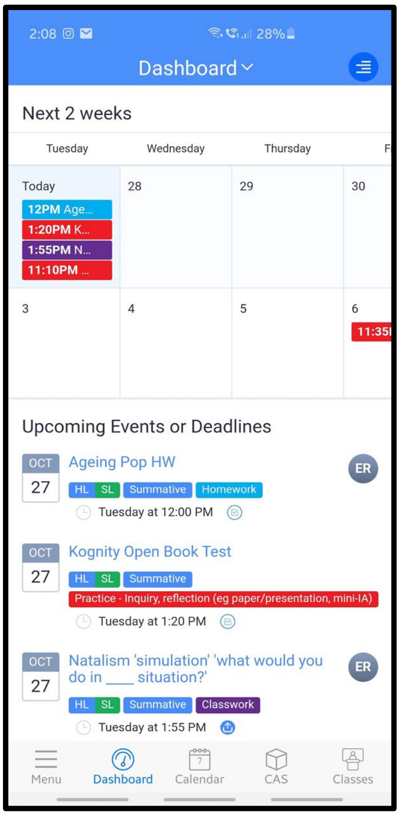

Figure 4 a. Student View of the Dashboard

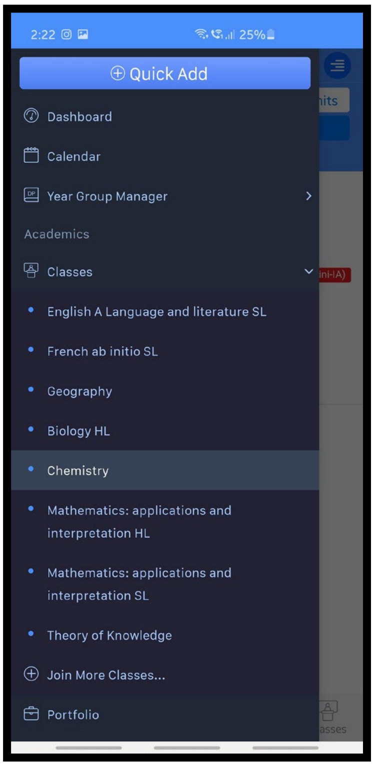

Figure 4 b. Student View of the Menu Panel

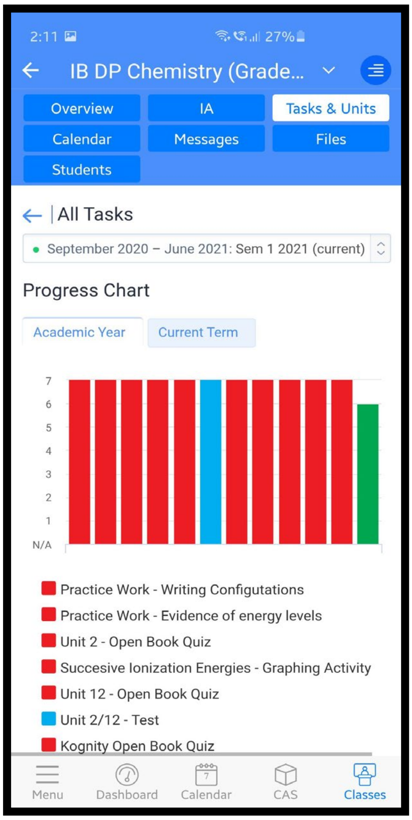

Figure 4 c. Student View of Feedback

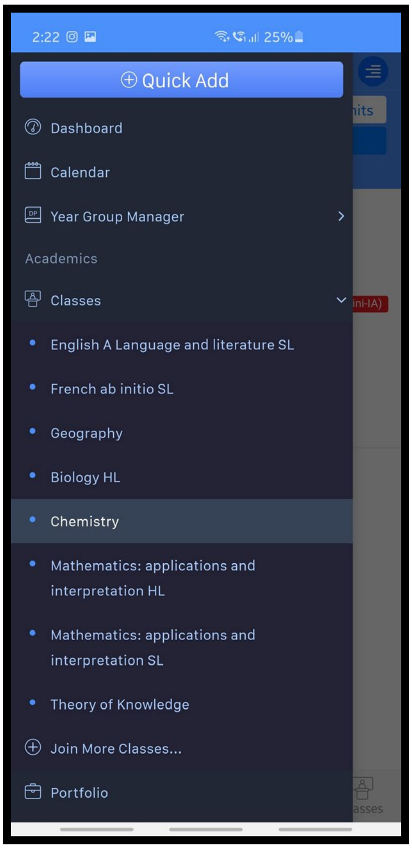

Figure 4d. Student View of Assigned Class

Added features like the ability to scan and send work, annotate documents, comment on shared documents etc., on to any LMS platforms and its accessibility on the phone as an app improves and increases the rate of information flow between students, teachers, parents and administrators [28].

Google classroom, a web-based LMS was another popular choice of many educators. Google classroom has proved effective in the past for leveraging learning by tracking and evaluating assignments, sharing learning material in forms of video links, files and pictures, and supporting communication amongst students [28]. The app's ability to mimic a traditional classroom structure was a leading reason for its top rank in the education apps downloads [29].

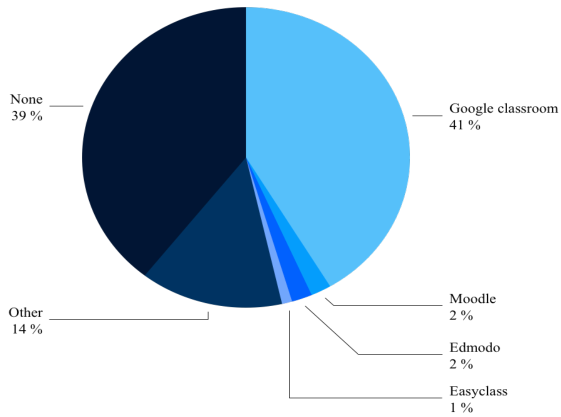

Figure 7. Leading online learning platforms during COVID-19 epidemic in Romania 2020

Many US districts employed Google Classroom to dispense information and connect with their students. With no other technical system in place, this was the only way they connected with their students.

Schoology and Canva have been in the LMS market for a decade however they observed an unusually high number of fresh additions at the initial stage of the school closure. Both these LMS provide free to download mobile apps for their users. While Schoology is designed to align with K-12 education Canva offers both K-12 and college support. Canva had 2 million users in the US alone, in April this number shot up to 6 million in October. Similarly, Schoology usage went up by 400% at the start of the pandemic. Both these apps were used to provide tailored assignments to students and the integration with Microsoft Teams and Zoom supported live instruction.

Apart from the typical email applications, the app stores have a plethora of communication apps. Google Classroom along with Microsoft Teams, Google Meet and Zoom have largely assisted the classroom environment when the schools shut. Many local newspapers reported the migration of schools to either of these virtual conferencing platforms and protocols for their safe usage were shared on many government portals [30].

Analytical reports released by organizations like App Annie and Sensor Tower showed a sizable increment in their app downloads as compared to the weekly average download during quarter 4 in 2019 (Figure 5) [31].

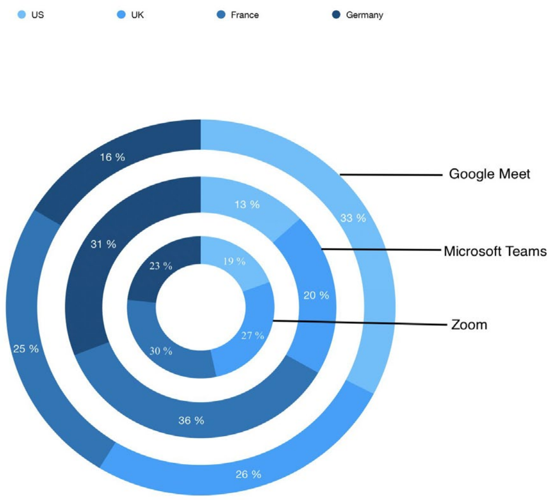

Figure 8. Percentage growth in Downloads for Google Meet, Microsoft Teams and Zoom, A Comparison of downloads during the week of March 15-21 vs the weekly average for quarter 4 of 2019.

These apps were the predominant preferences for schools with an up and running digital infrastructure, but for economically challenged parts of the society it was WhatsApp.

WhatsApp is a freely available cross-platform instant messenger. Because of its low-cost subscription model, it has dampened the market of carrier-billed SMS texts, especially in international and group messaging. In the United States alone, WhatsApp users spiked in 2020 [32]. The rising acceptance of the app in markets can be credited to both low-costs and its many features. Numerous schools that lacked a concrete digital infrastructure hopped on to exploit this [33, 34]. WhatsApp has the following features which have aided regular school activities during school shutdowns.

a. Group video and audio calling
b. Share audio and video
c. Create rooms
d. Share documents in PDF format
e. Record messages

With these features, teachers could conduct video calls or have threaded discussions for collaboration, lesson recordings could be shared and guidelines could be provided as audio messages, documents could be exchanged as pdf and pictures and recent updates further provided the creation of 'rooms' for smaller group conversations.

With the transformation in the role of the school in community today, schools not only disseminate information but also work to develop skills, character and values [35]. Within a classroom the following processes take place simultaneously; learning, assessment, management and counseling. To support a students wholesome development, educators create experiences in three learning domains namely, Cognitive (knowledge), Psychomotor (skills) and Affective (attitude).

1. Apps sustaining 'Cognitive' Learning - Cognitive skills are linked to the development of the brain or mind. Anderson and Krathwohl's Taxonomy, more frequently addressed as Bloom's revised taxonomy, is a means to evaluate teaching and learning for the cognitive domain [36]. Its sub categories are Remembering, Understanding, Applying, Analyzing, Evaluating and Creating. All these are further sub-categorized as in Figure 9.

These skills are presented in a hierarchy. Remembering, Understanding and Applying fall in the 'Lower Order Thinking Skill' (LOTS) and 'Analyzing, Evaluating and Creating are collectively called the Higher Order Thinking Skills' (HOTS) [37]. This hierarchy has been widely applied by educators, researchers, curriculum planners and examiners, at various levels and types of education systems [38].

Structure of the Cognitive Process Dimension of the Revised Taxonomy	
1.0 Remember – Retrieving relevant knowledge from long-term memory.	1.1 Recognizing 1.2 Recalling
2.0 Understand – Determining the meaning of instruc- tional messages, including oral, written, and graphic communication.	2.1 Interpreting 2.2 Exemplifying 2.3 Classifying 2.4 Summarizing 2.5 Inferring 2.6 Comparing 2.7 Explaining
3.0 Apply – Carrying out or using a procedure in a given situation.	3.1 Executing 3.2 Implementing
4.0 Analyze – Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.	4.1 Differentiating 4.2 Organizing 4.3 Attributing
5.0 Evaluate – Making judgments based on criteria and standards.	5.1 Checking 5.2 Critiquing
6.0 Create – Putting elements together to form a novel, coherent whole or make an original product.	6.1 Generating 6.2 Planning 6.3 Producing

Figure 9. Subcategories of the Cognitive skills

Khan academy and Byju's are open educational platforms that provide instructional videos streamlined with national and international curriculums. They come with user friendly apps which are a good way to ensure knowledge, understanding and application of concepts, the LOTS [39]. Khan Academy's traffic nearly tripled and parent registrations increased by 20 times on a daily basis, at the outbreak of the pandemic, revealed Salman Khan, founder of The Khan Academy. [40].

Another major support to many teachers, especially the one teaching practical subjects, was YouTube. YouTube has been in the market since early 2005. News Reports have revealed that teachers used YouTube widely to teach topics and practical skills.

Major investors took interest in Kahoot and Socrative, apps that gamify the 'recalling' process where participants can compete with each other in real time and see their positions on a leaderboard [41]. Retention rates can be increased with virtual learning. The Research Institute of America determined that while most learners retain only 8-10% in a physical classroom, an astonishing 25-60% is retained when learning online, as reported in the Forbes [42]. These apps make online testing interactive and pleasant and increase retention [43].

In many schools, teachers turned to project-based learning [44]. Apps like google docs, sheets, microsoft word were the dominant choices for this. Flipgrid was another popular preference to prompt discussion for critiquing and reflecting. Flipgrid is a social-learning video-based platform also available as a phone app. It allows teachers to create prompts for students to upload self-recorded videos. Students can interact with each other in this asynchronous space by using buttons to comment, like, respond to, or provide feedback to each other. The app also offers an opportunity to connect and collaborate with schools around the world that are registered on Flipgrid.

2. Apps Sustaining 'Affective' learning - The affective domain is also loosely called the 'feelings domain'. This domain focuses on the emotional aspect of learning, i.e. the sentiments and attitudes of learners [36].

Yet again, video conferencing apps cut the deal. These platforms were utilized to organize focus groups to communicate emotion, vent and connect with peers. In the app market, April 2020s top performers by downloads were dictated by meditation apps, with Calm at No. 1 with 3.9 million downloads, Headspace at No. 2 with 1.5 million installs, and Meditopia at No. 3 with 1.4 million [45]. Educators used these apps to present options like breathing exercises during a class or journaling prompts to check on a student's mental health. Many school psychologists went online to support students with anxiety and depression issues.

3. Apps sustaining 'Psychomotor' learning - Lastly, the psychomotor domain encompasses physical operations like reflexes, hand-eye coordination and interpretive actions. For example, a student must not merely know what a measuring cylinder is in the chemistry lab but must also know how to use it correctly.

There are some successful phone apps for virtual experiments like PheT Simulations by the University of Colorado. The traffic for this website increased immensely amidst the closure of schools [46]. These virtual experiments provide an immersive experience to improve skill of using technical apparatus [47].

There are several other apps on the phone that utilize the numerous sensors engineered onto the smartphone. These sensors can be applied to run full-fledged experiments at home and develop the psychomotor skills associated. Though this way is not original to many classrooms [48], it has come as a respite to many teachers seeking to reduce screen time in class. An app called the Physics Toolbox allows users to record measurements using these sensors. According to its makers, downloads of the app went up 25% in March. Another similar app, Phyphox, followed a download uptick of 30% in the second half of March [49]. Psychomotor skills vary from manual tasks, such as holding an instrument properly, to more complex tasks, such as angling the phone to collect measurements with precision. Phone apps like these have continued learning in the psychomotor domain during the school closures.

6. Physical Requirements for Apps

India boasts of having the highest number of mobile phone users only second to China but only a small majority own a smartphone. A smartphone is the latest technology in the lineage of phones. Its functions are similar to that of a computer as it can connect to the internet and run a variety of apps. Basic phones and feature phones are not at par with it as a basic phone can be used for making calls and sending SMS and a feature phone can connect to the internet but can run very limited apps. In most developing nations people show the same ownership pattern as shown in Fig. 10 [50].

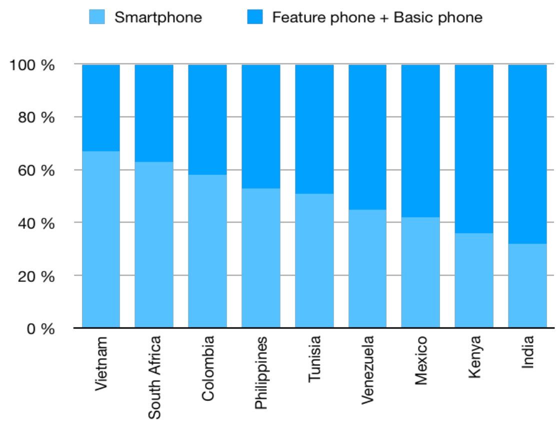

Figure 10. A percent comparison of mobile phone ownership in some developing nations

Most applications that were used for virtual learning during the school closures need a smartphone to run. Zoom requires a 1 GHz single core processor or better to run (non-Intel) and works best on phones with iOS 8.0 or later and Android 5.0x or later. Teams is only compatible with the latest four versions of android phones and the two latest versions of iOS [51]. Most of these apps also have a minimum bandwidth requirement for seamless connections, multiple screen use, higher quality images, screen shares etc. A comparative requirement for a few scenarios is in Figure 11 [51].

Scenario	Zoom	Microsoft Teams
1:1 Video Call HD360p	0.5Mbps (up/down)	0.5Mbps (up/down)
1:1 Video Call HD720p	1.2Mbps (up/down)	1.2Mbps (up/down)
1:1 Video Call HD1080p	1.8Mbps (up/down) for sending 1.8Mbps (up/down) for receiving	1.5Mbps (up/down) for sending 1.5Mbps (up/down) for receiving
For Phone	60-100 kbps	30 kbps

Figure 11. Bandwidth requirements for video calling in Zoom as compared to Teams

It’s evident that a basic phone or a feature will not be able to carry out the operative functions of these apps even with proper internet bandwidth. A stable internet bandwidth is another fundamental need to smoothly run these apps on the phone to maximize bandwidth. 4G availability is fueling the use of smartphones as the penetration rate has crossed a 50% in many countries worldwide. 4G speeds are reportedly higher in many countries [52]. This makes using data heavy apps seamless but the emergence of 5G will challenge this further. 4G connections are predicted for growth in the next two years before peaking at about 60% of global connections in 2023. In contradiction, 5G connectivity is pacing: it is now available in 24 national markets and is predicted to account for 20% of global connections by 2025. Yet, a large section is still using other slower network situations as visualized in Figure 12 [7].

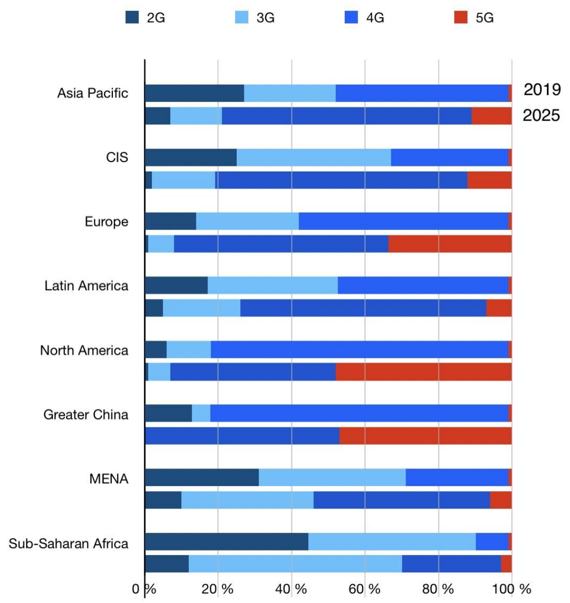

Figure 12. A region-wise prediction of the Change is Network distribution

**CIS is Commonwealth of Independent States and MENA is Middle East and North Africa*

7. M-learning Applications and Networks: Challenges and Solutions

Current situations have revealed that M-learning has arrived and that K-12 education has many ways to benefit from it. However, for a complete implementation of M-learning, a lot more can be done in terms of improved network performance, increased accessibility, convenience and uninterrupted service.

In most schools, class schedules permit a period to run for a minimum of 30 minutes or a maximum of 45 minutes. Unfortunately, most of the allocated time is used up in establishing proper connections and getting the class onboard. Hence, a decent data rate is a prerequisite for reduced obstruction in an online lesson. This situation decreases the need for students and teachers to repeat themselves in conversations so the virtual can class closely mimic face-to-face discussions. Network issues are also a core cause for many students to miss out on important information or instructions shared on the platform. The problem of low image resolution is a classic case of disruption when studying online. A student may miss out on valuable screen shares with a 2G internet despite owning a smartphone with the correct technical requirements. Therefore, the connection to an uninterrupted internet source is vital to maintain both, the quality of learning and the sanity of all participants in the classroom.

M-learning must also work towards supporting non-verbal learners or learners with reduced language capabilities by easy switching between languages. Although accessibility features like these are existent, they are limited to the more expensive ranges of smartphones. Reducing the price of integrating accessibility software and making them available in the cheaper phones will allow more learners to route their learning through smartphones and will support the implementation of M-learning in K-12 education.

Assessments assist as checkpoints to gauge a student's current learning and understand the gaps in them so the teacher can provide meaningful feedback in due time. Existing technologies like the fingerprint scanner, face detection or iris scanner must be used to develop affordable, authentic and reliable examination software. Also building low-cost software that blocks sifting through tabs or measures inactivity time must be prioritized. Such systems once in place can increase the implementation of M-learning as the chances of using unfair means will be reduced to an extent.

New network technologies and standards will most certainly aid the adoption and penetration of M-learning and Ed-tech applications. However, more advanced technological innovations such as sharing of the unlicensed spectrum and network densification have caused several challenges as well [2]. Coexisting technologies, such as Wi-Fi and LTE have different medium access control (MAC) protocols. Thus, there is a need for standards that enable fair and efficient coexistence between the two technologies. Currently, two LTE-WiFi coexistence standards have been put forth by the standardization bodies, viz., LTE-U and LTE-LAA [4].

The LTE-LAA based LTE-WiFi coexistence has shown to perform better than the LTE-U standard as it relies on a MAC mechanism quite similar to that of Wi-Fi. Consequently, most cellular deployments of LTE-WiFi [53]. However, several challenges in coexistence networks remain such as fair sharing [3], interference management [54, 55], and optimal resource allocation [4].

Likewise, network densification may offer high bandwidth and low latency, but it also poses several new problems [2]. For example, work should be done to devise novel solutions to improve traffic management and radio resource allocation in dense networks.

5G edge computing capabilities can also benefit M-learning applications when network core performance can be offered near the user, at the edge of the network. Seamless integration of 5G edge services with the core mobile network is a challenge in itself [5].

Ed-tech and M-learning applications can immensely leverage from the potential of the unlicensed coexistence paradigm, network densification, and 5G edge services when feasible technical solutions to these problems have been designed and employed.

8. Conclusion

Although all individuals have been afflicted equally by the COVID-19 pandemic regardless of their nationality, socio-economic state or gender, the same does not hold for the magnitudes of its aftereffects. The most defenseless have been struck the harshest, and this is most apparent in the education sector. Students from privileged communities have found it easier to maneuver past the locked doors of institutes and access school via the internet and smartphone or other expensive devices. But, students from the weaker segments of the society have either altogether lost access to education or, are beat down with lower-quality substitutes of schooling.

We cannot dismiss that some operative components of M-learning are access to smartphones, the ability to connect to a steady internet source, preferably 4G and electricity. When these things were in place, mobile phones allowed many learners and their care providers to stay connected to their schools for learning, guidance and counseling. Apps like WhatsApp, Microsoft Teams, Zoom, Khan Academy were imperative for schooling and topped the app markets. Although the COVID-19 crisis has spawned umpteen obstacles to the school-based learning system, mobile phone apps have neutralized some of them [56]. Based on the sources reviewed in this study, we can thereby establish that mobile phone apps have led and sustained K-12 learning amidst the COVID-19 school closures and will play an increasingly important role in education delivery should similar situations arise in the future.

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