E-Learning enhancer: A progressive Web Application for improving Moodle accessibility

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Abstract

The COVID-19 accelerated e-learning in teaching as universities had to practice online learning to ensure continuity of teaching and learning activities while in lockdown. Most of these online learning systems require internet connectivity for their accessibility and thus pose accessibility challenges in areas with poor or no internet connectivity. Therefore, there is a need to review the system and propose technical solutions to improve its accessibility. This paper highlights accessibility challenges posed by the MU e-learning system and presents a progressive web-based application (e-learning enhancer) to addressthe gap. The application can cache viewed contents for accessibility in offline mode and utilise Short Message Service (SMS) to notify learners about updated content. We tested the system prototype with a small group from MU Main Campus to assess its applicability. The e-learning enhancer was found useful, and it can be used by any university that uses the Moodle platform for e-Learning services to improve system accessibility. Mzumbe University (MU) uses a customised Moodle platform to offer e-learning services to its students.

Keywords: *e-learning, Moodle platform, e-learning content accessibility, Mzumbe University Moodle, e-learning during covid-19.*

1.0 Introduction

The outbreak of the COVID-19 pandemic transformed the way of working worldwide due to several introduced safety measures, including lockdown. Different sectors were forced to change their business operations and services from face-to-face to online activities to ensure continuity of services during the lockdown periods (Di Domenico, Pullano, Sabbatini, & Boëlle, 2020). For instance, in the education sector, facilitators and learners were forced to meet remotely through online learning platforms, also known as electronic learning (e-learning) systems to continue working during the pandemic (Sahu, 2020). After a survey of various definitions of e-learning done by Basak et al. (2018), to qualify as e-learning, there should be web-based applications to facilitate the transfer of contents and instructions from the educators to the learners through the internet. E-learning is a creative approach to providing a well-designed, learner-centred, and supported learning experience ranging from synchronous to asynchronous learning through deploying digital technologies and other learning materials tailored to an open, scalable, and distributed learning environment (Ogbonna, Ibezim, & Obi, 2019).

The popularity of e-learning globally increased during the COVID-19 pandemic due to the enforcement of lockdown measures. This is because there was a need for such initiatives to support students remotely to promote

social distancing (Ebner, Schön, Braun, & Ebner, 2020). The demand for e-learning systems is still there as the world yet practices social distance and people prefer to study and work from home. To address this, different nations use popular video conferencing applications like Zoom, Skype, Microsoft Teams, WhatsApp, and the Moodle platform to teach and deliver learning materials to students (Correia, Liu, & Xu, 2020; Mathivanan, Jayagopal, Ahmed, & Manivannan, 2021). Looking into Tanzania, some schools, especially those whose students were preparing for national examinations, used Zoom and Google Meetings to provide synchronous online learning during COVID-19. The government also used dedicated programmes on Radio and Television Channels to conduct synchronous learning for primary and secondary school students during the school closure (Feruzi & Li, 2020). In Tanzanian higher learning institutions, for example, Mzumbe University, teaching was not conducted online during lockdown despite the availability of the e-learning system. This is because, first, neither the university nor students were prepared to completely go online due to issues related to internet connectivity to upload and access materials from home. Secondly, doing so would go contrary to the registered delivery mode of the programs, that is face to face mode, from the Tanzania Commission of Universities (TCU). Therefore, the university failed to use the e-learning Moodle despite its potential during the lockdown.

The system in use for e-learning at Mzumbe University is a customised Moodle open-source Learning Management System (Ghasia, Machumu, Zhu, &

Depryck, 2020). Despite the contained features, the system is a web application requiring internet connectivity for operation. The need for internet connectivity hinders some students, especially those located in remote areas, from attending online classes and accessing materials. Similarly, the current configuration of the Moodle platform at MU is set to send email notifications to enrolled students in a course when there is an update on the course content. This is in line with the observations by Krašna and Pesek (2020) regarding the Moodle platform's ability to send notifications to enhance students' engagement. However, the recipients need to have active internet connectivity to get the email notifications. This widens the challenges faced by students in remote areas, as they will need to travel to places with internet connectivity to check whether there are updates or not. Henceforth, thereis a need for an approach to improve the accessibility of e-learning materials to students living in remote areas.

Various researches on e-learning before and during the pandemic communicate focused on challenges faced and provide recommendations (described in sections 3.1 and 3.2 of this article). Still, the proposed solutions do not apply to areas where internet connectivity is still challenging. Therefore, this paper aims to bridge the gap in the literature by presenting a progressive web-based application that promotes accessibility and student engagement in the MU e-learning system, especially for students living in remote areas with challenging internet connectivity, through SMS notifications. The objective is narrowed down into two research questions: (1) What are the requirements of the proposed application, and (2)

what features should it include to ensure its usability to users? The evaluated prototype, after its improvement, can be deployed at Mzumbe University to improve the accessibility of e-learning content to students with limited internet connectivity.

2.0 Research Design

This paper falls under the design and development of information systems since it aims to develop a progressive web application. Thus, we deployed a Design-Oriented Information System Research methodology proposed by Österle et al. (2011) to be the appropriate methodology to achieve the goal. The methodology guides researchers in designing and developing prototypes under four phases: analysis, design, evaluation, and diffusion. The analysis phase involves rationalisation of the problem and requirement gathering. This paper highlights research problems from the review and practitioners (MU), and the paper's objective is formulated (see Section 1).

Furthermore, the analysis phase in this paper includes the gathering of requirements of the proposed system. We derived the requirements from the review of challenges gathered from literature as explained in section 3.2. Also, the requirements were gathered from observing the existing customised Moodle system at Mzumbe University. We identified shortcomings of the system and proposed improvements. The findings from the literature supported improvements.

With regard to the design phase, we designed several artefacts including the architectural design of the proposed application. This article presents design artefacts that are crucial to system development in sections 4 and 5. Also, the implementation of the developed models was done at this phase. The product was the progressive web application with an SMS feature to alert students when new contents have been uploaded to the Moodle system and a cache function to enable the preservation and loading of contents in areas with challenging internet connectivity.The application was evaluated in the third phase, where nine (9) experts from the Department of Computing Science Studies at Mzumbe University were presented with the system to assess the applicability and usefulness of the application at the university level. Subsequently, this paper accomplishes the last phase by disseminating the findings and proposed application to the community and practitioners.

2.1 Related Works

The use of e-learning in teaching and learning started before the pandemic. During the pandemic, the lockdown and social distancing promoted e-learning to ensure that students and facilitators still interacted online. Still, the implementation of e-learning systems is associated with challenges both before and during the pandemic. This section presents the review of e-learning challenges and how MU Moodle has addressed the difficulties identified.

2.2 A review of e-learning challenges before and after the pandemic

Th existing literature presents similar challenges to e-learning, including and not limited to financial constraints, inadequate internet bandwidth, lack of operational e-learning policies, technical e-learning skills, interest, and commitment to the teaching (Nasrat, Khamosh, & Lavangnananda, 2020). Few researchers discuss these challenges further on three levels: university management, facilitators and students. In the former, a lack of clear policy to support e-learning implementation at the university level is a challenge (Basilaia & Kvavadze, 2020). Also, a lack of well-established infrastructure, including hardware, software and internet connectivity, hinders the adoption of e-learning (Oye & Iahad, 2011).

With regard to facilitators/lecturers, a lack of training on the usage of technologies, difficultiesin creating digital content, and poor internet connectivity are among the challenges slugging the adoption of e-learning (Nasrat, Khamosh, & Lavangnananda, 2020). As for students, they are reported facing similar challenges as those facing the instructors. Additionally, power cuts in and outside the university and the high cost of data bundles hinder students from accessing e-learning materials. From these challenges, technical factors are imperative to the success of e-learning implementation, which requires reliable internet connectivity and a solid infrastructure to handle all users (Oye & Iahad, 2011). Furthermore, a recent study on e-learning challenges revealed a need of exploring the challenges of utilising e-learning that hinders students from achieving their learning goals because they are the system's primary

users (Basilaia & Kvavadze, 2020). Therefore, this paper addressed the need by focusing on MU students' challenges when participating in e-learning through the Moodle system, both before and during the COVID-19 pandemic.

The implementation of e-learning during the pandemic revealed several challenges to the system empirically. Based on the global review, lecturers are challenged by competency, which was also identified before the pandemic (Aini, Budiarto, Putra & Rahardja, 2020). The study also highlighted a shortage of funds and management change as challenging issues for e-learning adoption in universities during the pandemic. Research conducted in Pakistan cited a lack of access to internet facilities and ineffective technology as among the significant challenges to e-learning implementation during a pandemic (Adnan & Anwar, 2020). The study by Adnan and Anwar (ibid) identified poor internet connectivity as the major hindrance for students accessing e-learning systems during the pandemic. Similar findings are reported in a study by Almiah Al-Khasawneh and Althunibat (2020).

Additionally, research in Malaysia supported that a lack of internet connectivity in some areas and limited data plans contributed to the low usage of e-learning during pandemics (Azlan, Wong, Tan, & Huri, 2020). These findings are also noted in studies the African countries such a Nigeria and Namibia and a global review on e-learning challenges during COVID-19 (Adeoye, Adanikin,& Adanikin, 2020; Kaisara & Bwalya, 2021;

Aini, Budiarto, Putra & Rahardja, 2020). Looking into the African context, power cuts and the high cost of purchasing bundles were also identified as major challenges in accessing e-learning (Adeoye, Adanikin, & Adanikin, 2020; Kaisara & Bwalya, 2021). Thus, universities are recommended to address the identified challenges aggressively and build on the opportunities e-learning offers institutions even post COVID-19.

3.0 Proposed solutions to the challenges

Research from developing countries disclosed poor internet connectivity, shortageof power supply and cost of data purchase as critical challenges to students' accessibility to e-learning before and during pandemics (Subedi, Nayaju, Subedi, Shah & Shah, 2020). According to Almaiah et al. (2020), students fail to access e-learning platforms, as a result, non-downloadable materials become unavailable to such students, particularly those living in rural areas. Their study further recommended designers and developers deploy approaches that will ensure the availability and accessibility of the e-learning platforms. Other researchers also communicated these suggestions (Basilaia & Kvavadze 2020). Also, the study conducted in Afghanistan recommends public universities improve internet connectivity and provision of power supply (Nasrat, Khamosh & Lavangnananda, 2020). Still, improving these factors will help students access e-learning systems in a university environment and not in remote areas where connectivity is challenging.

While universities invest in providing training to facilitators on the design of e-learning content and the usage of the technology among students, emphasis should be given to technical challenges that will improve the system's usability. The usability of this technology is highlyaffected by its accessibility and availability, with less restriction on the continuous need for internet connectivity (Subedi, Nayaju, Subedi, Shah & Shah, 2020). However, there is no clear technical approach to the accessibility of e-learning, particularly in areas where there is poor internet connectivity and a high cost of purchasing data. This paper looks into the accessibility of learning materials posted in the e-learning systems in an environment with limited resources (internet availability and the ability to purchase data). We used the e-learning system at MU, a customised version of Moodle, as a case study.

The Moodle platform and the Moodle mobile App have improved students' engagement to enhance learning. Mzumbe University uses Moodle platform to offer e-learning services to students and facilitators. The platform allows facilitators to post assignments, announcements, discussions, among others and upload slides and other learning materials. Students can log in to Moodle, download all uploaded learning materials, participate in discussion forums and submit assignments (Ghasia, Machumu, Zhu, & Depryck, 2020). Although the platform provides more learning content to students and enables them to learn outside the classroom, its implementation is also compromised by the challenges identified by previous researchers. Students can access neither the system nor contained materials without the

internet. As a result, no non-downloadable materials such as previous forums and discussions are accessible in areas with poor internet. Likewise, it becomes expensive for students to use data bundles to view discussions viewed previously on an internet connection. This calls for the need to increase the accessibility of the contents by including additional features. Thus, we propose using cache technology to preserve data to enable students to access it while offline. This demand was also highlighted by Renz et al. (2017). Therefore, this paper aims to implement cache technology in the proposed progressive web application to improve the accessibility of non-downloadable e-learning content. These findings derive the first functional requirement of theproposed web-based application.

> ***Requirement 1:*** *The proposed web application should have the ability to store (cache) accessed content(s) and make it available to users when they next visit the e-learning system without internet*

In the same line of reducing the cost of data to access the system several times to check for new content, Mzumbe e-learning Moodle provides notifications. Students can receive push notifications through the Moodle Mobile app, while notifications are sent through emails (Krašna & Pesek, 2020; Alragawi & Zahary, 2018). While this is an advancement, there is one major flaw. For a notification to be sent through the Moodle App, there needs to be a connection between the client device and the system's server. This means that the user (client's smartphone) needs internet connectivity for the server to push the notification to the Moodle app on their smartphone.

Moreover, in the web version, the user needs to have internet connectivity for the email bearing the notification to be received by the user. Therefore, both options require internet connectivity to achieve the desired students' engagement, thus not ideal in developing countries with limited resources.Meanwhile, SMS applications are widely used in such countries for notification in various services (Nyamba &Mlozi, 2020). This is because developing countries have well-established mobile networks in urban and rural areas. Also, most of the population use cell phones to communicate and perform monetary transactions (Hughes & Lonie, 2007). Therefore, a similar approach can notify students of new learning materials in the system. These findings derive the following functional requirement of the progressive web application.

> ***Requirement 2:*** *The system should use an SMS application to notify learners of the updates in the e-learning system*

The two established requirements are integrated into the proposed progressive web application to improve the accessibility of e-learning content in areas with limited internet connectivity and to people who hardly afford internet packages.

4.0Architectural Design of the E-Learning Enhancer

The system's architectural design presents how the system should be designed to realise the envisioned requirements. It demonstrates how the system is to be broken down into manageable modules (subsystems) and how these modules are to be organised and interact

to form the desired system as a whole (Sommerville, 2011). Figure 1 shows the architectural design of the E-learning Enhancer.

The design is divided into three phases. Phase one has the API, which fetches data from the MU Moodle. These data include Moodle micro-services endpoint fetched data, such as student records, course information, discussions, forums and posts. Phase II is where the business logic takes place. This phase has the main discussion module, which fetches discussion data from the application database and transfers them to another module known as the Broadcast module. The Broadcast module compares the data it receives with data from the MU e-learning system and sends a notification to the user through text message (SMS) if there is any update. The last phase involves user interface components that fetch data from the Broadcast module and the MU e-learning system and cache these data to the cached Redux Store. These cached data will be available to the user for viewing, even in areas with poor or no internet connection.

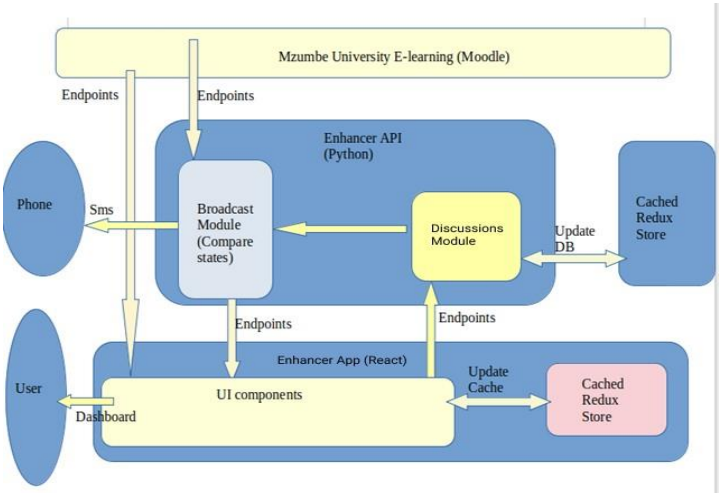


Figure 1: The architectural design of the E-learning Enhancer

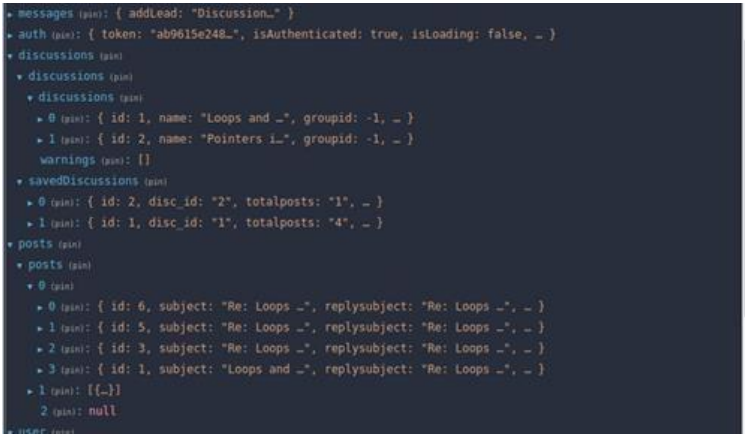
5.0 E-learning Enhancer

This section presents the development of a progressive web application and its evaluation. We used react in the javascript with react and react-redux framework in the front end and python with Django framework in the backend. This paper presents the two added functionalities of traditional MU Moodle.

5.1 Cache Implementation

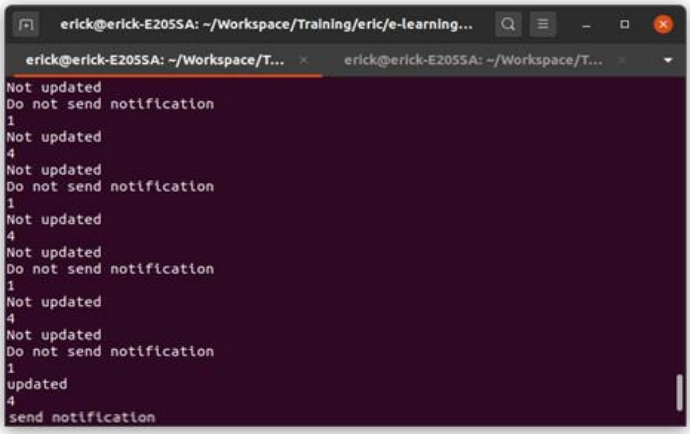
The deployment of cache technology was in the server of the progressive web application where accessed content from the MU Moodle server (e.g., discussions) is cached. To cache the discussions in the front end, react-redux was used to save the application's state in the browser's cache for the discussions to be accessed instead of directly from the e-learning application. As a result, it helps students access discussed content offline, as the content is cached in the application server.

Figure 2: Implementation of the cache functionality



5.2 Scheduler check up and SMS notification

For periodic check-ups, python with Django framework was used to check the number of discussions present in the e-learning system. The number is then compared with the number of cached discussions in the front end,



then fires an SMS to a student once the two do not match via an SMS service called Twilio[1].

[1] https://www.twilio.com/

Figure 3: Condition to send an SMS to the student

```
    for Setting in Settings.objects.all():

        if Setting.owner.id in updatedDiscs:
            print(f'user {Setting.owner} with phone {Setting.phone} has to be notified')
            # SMS SENDING HERE

            message_to_broadcast = ("Please visit e-learnig discussion has been updated")
            client = Client(settings.TWILIO_ACCOUNT_SID, settings.TWILIO_AUTH_TOKEN)
            client.messages.create(to=Setting.phone,from_=settings.TWILIO_NUMBER,body=message_to_broadcast)
        else:
            print(f'user {Setting.owner} with phone {Setting.phone} should not be notified')
    # entry_list = list(discussions)



    return HttpResponse(discussions, 200)

ef start():
    scheduler = BackgroundScheduler()
    scheduler.add_job(broadcast_sms, 'interval', minutes=1)
    scheduler.start()
```

Figure 4: Instructions to send SMS to a student when there is an update

5.3 System implementation

The front end of the application is built with HTML, CSS and JavaScript, with the use of a popular JavaScript library called Reactjs. HTML stands as an abbreviation for HyperText Markup Language and is used to create the markup elements of the user interface. CSS is an abbreviation for Cascading Style Sheet that gives the beauty and alignment of the elements. Then, JavaScript is a programming language for the browser and provides the user with interactive interface elements. The use of the Reactjs library helped manage the user interface elements and handle the requests as far as caching of data with the help of the Redux state manager.

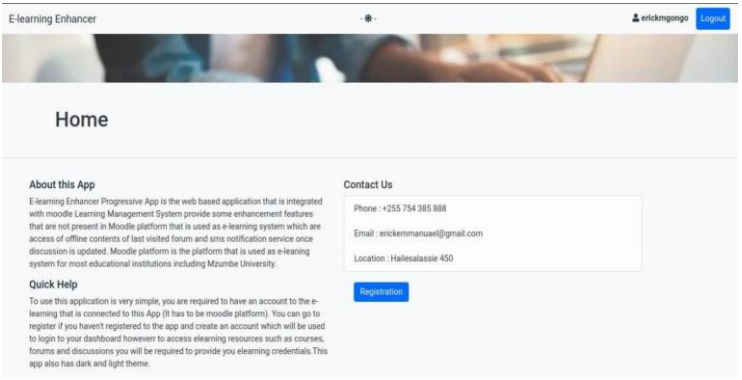
When you open the application, on the root route, you will see the home page with an image on the hero

section, a navigation bar to the register and login pages, both with a footer that provides crucial information about the application.

Figure 5: The landing page

Registration page

This page will give the user a chance to create an account



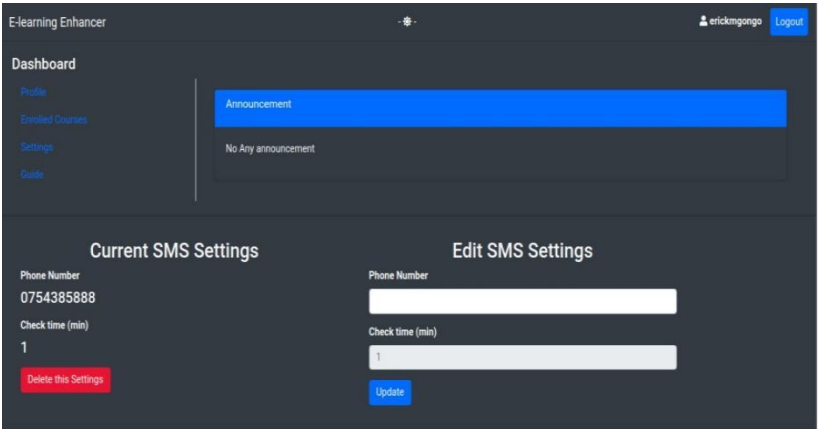
for the application; however, to view the resources from the e-learning, they need to have an e-learning account. The register page will allow a user to insert the first and last name and email and set apassword to be used during the login process.

E-learning Credential page

Similar to the login page, this page authenticates a user as a valid student with a valid account in the e-learning system. It will provide two input fields for the username and password for an e-learning user where these credentials will be used to fetch relevant resources.

Dashboard

The dashboard will provide the user interface for a student to read the posts and the settings page to set the phone number for text message notifications. Also, on



the dashboard, a user can view the application profile and e-learning profile and the state of the e-learning profile.

Figure 6: The dashboard5.3.2 Back End

The backend part of this application is built with Python programming language, using the Django framework connecting to Postgres Database Management System for data storage. Django framework is built with the architecture of apps where the system functionalities are grouped in apps within a certain Django project. The following are apps in this application explained

Accounts App

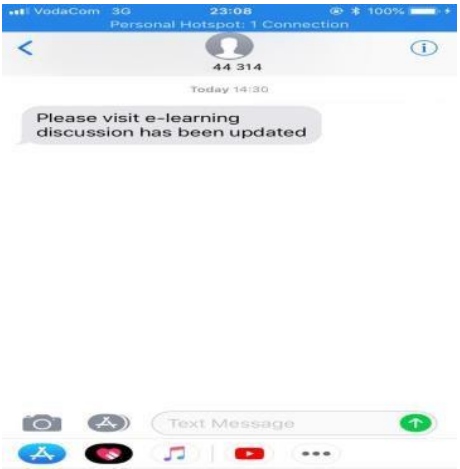
This app is responsible for handling user authentication and the login functionalities of the application, where the model included was the built-in model that defaults with the Django framework. Authentication was implemented using the package known as Knox, which is very efficient in building token-based authentication of API.

Front End App

This is the app holding our user interface. A single index is an HTML file with react configured to handle the user interface elements' life cycle assets throughout the application development. This application communicates with the rest of the system as far as sending and receiving data is concerned through an axios client. Axios is the library used to make requests to the API's.

Broadcast Application

This app handles the fetching of the current data states from both the application database and the e-learning API. It compares the states and makes sure if the student



has not seen any update, the text message notification is sent to that particular student.

Figure 7: Sample SMS screenshot sent from the E-learning Enhancer

Discussions App

Here all the processes about the storage of the state of the discussion are handled. The API endpoints are created using Django API Framework, and the serialisers are registered here to allow the creation, reading and update of the discussions.

Settings App

The settings app was implemented to set the account details required for the user to fulfil the intended

business logic. The settings app ended up being used to set the phone number for a text message notification.

5.4 System Evaluation

We adopted an expert review from the design-oriented information system research methodology (Oeslre, 2011). The approach is used to validate the applicability and usefulness of the applications from experts' perspectives. The evaluation process involved nine (9) lecturers of ICT, and between them, two (2) members were leaders from the directorate that manages the e-learning system at Mzumbe University and 15 students. The proposedapplication was demonstrated publicly to these experts to evaluate it from different perspectives. In this paper, we present results related to the paper's objective by focusing on assessing the additional features, i.e., cache and SMS technology. We evaluated two factors: the applicability and usefulness of the proposed application and its features in improving the accessibility of e-learning content.

All members agreed to the applicability of the application (prototype) to the Mzumbe e-learning system. However, four (4) lecturers recommended improvements to the SMS application. According to them, reporting every update can be costly during implementation. Therefore,modifications are required to allow lecturers to assign essential updates. Otherwise, they provide notification once a day.

With regard to the usefulness of the proposed application, all members agreed that the application

would improve the accessibility of e-learning materials to students, including those living in areas with limited internet connectivity. Experts further recommended deploying the application online for testing with end users to oversee the risks that could happen if the significant e-learning platform was down and propose mitigation strategies accordingly. Since the presented system was a prototype, members recommended improving it before testing it on a broader number of end-users.

6.0 Implication and Outlook

The use of digital technologies to facilitate teaching remotely is the new normal globally during the pandemic period. Still, its adoption is associated with challenges that hinder its implementation. The problems were observed before and during Covid-19, including the need for an internet connection to access content from e-learning anytime and poor communication between the content creators and the students in the rural areas as far as online learning is concerned. Electronic learning has to be enhanced to support remotely learning in some way. Thus, universities need to prepare themselves for the implementation of such systems. These include having a defined implementation policy, well-established infrastructure and trained users of such systems. Concerning infrastructure, developing countries are still suffering from low internet connectivity to support online learning. As a result, conventional approaches need to be used to ensure the accessibility of e-learning materials to marginalised

groups. This paper proposed the enhancer web-based application (e-learning enhancer) to bridge the gap.
E-learning enhancer aims to increase the accessibility of online learning materials by implementing a cache feature, which enables students to access all non-downloadable learning materials such as discussions pulled when the internet was available last. Also, the application informs students of the new learning materials in Moodle through text messages, which reduces the bundle costs of accessing the platform to check for any new content. The application offers intended goals for over 80% of where offline content is preserved at the point of writing.

E-learning enhancer application is an ongoing project since its advantages can be extended and shared with all institutions using Moodle platform as their e-learning systems. This is the first attempt at implementation; the application should be evaluated to determine its place in the community of electronic learners. Once it is adopted, the requirements for version 2 should be collected from the users to get these weaknesses fixed before another pandemic outbreak or disaster that will force people to learn remotely. Also, notifying every update can bring discomfort to users and increase operating costs. Therefore, future research should focus on a better approach to handling notifications. Since most students possess both smart and normal mobile devices, future researchers need to emphasise mobile learning (m-learning) and establish guidelines for creating content for m-learning.

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