ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 9, Issue 3, March 2022

Overcoming Learning Challenges Associated with Covid-19 Pandemic Using PWA Development Approach

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Abstract*— The educational sector is now faced with the reality that online learning is inevitable as with the outbreak of Covid-19 which broke out in the year 2019. Countries were affected by this pandemic as the economy crumbled due to the enforcement of the lockdown as advised by the World Health Organization (WHO). The educational sector was not immune from the adverse effects brought about by the Covid-19 pandemic. While some educational institutions were able to carry on with learning online, some institutions remained shut down thereby disrupting the academic schedule and timelines. After identifying the major setbacks and impact of the Covid-19 within the educational sector, an e-learning PWA model was proposed. A critical review to solidify the arguments for the PWA technology was carried out. The adoption of this model will allow e-learning applications to run on computers of any operating system as well as mobile or smartphones of any platform, the proposed model will also ease the development of e-learning applications and facilitate learning especially for students in remote areas.

Index Terms*— Covid-19, E-learning, Online Learning, Progressive Web Application (PWA), Service Worker.

I. INTRODUCTION

Coronavirus Disease 2019 is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. The Covid-19 pandemic has spread over several countries around the world [2] and has thus forced human society to maintain social distancing. The World Health Organization (WHO) on February 11, 2020, proposed an official name for this new virus as COVID-19. It was first identified in Wuhan, China on December 31, 2019 [3]. The first death by COVID 19 was the 61-year-old man in Wuhan, China in January 2020.

The COVID-19 pandemic has gone beyond the national borders and has affected people regardless of nationality, level of education, income, or gender. It has significantly disrupted the education sector which is a critical determinant of a country's economic future. WHO advised to maintain social distancing as the first prevention step after observing the trend of the virus. This action then forced lots of countries to begin the action of lockdown to separate the contaminated people within the society. The education sector in most countries including schools, colleges, and universities became closed. Classes were suspended abruptly and indefinitely, examinations were either canceled or indefinitely suspended as well. The lockdown destroyed the schedules of every student. The COVID-19 pandemic had a severe impact on higher education as universities closed their campuses and countries shut their borders in response to lockdown measures.

The COVID-19 crisis exposed the inadequacies within the education systems in most countries – from access to digital equipment such as mobile phones, computers, and other necessary tools needed for online education, and the supportive environments needed to focus on learning.

Although higher education institutions were quick to replace face-to-face (traditional) lectures with online learning by coming up with various e-learning platforms where lectures and examinations can be carried out. Despite this brilliant move by universities, most students who reside in remote parts of the country had issues accessing the online platforms provided by their institutions due to bad or flaky internet connections. Progressive Web Applications (PWA) is an emerging technology that has been embraced by some mobile developers in the software industry. PWA which was introduced by Google provides lots of benefits to its users especially those with inconsistent internet connections. Therefore, this research work aims at providing a PWA model that can be adopted by institutions to facilitate learning without time, location, and network constraints.

II. LITERATURE REVIEW

PWA is an emerging technology that is gradually gaining academic involvement in terms of research. This is evident from the handful of research articles as regards PWA across various academic search engines which will be duly reviewed.

[4] identified high development time, high testing, and

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 9, Issue 3, March 2022

maintenance cost as a major challenge of the native app, [5] called this a challenge of mobile fragmentation which implies that a code written for one mobile platform (for example, java codes for the android app) cannot be used for another platform such as Apple iOS app which is written in Objective-C. in an attempt to overcome the challenges of the native app where each platform has its own Software Development Kit (SDK) with different development capabilities, several cross-platform architectures were developed which allows deployment of mobile solutions using a single SDK. A survey of several cross-platform approaches was carried out by [6] while [7] discussed the taxonomy of these cross-platform approaches. These approaches identified are the web approach which is used in developing mobile applications using web technologies (HTML, CSS, and JavaScript) hosted on a remote server thereby making it platform independent because the mobile-optimized website/app are accessed via a browser app such as Chrome, Firefox or Safari which must be pre-installed on user's mobile devices [4], [8]. A major challenge of this approach is that apps are only accessed via a Uniform Resource Locator (URL) using a reliable and constant internet connection which implies that apps cannot be downloaded via various app stores. The hybrid approach according to [6], [7] tried harnessing the advantages of the native and web architecture. In the hybrid approach, mobile solutions are developed using web technologies but rendered inside the native apps and are distributed via various app stores. Other approaches discussed were the interpreted approach which uses a common programing language such as JavaScript to write a code which in turn generates the equivalence for the native component for each platform, the cross-compile approach which enables developers to write codes using any common programming language which is then transformed by cross compilers to a specific native code.

To overcome the challenges posed by the various mobile development approaches (architectures) as identified by the above researchers, another development approach known as Progressive Web App (PWA) as coined by [9] was developed. [10] provided a general introduction to the concept and technologies behind PWA by showcasing some major features and providing technical comparison alongside existing mobile development architectures. Biørn-Hansen and his team performed a measurement comparison of the size of the installation, launch time, and time from app-icon tap toolbar render among the hybrid, interpreted, and PWA mobile development approach. The result showed that PWA had the least size of installation as well as the smallest launch time but has the highest time from app-icon tap toolbar render. To further elaborate the general concept and technology of PWA, [11] discussed the architectural pattern on which the PWA is based that is responsible for the improved loading time of mobile apps.

The background operation of the service workers in PWA might make mobile app developers and users think it has an adverse effect(s) on the battery life (energy) which is one of the scarcest resources of a mobile device. To nullify such assumption, [12] assessed the impact of service workers on the energy efficiency of PWAs by carrying out an empirical experiment on seven (7) existing PWAs using two (2) devices (low and high-end devices) over a 2G and Wi-Fi network. The result showed that the service workers have no significant impact on the energy consumption on both devices irrespective of the network conditions. However, the load times of PWAs as regards their counterparts were not evaluated. Also, the assumption that the caching of contents by the service workers might reduce the performance of PWAs was nullified by [13] in the analysis of the cache component in the service workers in comparison to other mobile development patterns, the google lighthouse (beta) was used to prove that the performance of a PWA is better than its counterpart – native app (android) due to the caching process embedded in it. However, there was no result showing the performance of the iOS counterpart.

Based on the reviews, it is evident that different learning models can be adopted for the development of e-learning solutions with each having its pros and cons. An attempt is therefore made to propose a PWA model to aid learning.

III. LEARNING OVERVIEW

Learning is the acquisition of new knowledge, skills, values, and behaviors that can be possessed by humans, animals, and even machines [14]. Learning could be considered immediate when induced by an event such as touching a naked electric wire with bare hands, learning could also take place after an accumulation of repeated experiences that could last a lifetime [15]. The focus is on human learning which starts at birth and continues until death (Daily, 2007). Learning may be informal or formal. While informal learning is the acquisition of knowledge and skills gathered through a general social process needed to function in a particular culture or setting, formal education is a process where teachers instruct students in various courses within an institution [16]. To obtain formal learning, students attend institutions of learning ranging from primary to the university level under the guidance of a teacher who has sufficient knowledge in the subject area.

A. Forms of Formal Education

The focus of this research work is on formal learning and could be carried out offline following the traditional approaches or online by applying and using ICT technology or both which is a blend of offline and online learning often referred to as Blended Learning. below are the details of each type of learning

1) **Traditional Educational System:** This is the traditional approach to learning in which students are put under a roof at a particular time and place with a teacher at the front of the class passing knowledge to the students. It is

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 9, Issue 3, March 2022

often said that this type of educational system is teacher-driven [17] because the knowledge depends on the current knowledge of the instructor. This form of educational system utilizes conventional learning tools such as chalks, books, and blackboards. Learners get direct assistance from either their peers or the teachers during free periods [18]. Running the traditional educational system where students gather physically can help to promote learning outside the classroom in form of extra-curricular activities which can help develop learner's brains and minds, the presence of a teacher in the physical classroom can help to clear the doubts in the minds of learners during class periods. Questions could be asked, answers and clarifications will be given [18]. A major setback of the traditional educational system is that it adopts a rigid schedule which is difficult for learners to cope with especially students who are working, also any external factor beyond the institutions' control such as the COVID-19 pandemic will disrupt the set schedules[17].

2) **Modern (Online) Educational System:** Technological advances have brought about notable improvements in learning. The modern educational system is one in which learners can learn from the comfort of their homes through the internet. A modern system was introduced to overcome the barriers associated with the traditional form of the educational system [17]. The online educational system is student-centered such that learners must be self-directed and self-motivating in achieving their academic goals. Below are the advantages and disadvantages associated with the modern educational system. The world of education experienced series of innovations between the early 1990s especially with the introduction of the World Wide Web (WWW) in 1992 [19]. This groundbreaking event created opportunities for learning online thereby making learning accessible to people at different locations and bringing about new pedagogical models (Harasim, 2000). This form of learning is flexible such that learners can choose their convenience without being restricted to a particular time or location [20], [21]. A major setback to this form of learning is poor internet connectivity in remote areas such that students will not be able to access the learning platform

B. Impact of Covid-19 on Learning

Though the Covid-19 pandemic has brought positive impacts on the educational sector by accelerating the adoption of digital technologies to deliver education. It has forced institutions of learning to adopt the blended mode of learning and has also encouraged both teachers and students to become more technologically inclined [22]. Despite this positive impact, there are numerous negative impacts of the Covid-19 on the educational sector as harnessed from [22]–[24] which need to be addressed. These impacts are highlighted below:

1) **Disruption of Educational Activity and Schedules:** The global pandemic has caused the suspension of face-to-face classes and exams at different educational levels. Annual examinations and entrance tests have been postponed indefinitely by respective regulating bodies. Admission processes have been delayed.
2) **Sudden Shift to Online Education:** Not all teachers and students were ready for this sudden transition from face-to-face learning to online learning. Many teachers due to their age do not have a full grasp of these learning tools and are just conducting lectures on video platforms such as Zoom, Google meet, and so on. This may not be real online learning without any dedicated online learning platform.
3) **Responsibility of Parents to Teach:** The pandemic has made some parents become teachers at home irrespective of their educational attainment. Some educated parents can guide but some may not have the adequate level of education needed to teach children in the house.
4) **Limited Access to the Digital World:** Many students have limited or no internet access in their places of abode, many students cannot afford technological gadgets such as computers, laptops, or mobile phones in their homes that facilitate online learning. This can therefore create a digital divide among students and may enhance the gap between the rich and the poor as well as the urban settlers and rural settlers.
5) **Access to International Education:** The pandemic has significantly disrupted the higher education sector. International students were particularly badly hit at the start of the lockdown as they have had to sort out the implications of university closures on their status on campus and within their host country. Students had to decide whether to return home with limited information about when they might return or remain in their host country with restricted employment and education opportunities, all while sorting out their visa status. A large number of students who are enrolled in many universities abroad, especially in worst-affected countries were evacuated from their host country by their home country to prevent them from being affected badly. If the covid-19 situation persists, in the long run, there will be a significant decline in the demand for international education.

IV. PROGRESSIVE WEB APPS (PWA)

PWA is a mobile development approach that overcomes the challenges associated with traditional mobile development approaches. Adopting this approach produces a special kind of web application that requires no installation before use and is served from a remote server via a secured Hypertext Transfer Protocol (HTTPS) unlike regular mobile

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 9, Issue 3, March 2022

web apps which might be served using the HTTP [11], [25].

The PWA is based on the concepts of a single application for all platforms [26] just like the hybrid approach. However, it possesses distinct capabilities such as instant loading, push notification even in the offline state. The term progressiveness according to [9] also involves not making an immediate choice of installing the application on the mobile device because it can progressively become an application rather than just a website. PWAs are designed to act like a regular native application that can be uploaded to the home screen of the device, work without a browser environment, work across all browsers and devices and also have a near-instant loading even in the presence or absence of flaky or good networks [27].

A. Components of PWA

There are three major components of PWA which are Service Workers and App Shell, and Web Application Manifest.

1) **App Shell:** This is used to store static contents of an application such as the navigation bar, home page, and other resources which remains the same across the app (HTML, CSS-Minimal, and JavaScript). This is done to provide a skeleton of the application when an offline request is made. This feature helps to reduce the loading time of applications which further reduces as the user revisits the web application as evident in a load time test performed by [11].
2) **Service Workers:** This offers technical groundwork such as background synchronization and push notifications [13]. This is efficiently done because the service worker runs a separate browser thread alongside other APIs to provide the native-like application features [11]. A service worker is a script that runs in the background to receive messages even if the application is not active. As indicated in research carried out by [12] service workers do not adversely affect the energy stored in a mobile device.
3) **Web Application Manifest:** This is a file that exposes certain modifiable settings to the app developer such as the logo image path, app name, and so on. It is used to modify the behavior and style of PWA [10].

B. Features of PWA

The PWA was advocated by google and has compiled a list of considered features that are the baseline requirements for a PWA as identified below.

1) **Offline Capabilities:** PWAs can work to a great extent even if the device is offline (airplane mode or out of network coverage).
2) **Push Notification:** PWAs can display re-engaging notifications as defined in the push API.
3) **Add to Home Screen:** Ability to install the web app to the user's device at will.
4) **Background Synchronization:** Ability to synchronize data in the background.
5) **Storage Estimation:** The ability to estimate the available storage that an application uses and also to know the amount of storage left.
6) **Web Share:** Ability to make use of the native sharing widget belonging to the Operating System (OS) as specified by the web share API.
7) **Cross-Browser Usage:** The ability to work on major browsers.
8) **Page Unique Identity:** Every page has a unique URL which makes it linkable with other pages.
9) **Payment Request:** Ability to use the web payment request API to act as an intermediary among merchants and users.

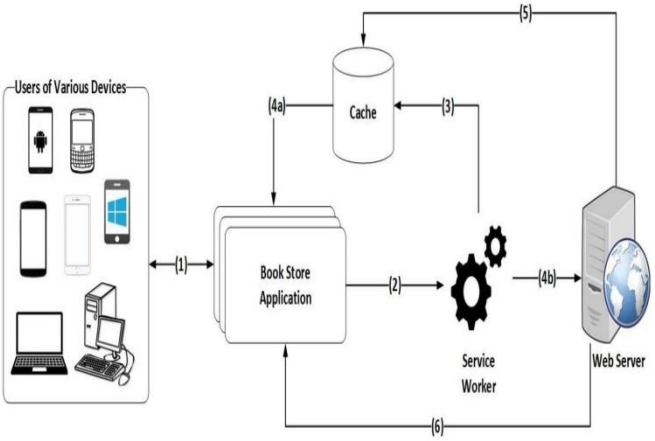

Figure 1: E-learning PWA Model (Researcher's Model)

V. PROPOSED SOLUTION

The proposed solution to the challenges and negative impact on the educational sector brought about by Covid-19 is an e-learning model based on the components of PWA technology. This model as shown in figure 1 can be adopted by any learning institution to help students participate in learning irrespective of the network condition. Based on figure 1, the model flow is detailed below.

1) **Step 1:** The user from any device (desktop, laptop, mobile phones, or any smart device) visits the E-learning URL to access the web application front-end for the first time.
2) **Step 2:** For any page request, the service worker which is a major component of the PWA technology intercepts the user's request. This intercept is done to prevent the default browser message when the internet connection is absent. Background synchronization takes place in this step as well.
3) **Step 3:** After a successful intercept by the Service Worker, an attempt is made to retrieve the response from the cache. This could result in a cache hit if the resource(s) is available or cache miss if the resource(s) is not available.

4) **Step 4a:** A cache hit occurs when the response to the request is found in the cache. Hence, the response is sent to the user without accessing the Web Server.
5) **Step 4b:** A cache miss occurs if the corresponding response to the request wasn't found. The service worker then transfers the request to the webserver by accessing the user's specified Uniform Resource Locator (URL) through the internet.
6) **Step 5:** Once the corresponding result has been found, the webserver then updates the cache memory so that it can subsequently respond to a similar future request.
7) **Step 6:** While the cache is being updated, the response to the user's request is sent to the user.

VI. CONCLUSION

The educational sector across the globe has been hit badly by the Covid-19 pandemic, while some institutions were able to recover after a while due to the presence of e-learning tools, some institutions (especially public or government-owned) are still struggling to get on their feet as regards teaching the students online. Students whose institutions have recovered still face some challenges due to lack of sophisticated technological gadgets, flaky internet connections at their respective places of abode, purchase of internet data, and so on. PWA has brought a revolution in web and mobile development and this needs to be embraced. Adopting PWA technology in e-learning platforms will make applications run on computers of any operating system as well as mobile or smartphones of any platform providing users with the look and feel of native applications. This research recommends the adoption of the proposed model to ease the development of e-learning applications and facilitate learning among students.

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