Mobile Virtual Laboratory in Nigeria

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Abstract: This research has explored the use of Mobile Virtual Laboratory (MVL) for laboratory practicals in institutions of higher learning in Nigeria by designing, implementing and evaluating the developed MVL cross-platform application that works on different mobile operating systems, contrary to previous research works that deployed virtual laboratories for only specific mobile operating systems.

A cross-platform Mobile Virtual Laboratory architectural framework was developed with the client side in Java and the server side in PHP. This had four layers which were application server, database server, client (Mobile device) and the admin console and the Rapid Application Development (RAD) model was used. Thereafter science laboratory practicals were uploaded and one hundred and twenty students were purposively selected to evaluate its implementation.

A user evaluation of the mobile virtual laboratory developed was conducted to evaluate its usability, conceptual learning and re-usability. Using the Fiedman's test, a significant relationship was found between Mobile Virtual laboratories and conceptual learning, and also with re-usability, whereas no significant relationship was observed with usability.

Analysis of this study indicates that while there is important evidence in Nigeria that there is an increase in the usage of mobile devices, more research work needs to be carried out on how it can be used positively to impact educational outcomes. This research demonstrated the superiority of the developed framework over other existing techniques for it being a cross-platform solution. Though targeted at tertiary institutions it could be integrated into teaching science laboratory practicals at all levels.

Keywords: *Cross-platform, m-Learning, Mobile Virtual Laboratory.*

1. Introduction

A virtual laboratory is an interactive environment for creating and conducting simulated experiments using mobile devices. Virtual laboratories were created because it was necessary to use them in real-time, so that a huge number of persons can access it at anytime of the day, since a large number of people can share the same experience whether they are in the same town or geographically apart. Furthermore, the expenses of using a real laboratory can be, in many cases, a burden to institutions. The availability of mobile virtual laboratories is made through the Internet using multimedia (sound, images, graphics and animations), so it can be possible to simulate the experiences. Their objects are mainly drawn images or pictures of real things.

The increasing ability to access Internet through personalized, wireless, tiny, handheld and portable devices means that learning content can be accessed through these devices (Ayala and Castillo 2008).

Learning objects have been variously defined. A learning object is "any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning" (IEEE, 2010). This study emphasizes the digital nature of a learning object and thus adopts Wiley's (2001) definition. In Wiley (2001) a learning object is defined as "any digital resource that can be reused to support learning". The pedagogic importance for conceptual learning of learning objects characteristics such as reusability, portable, modular, adaptability, sustainability, durability, and interoperability cannot be overemphasized (Bottentuit and Coutinho, 2007). The authors however predicted that mobile technologies will very soon be the most used for learning because there is more demand for conceptual learning. They however suggested for

further studies, improvement in user experience, evaluation of all learning gains when teaching content through mobile devices, creation or adoption of more e-content to a virtual mobile laboratory.

However, with the recent advances the mobile device technology mobile devices can also be used in order to open additional degrees of freedom within the virtual or remote teaching fields. Most students have mobile phones, and if virtual and remote courses are available for these mobile devices, they can work from anywhere and without temporal constraints.

There are three main approaches for developing mobile laboratory applications the first is adapting a web version to the constraints of the mobile device and the second method is to develop a native application that supports the mobile device operating system and the third is a hybrid cross platform application.

Mobile Learning
Ubiquitous technologies are making it possible for learners not to be bound in fixed classrooms for learning purposes. Such "anytime", "anywhere" computing platforms have ignited a paradigm shift from e-learning models to m-learning models (Luis de Marcos *et al.*, 2006). Four major mobile operating systems considered are Android, iPhone Operating System (iOS), Microsoft and Research in Motion (RIM).

MOBILE PLATFORM FRAMEWORKS

Three major mobile platform development technologies reviewed by (Hasan *et al.,* 2012; Juntunen *et al.,* 2012; Garaizar *et al*., 2012) are: Native applications, Web applications and Hybrid Applications.

Native applications
Most, if not all, modern mobile operating systems provide developers with the necessary tools to develop applications that can later be installed by users to extend the smartphone capabilities. Each vendor provides developers with different tools, but the basics include a compiler and a debugger. These tools enable the developer to build native applications, with access to all the capabilities of the smartphone, such as camera, GPS, sensors, hardware acceleration. Taking advantage of these capabilities, the developer can build very interesting applications that integrate with the platform and provide an excellent user experience. Applications can be tested by running in the included simulator (Hasan *et al.,* 2012).

Web applications
The idea of using a single code base for targeting several platforms has been the main motivation for using web technologies such as HTML5, CSS3 and Javascript to develop applications. With access to the Internet and navigating through websites being a common functionality on smartphones, web applications for mobile devices have become popular. Recent smartphones include powerful Web browsers and Javascript engines, capable of rendering complex websites and with a very good support of the HTML5 and CSS3 standards. (Juntunen *et al.,* 2012).

Hybrid applications

They are HTML5 apps wrapped in a native container and are cross-platform applications. Hybrid apps can be downloaded from the app stores and will also be partly installed on the system. Cross-Platform Applications (Apps) work similarly to standard native apps, as they are built using the platform's operating systems Application Programming Interface (API) and Software Development Kits (SDK). They have full access to the device hardware and sensors, and have a user experience that is native to the platform. Unlike native apps however, cross-platform native apps are generally not built using the default development tools of the platform but rather are built by using a 3rd party product or framework and the code is then compiled on different platforms to produce completely native apps that share code between them.

Cross-platform mobile application development tools
There are several cross-platform tools such as PhoneGap, Titanium and Codenane One. They allow implementing an application and its User Interface (UI) using web technologies like HTML, CSS. Codename One was selected because is the first and only tool to allow Java developers to write true native applications on all mobile platforms. It also provides a full-development tool chain for writing iOS applications in Java. Applications written in Codename One can be deployed to a variety of devices, including Android, iOS, BlackBerry, Windows Phone, and J2ME (although some features may not be available on lower powered devices).

A review of literature by (Guerra et al., 2011; Orduna et al., 2011; Maiti and Tripathy, 2012; Rochadel, 2013; Bhosale and Livingston, 2014; Shah et al., 2014) indicated that their focus is on developing device-dependent mobile apps for accessing the experiments of the mobile virtual laboratory. The limitations of this approach are that device dependent mobile apps cannot offer seamless access to various mobile operating systems as such limits the students that can access the various experiments. From the literature reviewed there is need for further research on the following:

1. Development of a hybrid application that is cross-platform across various mobile operating systems.
2. Reusability of content across various institutions
3. Creating a platform for various HTML5 learning objects of simulated laboratory practicals.

This research work focused on addressing the research gaps by developing a hybrid cross-platform application and evaluated its implementation.

2. Methodology

After a systematic review of literature, the learning environment for MVL was structured using the Rapid Application Development (RAD) Model, which is considered as one of the important models for software development.
Subsequently, a cross-platform Mobile Virtual Laboratory architectural framework was developed with the client side in Java using the Codename One tool and the server side in PHP. This had four layers which were application server, database server, client (Mobile device) and the admin console.
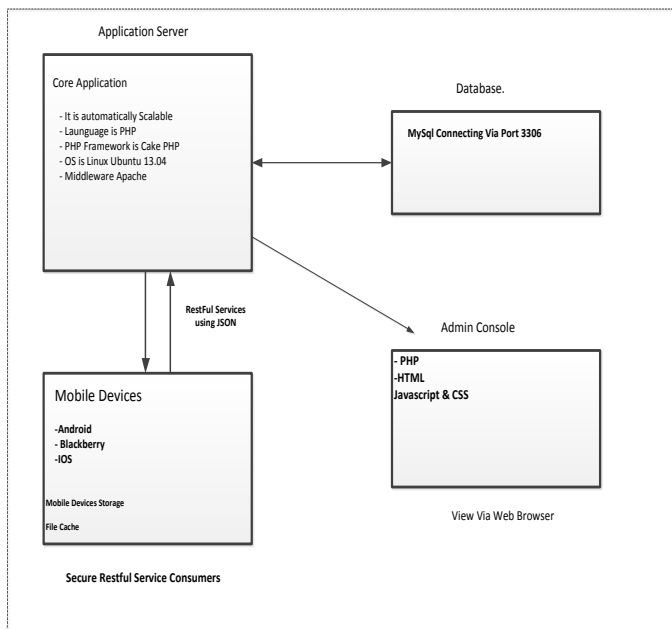
Figure 1. Mobile Virtual Laboratory Architecture (Developed)

The Main Application server

The application server takes care of application data and application files. It is responsible for serving required services as needed by the Application Programming Interface (API) calls. It is also responsible for managing users credentials sessions and processing of user requests. It is running on an Ubuntu Linux Operating System (OS), Apache as web server and PHP as programming language.

Web Service

A web service is a block of code that resides on the server and can be remotely invoked by the client. The client invokes the web service by calling a Hypertext Transfer Protocol (HTTP) link.

Security

Security of the system is mainly concerned with the safety of the instrument. As the instruments are very expensive, validation of inputs is performed to check whether the input may cause any damage to the instrument or not checking the given parameters against all limits for any parameter does this.

• Connection oriented services: In this case the client, usually a browser or a flash program, calls a web service and get the reply as data. The server keeps listening on a specified port (HTTP 80) for any incoming requests. A Representational State Transfer (RESTful) or Simple Object Access Protocol (SOAP) web service performs the experiment using signal generation and acquisition operations and a response in XML format is sent back and the client converts the data and displays it to the user.

Secured Restful Consumer (Client)

The client side of the application is supposed to perform the following functions and characteristics:
i.) Logging into the systems:
This interface takes user credentials from the user. The server side consists of PHP files with MySQL as database.
ii.) Run the experiment: The interface must receive proper input parameters from the user regarding the experiment.

Validation is necessary for correctness of input data to be transmitted to the server.
iii.) View results: The results returned are always in XML format or in a picture format. The interface must plot graphs, charts or simply show the data.
iv.) It is a small program that can run fast and fits within the small display area.
v.) The mobile virtual laboratory client application needs to parse Extensible Markup Language (XML) files.
The client interface was built using a Cross-platform Java program codename one.

The evaluation was carried out using Science students from Ambrose Alli University, Ekpoma – Edo State. This institution was selected because it is located in a rural area and this requirement was important in the evaluation of the Internet penetration in rural areas of Nigeria for m-Learning. One hundred and twenty targeted learners were purposively selected and 102 consented participants completed the questionnaire. The students undertook mobile virtual laboratory practical's using the various simulated practical lab sessions from PhET in Chemistry, Physics and Computer science (Logic gates).

The information assessed included socio-demographic data of respondents, the researcher evaluated the impact of the mobile virtual laboratory on usability, conceptual learning and reusability. At the beginning of the experiment, participants had a one-hour orientation session on how to download and use the mobile virtual laboratory components. In the orientation session, each student was informed of the study and briefed on the research instrument.

After returning the questionnaires, the data was processed in preparation for analysis. Data were checked to ensure that there were no inconsistencies and inaccuracies. However, care was taken during survey design, to ensure that clear instructions were given. Each questionnaire was given a unique identifier to avoid duplicate entries during analysis. Unstructured (open ended) responses were categorized into mutually exclusive groups and coded.
The Statistical Package for Social Sciences version 21 [SPSS-21] specifically designed for processing statistics in social science disciplines was used to conduct the statistical analysis. The researcher used the Friedman's test to determine test of significance.

To access the virtual laboratory students with Android or Blackberry phones which were the predominant devices used by the students as deduced from the needs assessment, were to use either of three options; website address, Quick Response (QR) code and for those who use android phones they could download the app from the app store.
Different kinds of resource tools were provided to assist students in achieving the learning objectives by participating in the laboratory practicals. At the end of the program, the students were asked to answer the given quizzes.

The user interface

The Graphic design is an important part of the app because it bonds users with the app emotionally. Main app icon is an important part of graphic design. While designing the main screen, the focus was on keeping simplicity and ease of use. See screenshots of the user interface. Figure 2 to Figure 4.

Figure 2. Virtual Lab in the Google app store

Figure 2 is a screenshot of the virtual laboratory app in the Google play Android app store for download. It is the screenshot of the installation interface indicating the number of downloads, the rating of the app and the category the app belongs to for the user to take an informed decision before downloading.

Figure 3 is a screenshot of the students authentication interface that receives the unique identifier (Reg. No.) and the password for login.
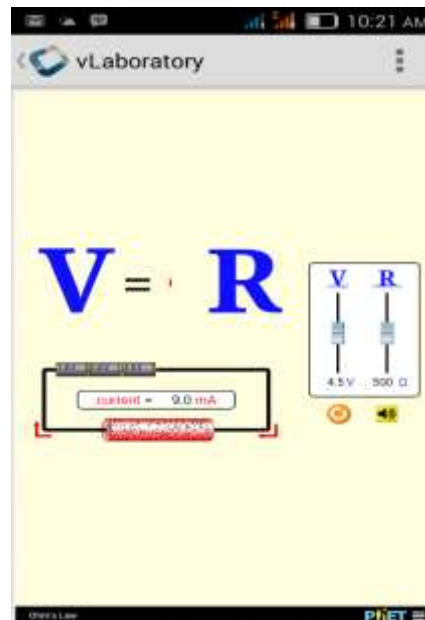

Figure 4. Screenshot showing the virtual lab

Figure 4 is the screen shot of the laboratory practical's. This particular experiment is on Ohm's law a physics practical laboratory experiment with the simulated laboratory practicals got from PhET repository.

3. Results

After the result of the needs assessment, which revealed that majority of the students, used the Blackberry and the Android phones, one hundred and twenty targeted learners were purposively selected and 107 consented participants completed the questionnaire. Since it was necessary to profile the users who would benefit from the mobile virtual laboratory by students who use blackberry and Android devices, this was achieved by using purposive sampling.

This shows that majority of the participants were year 1 (100 level) students. 52.3% of the respondents were female while 47.7% were male. Majority of the participants were from the Faculty of Natural Science.

4. Discussion

The user evaluation was carried out to assess usability, conceptual learning and reusability. The results in these sections provided better understanding into the learner outcomes from the use of mobile virtual laboratories for m-learning.

Learners background information relates to their gender, category of programme of study and year of study. In the survey, slightly less than half of them were male and a little over half of the one hundred and seven participants were female. Over three quarters of the learners surveyed were from the Faculty of Natural Sciences while less than a quarter of them were from the Management Sciences and Medical Sciences. Participants were drawn from various years of study while over half of them were 100 level students, about one quarter of them were 200 level students, 400 level and 500 level were about one quarter while the rest of the students ,

were 600 level and Master of Science (M.Sc.) postgraduate students.

It was revealed that there was no statistically significant relationship between Mobile Virtual Laboratory and the usability of mobile hand held devices. This was likely due to the fact that for most of the participants, this was the first time they were using a Mobile Virtual Laboratory. Contrary to (Rochadel *et al.*, 2013) with a large sample size, the study showed that there is no significant relationship between Usability and mobile virtual laboratory. The contrast in the findings could be a result of the sample size of the study.

The study shows that there is a significant relationship between mobile virtual laboratory and conceptual learning of students. This supports (Chen *et al.*, 2011) that reported a similar result postulated that its use for learning, improved learning outcomes. The study also showed that there is a significant relationship between mobile virtual laboratory and re-usability. This was because the MVL was designed to run any HTML5 learning object uploaded from the repository or any source making use of the native component particular to each device. The advantages are that this increases flexibility of the learning content thereby increasing cost effectiveness by allowing reuse of the learning content.

5. Conclusion

Mobile learning is the future of education in Nigeria and many developing countries particularly because of the improvement in Internet penetration and the availability of mobile devices. This study identified the factors that can guide stakeholders considering the implementation of MVL. Given that MVL uptake will be easy and enhanced if planning is done with the consideration of learner factors like informed choices, convenience, mobile device, preferred network, cost existing infrastructure amongst others are considered.

Analysis of this study indicates that while there is important evidence in Nigeria that there is an increase in the usage of mobile devices, more research work needs to be carried out on how it can be used positively to impact educational outcomes. One of the methods is what has been discussed in this study, which is the adoption of Mobile Virtual laboratory for teaching science practical experiments.

This paves way for other researchers to build or develop tools for other academic levels from secondary education level to the tertiary level. Mobile Virtual Laboratory implementation strategies require policy makers to ensure that various stakeholders take advantage and explore the opportunities in reaching out to rural communities. We also advocate creation of awareness on MVL.

Future works

Future work would be in the area of measurement of the possible impact that can be achieved with the proposed approach in terms of administering the survey instrument in two other institutions of higher learning and then carry out a comparative analysis of the result.

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