UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

MASTERS OF SCIENCE IN COMPUTER SCIENCE

AN INTERACTIVE AND PLATFORM INDEPENDENT M-LEARNING GAME FOR EARLY GRADE LEARNING

BY

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SUPERVISOR

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Submitted in partial fulfillment of the requirements of the Master of Science in Computer Science

DECLARATION

I, **Michael O. Anindo**, hereby declare that this research project and the work presented in it, is my original work and has not been presented for any other University award.

Signature: _____ **Date: _____**

Name: Michael Anindo **Reg. No.: P58/65002/2011**

This project has been submitted in partial fulfillment of the requirement of the Master of Science Degree in Computer Science of the University of Nairobi with my approval as the University supervisor

Signature: _____ **Date: _____**

Name: Dr. Robert Oboko
School of Computing and Informatics
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DEDICATION

To

My family both nuclear and extended,

My supervisor,

My Lecturers and colleagues,

For your valuable support throughout the whole process

I sincerely cherish you all

May the almighty God bless and be with you all the time

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May God bless each and every one of you.

ABSTRACT

There have been major efforts by the Kenyan government to implement the Education for All (EFA) goal no.6 which focuses on improving quality of education in both literacy and numeracy as well as the Millennium Development Goal (MDG) number 2, 3rd target) which stipulates Universal primary education through ensuring that boys and girls everywhere get compulsory primary education by 2012 through ensuring Free Primary Education (FPE) initiative of 2003.Despite the massive gains made by these efforts, it's apparent that the education sector still faces other challenges. The challenges include compromised quality of education owing to inadequacies such as low teachers to pupils' ratio and as a result pupils tend to cram instead of understanding concepts taught. Pupils are forced to adopt memorization of facts and procedures instead of increasing their understanding of math skills and concepts as well as literacy. This is partly caused by high student to teacher ratio hence there is no personalized attention given to students.

This project developed of an interactive mLearning application to facilitate provision of personalized learning methods in form of interactive games for teaching pupils of 5to 11 years of age on how to perform numeracy and literacy tasks. The study aimed at fostering innovative learning approaches and an environment for early grade learners who are currently not well served by existing education systems. The study also sought to bridge the digital gap between those who access traditional learning methods and those with alternative, interactive learning methods using computing devices such as mobile devices and personal computers (PCs).

The study sought to develop a hybrid mobile application which combines both the advantages of native mobile apps and mobile web apps. Since there is no standard evaluation technique for interactive multimedia learning applications, the evaluation of this learning system was based on its usability, accessibility, didactic effects and the number of modules requiring modification or implementation. The measurements were based on students' participation, content understanding, and students' ability to solve the presented problems.

Due to the complexity of conducting mobile learning research among early grade learners, six (6) research assistants were conscripted who doubled up as proxy respondents to facilitate filling in the Questionnaires which were used for collecting learner responses and observations. The evaluation of usability and accessibility was performed by means of the SUS evaluation tool adapted from the SUS questionnaire developed John Brooke in 1986. The average SUS score for this study was 78.5% indicating user satisfaction considering usability, learnability, and playability of the Mobile Learning Game.

Keywords: Primary school, learning content, mobile learning, mobile technology, mobile device, Native Apps, Mobile Web Apps, Hybrid Mobile Apps

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ACRONYMS

BYOD – Bring Your Own Device

CAMEL – Collaborative Approaches to the Management of E-Learning

CMS – Content Management System

CSS – Cascading Style Sheets

DI – Digital Inclusion

EFA – Education for All

E-Learning – Electronic Learning

FE – Further Education

FPE – Free Primary Education

GoK – Government of Kenya

GPS – Global Positioning System

GSMA – Global System for Mobiles Association

HE – Higher Education

HTML5 – HyperText Markup Language version 5

ICT – Information Communication and Technology

ICT4D – Information Communication Technology for Development

iOS – Apple's mobile operating system

KIE – Kenya Institute of Education

LMS – Learning Management System

M&E – Monitoring and Evaluation

MLearning – Mobile Learning

MoLeNET - The Mobile Learning Network

MP3 player - an audio device that plays digital music stored in MP3 format

NSS - National Student Survey

PDA - Personal Digital Assistant

RDF - Resource Description Framework

RIM - Research in Motion

RSS - RDF Site Summary (often called Really Simple Syndication). A way of publishing frequently-updated resources in a standardized format.

SCORM - Sharable Content Object Reference Model (a collection of standards and specifications for e-learning resources)

SMS - Short Message Service.

Stylesheet – See CSS.

TEL – Technology-Enhanced Learning

UN – United Nations

UNESS - UNESCO National Education Support Strategy

USB - Universal Serial Bus (a standard for connecting data and power supplies between computers and peripherals)

VLE - Virtual Learning Environment

Wifi - A standard for wirelessly connecting mobile devices to networks and/or the internet.

XML - A set of rules for encoding documents in machine and human-readable form.

DEFINITION OF TERMS AND CONCEPTS

Android – Google's (Open Source) mobile operating system

BlackBerry – Mobile devices produced by RIM

E-Learning - Distance learning using an electronic device e.g. television, computers, videos, video games and laptops

Hybrid Mobile App - Apps that wrap a mobile web interface inside a native container. Today, technology changes so rapidly that most businesses require immense flexibility and scalability to adapt content, design and even application architecture, all on the fly. By deploying applications that rely on a robust combination of HTML5 Web technologies and native OS features, you preserve a large degree of control over the content and design of the solutions we build for mobile platforms.

M-Learning - Mobile learning is the ability to obtain or provide educational content on personal pocket devices such as PDAs, smartphones and mobile phones.

Mobile Web App - Apps implemented with HTML5 and JavaScript that operate entirely inside a mobile browser. Mobile Web apps offer an attractive option for companies that are looking to get into the Mobility game but don't want to invest in building native applications across four different mobile platforms.

Native Mobile App - Apps developed exclusively for a specific mobile platform that can leverage all device capabilities.

Nearly all training includes some education. Nearly all education includes some training.

Smartphone - A smartphone is a mobile phone offering advanced capabilities, often with PC-like functionality. Many also feature MP3 player functionality, touschreens, cameras, wifi, GPS and 3G internet access.

SMS - Short Message Service (SMS) is the text communication service component of phone, web, or mobile communication systems, using standardized communications protocols that allow the exchange of short text messages between fixed line or mobile phone devices. SMS text messaging is the most widely used data application in the world.

SoC - System-on-a-chip or system on chip (SoC or SOC) refers to integrating all components of a computer or other electronic system into a single integrated circuit (chip). It may contain digital, analog, mixed-signal, and often radio-frequency functions – all on a single chip substrate. A typical application is in the area of embedded systems. [Definition from Webopedia]

Some mobile platforms also do conversions on the fly according to the needs of the device.

Tablet – a touch screen device that has some or all of the features of a full-size personal computer.

Touch Screen - A touch-sensitive screen that serves as the interface on some smartphones for controlling applications or entering data with a software keypad.

Training - Training is a means to an end. Training is done to learn how to do something—it provides the knowledge and skill to do a task or a job. Training objectives are generally nonnegotiable.

Transactional distance - the 'cognitive space' between instructors and learners in an educational setting.

Transcoding - Transcoding refers to the operation of changing data from one format to another, such as an XML to HTML, so the output will be displayed in an appropriate manner for the device.

Ubiquitous - Ubiquitous is a term used to describe existing or being everywhere at the same time, constantly encountered, widespread or pervasive. An adjective increasingly used to describe mobile computing as it is integrated into everyday activities.

UX - UX is a term used for User Experience.

Video support is included in the new HTML5 specifications, which reduce the compatibility issues.

Video - Not all devices support all formats of video. It is important to identify the proper format to use for the devices you are supporting. Some formats are MPEG-4, WMV, 3GPP and 3GPP2, SWF, and FLV. Software converters are available to create existing video in a different format.

WAP - Wireless Access Protocol (WAP) is a technology that allows cell phones to display specially formatted websites on a small screen. WAP was slow to catch on

because it was slow and very limited graphically. For these reasons only some Web sites are available in WAP format. New PDAs, smartphones and the iPhone probably spell the end of WAP.

WCDMA - Wideband Code Division Multiple Access (Wideband CDMA), also known as UMTS in Europe, is 3G standard for GSM in Europe, Japan and the United States.

Web App - A web app is an application that uses technologies such as JavaScript, CSS and HTML5 and is executed in a web browser. The application can be run directly from a website, or it can be downloaded and installed locally in some cases, for offline use.

Widget - A widget is a small, portable application embedded within a web page that adds dynamic content. Also known as modules, snippets, and plug-ins. Widgets are used to add entertainment and functionality to a web site.

Wi-Fi - Wireless Fidelity, more commonly referred to as Wi-Fi, is used to describe a set of standards for devices that connect to a local area network using wireless technology.

CHAPTER ONE

INTRODUCTION

1.0 Background

The emergence and adoption of mobile technology in education provides an opportunity to revitalize the concept of learning. Traditional definition of learning states that it is an interaction between teacher and learner in a classroom setting. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) education policy, Information and Communication Technology (ICT) is deemed essential in strengthening democratic and transparent education planning and management by expanding access to learning, improving quality and ensuring inclusion (UNESCO, 2013). In the event of scarce resources, judicious use of open-source materials through technologies can leverage the bottlenecks of textbook production, distribution and updating. Informed by studies conducted by UNESCO on the role of ICT in shaping policies in education, it is both normative and informative, gathering facts.

By use of desktop computers connected to the internet, the limitations of fixed physical settings for teaching and learning seemed to had been mitigated thus extending the learning opportunity at anytime and anywhere which is the major significance of e-learning (Insu et' al 2008).

The International Monetary Fund (IMF), United Nations (UN) and other donor agencies are directly or indirectly implementing ambitious multi-million dollar ICT-supported initiatives or projects in developing countries. These projects aim to unlock the potential of ICT to improve the quality of life of poor, often rural areas dwellers. Previously, the initiatives included a range of pilot projects, such as telecentres, multipurpose community access centres and information kioks (Harris, 2005).

The Kenyan government has embarked on ICT oriented projects geared towards bringing services closer to the citizenry. These services include e-governance, e-

learning, e-commerce among others. Despite all these noble initiatives, most of these services are not fully utilized at the community level especially with regards to the teaching and learning in schools (Munira, 2011).

In order to produce all round education for all school going pupils (boys and girls) in primary schools, the government of Kenya needs to invest in development and implementation of education policies that are effective, efficient and innovative. In addition, the mode of learning for early grade learners needs to be motivational and interactive. The recent trend of mobile technology for learning provides an interesting possibility to design learning environment across spaces and time (Insu et' al 2008).

Mobile learning offers modern ways to support learning processes through mobile devices such as tablet computers, smart-phones and mobile phones among others. Learning using handheld gadgets is in its infancy in terms of both technologies and pedagogies thus presenting ambiguity in definition especially in terms of devices and technologies as well as mobility of learners and the mobility of learning; and in terms of the learners' experience of learning with mobile devices (MOBI-21). Most researchers tend to view mobile learning as the immediate descendant of e-learning. As delineated by Pinkwart, et al (2003), e-learning is 'learning supported by digital electronic tools and media', and by analogy mobile learning as 'learning that uses mobile devices and wireless transmission'. It emerges as one of the solutions to the challenges faced by education systems.

This project does not aim at looking at the impact of m-learning on pedagogy, even though it is generally agreeable that its benefits will have great influence on pedagogical sustainability. This study sought to look at how m-learning could aid in facilitation of learning. There are various aspects of m-learning such as content development, access and interactivity, among others. Three perspectives can be addressed when developing m-learning applications (Yao and Joy, 2010),

i. **Pedagogy:** how materials should be designed in order to enhance the learning experience and meet the learning requirements of the students

ii. **Usability:** how the user interfaces of applications on mobile devices should be designed to improve human computer interaction.

iii. **Technology:** the physical layout of learning materials and how they can adapt to different mobile devices.

According to the UNESCO education policy, ICT is deemed essential in strengthening democratic and transparent education planning and management by expanding access to learning, improving quality and ensuring inclusion (UNESCO, 2013). In the event of scarce resources, judicious use of open-source materials through technologies can leverage the bottlenecks of textbook production, distribution and updating. Informed by studies conducted by UNESCO on the role of ICT in shaping policies in education, ICT use is both normative and informative in learning process.

In order to produce all round education for all school going early grade learners (boys and girls) in primary schools, the government of Kenya needs to invest in providing the education policies that are effective, efficient and innovative. In addition, the mode of learning for early grade learners needs to be motivational and interactive.

The Kenyan government implemented Free Primary Education (FPE) in all the Public Primary Schools in the year 2003 in an effort towards achieving the Millennium Development Goals (MDGs) number 2 i.e. to achieve universal primary education. The main target (Target 3) of MDG 2 was to ensure that by 2015, early grade learners everywhere, boys and girls alike, would be able to complete a full course of primary schooling. The FPE Policy led to increase in access to education. However, it brought with it the challenge of quality learning in schools due to shortage of instructional materials, teachers, physical learning infrastructure, and poor government/donor relationship. All these have impacted negatively on the academic performance, teaching process and participation of boys and girls (Kinoti, 2010).

Many expositional studies have shown that early learning approaches can have a strong positive impact on the ability of early grade learners to succeed in school and in life pursuits. However, in many parts of the African continent, early grade learners

are unable to access the information they need under existing education systems as asserted by TrustAfrica Foundation in their fact sheet (TrustAfrica, 2012).
If the education sector continues with the status quo in running the learning and teaching affairs, they will not only be wasting time and money, which jeopardizes overall efficiency in learning process and academic performance of the early grade learners in both Math and literacy. Also, undue inadequacy could lead to early grade learners dropping out from schools or resorting to the privately owned schools with better facilities which are expensive and not affordable to many but which provide both personalized and interactive modes of learning.

1.1 Problem Statement

To make education for all (EFA) initiative a success especially free primary education (FPE), it is important to make sure that apart from focusing on their establishment, the the initiatives should add value to the early grade learners.

Recent studies indicate that majority of public primary schools in Kenya are grappling with the challenge of inadequacy of learning materials, few teachers, among others due to limited resources allocated to the education sector by the government.

The FPE Policy led to increased access to education. However, it has brought with it the challenge of quality learning in schools due to shortage of instructional materials, shortage of teachers, physical learning infrastructure, and poor government/donor relationship. All these have impacted negatively on the academic performance, teaching process and participation of boys and girls (Kinoti, 2010).

As much as we would like to applaud the Kenyan government for the implementation of the ambitious FPE programme, which enabled many pupils to enroll in public primary schools to acquire the basic education, the greatest challenge that has emerged as a result is the fact that there has been a compromise in the quality of education owing to the disparity and inadequacy of teachers to offer the needed support for learning. The early grade learners tend to do cramming instead of

understanding the concepts being taught. The early grade learners have been forced to adopt the traditional memorization of facts and procedures instead of increasing their understanding of numeracy skills and concepts as well as literacy. Part of this is because the teachers are not in a position to give them personalized attention because of the high student to teacher ratio. This is evident despite the fact that the government spends an average of 25% of its GDP on education, most of which is spent teachers' salaries and administrative expenditures (UWESS, 2011), therefore leaving little for provision of teaching and learning materials. The impediments identified by (Uwezo, 2011) include;

i. Low basic skills in numeracy and literacy

ii. Shortage of teachers, with the trend being that teachers have an average of 52 pupils in class.

iii. Rampant absenteeism at 13% for teachers and up to 40% for pupils in some areas.

iv. Shortage of supplementary learning materials and sharing of textbooks, at an average of 3 pupils per book.

1.2 Proposed Solution

We proposed and developed an interactive m-Learning application to facilitate the provision of a personalized learning method in form of interactive games for teaching the early grade learners in the age bracket of 5 to 11 years of age how to do numeracy and literacy.

Borrowing a leaf from TrustAfrica Foundation's call for Letters of Interest from organizations with the capacity to design and implement an early learning innovation in which 4 African countries; Kenya, Uganda, Senegal and Mali were singled out as the countries to benefit from the Early Learning Innovation grants. This was due to the fact that it had been found out that most early grade learners in these countries are unable to access the information they need under the existing education systems (TrustAfrica, 2013).

Due to the fact that the governments in the above mentioned countries, Kenya included, had demonstrated interest in development policy reform, opening the doors to possibilities for future policy advocacy and potential for scaling up proven innovations, this project seeks to improve the learning outcomes in the learners (TrustAfrica, 2013).

The study was geared towards bridging the digital gap between those who have access to traditional learning methods and those who have alternative, interactive methods of learning using computing devices which include hand-held devices and mainly mobile phones and tablets PCs. The underlying issue is to look for design options appropriate for both the users with hand-held devices as their only computing gadgets and those with both traditional computers and hand-held devices.

Access to learning content across mobile platforms, times, topics and technologies would solve some of those problems. This should be from any location and transcend schools or regions. Pupils should access the content at any time in different contexts. The content should be accessible from majority of mobile devices. This ability for content delivery can be found by using mobile devices accessing content from a web-based application, as a native application or hybrid which combines native and mobile web app application.

1.3 Research Objectives

The main objective of this project is to foster innovative learning approaches and environments for early learners who are currently not well served by existing education systems.

Specific objectives of the study include;

i) To develop a hybrid mobile learning game for teaching pupils between 5 to 11 years old proficiency in both numeracy and literacy.

ii) To increase flexibility of learning offered to early learners.

iii) To evaluate the usability of the mobile learning system.

1.4 Research Questions

This research is focused on bridging the digital gap between those who have access to traditional learning methods and those who have alternative, interactive methods of learning using hand-held computing devices such as mobile phones and tablet PCs. The underlying issue is to look for design options appropriate for both the users with hand-held devices as their only computing gadgets and those with both traditional computers and hand-held devices.

The study sought to answer the following research questions:

1. What are the best design mobile phone applications as alternatives to or as extensions of traditional teaching and learning strategies?

2. What are the possible system related limitations of using mobile/hand-held devices as alternatives to or as extensions of traditional teaching and learning strategies?

3. What are the lacking capabilities of traditional teaching and learning environment that hand-held devices can leverage on as better learning strategies?

   Having considered the above questions, the study intended to answer them by focusing on the learners, teachers, and education stakeholders as our target groups. Our research sought to answer the following additional questions closely related to the above:

4. Which ICT innovations and architectures can be employed to design systems that can allow teachers, learners and education stakeholder collaborate in a manner that learning for early grade learners is made more efficient and cost effective?

5. Can the innovation being proposed be replicated at a national scale or even regionally?

1.5 Justification of the Project

Adoption of information technology worldwide is changing at a very high rate and at the same time the population is also growing fast. In the 21st century, the pace of

globalization and the growth of new information technologies, such as the Internet, are fueling both economic prosperity and human advancement. (Sundaram, 2003). Likewise, the uptake of mobile devices and innovative examples of mobile learning are on the rise worldwide (Shuler, 2009).

In light of the above observation by Shuler (2009), this research aims to seize the following mobile learning attributes to improve learning in pupils:

i) Encourage learning "anywhere, anytime" which enable students transcend the barriers imposed by the tradition physical locations of teaching and learning (L. Kolb, 2008).

ii) Promote situated learning by facilitating pupils to align their learning with actual situations, scenarios and environments to make basic concepts and vocabularies clearer and easier to remember and transfer (Gee, 2008).

iii) Break the perceived barrier between home, school and afterschool i.e. disconnect between learning in school and school as well as community setup. Seeking to harmonize learning in the three key environments (Shore, 2008).

iv) Reach underserved early grade learners countrywide since the adoption of mobile learning initiatives are on the rise in most of the underdeveloped parts of Africa where access to personal computers is limited but mobile devices are inexpensive and increasingly available (Aderinoye, Ojokheta & Olojede, 2007).

v) Foster collaboration which is deemed essential for the 21st Century success; in which traditional literacy e.g. reading, writing, and listening and numeracy (arithmetic) continue to be crucial skills (21st Century Skills, 2007).

1.6 The scope of the Study

The government of Kenya launched an ambitious FPE project in 2003 that saw many pupils enroll in public primary schools to acquire the basic education in line with the requirements of:

i) Education for All (EFA) policy; goal number 6 – seeking to improve quality of education in both literacy and numeracy (UNESS, 2011).
ii) Millennium Development Goal (MDG no. 2; 3rd target) - Universal primary education – ensure boys and girls everywhere get access compulsory primary education by 2012.

Despite the many gains, there have equally been some challenges that the education sector is grappling with especially resource allocation in public primary schools.

This study was restricted to public primary schools within Nairobi, Kenya. The mobile learning game was deployed in a selected number of schools within Nairobi County. A feasibility study will be carried out to inform a possibility of rolling out the project to all the 47 counties in Kenya.

1.7 Assumptions and Limitations

- The study required input from different groups of people and it was assumed that there would be total cooperation from them to make the research a success.
- The primary schools and their administration running the schools had necessary documents and reports that could assist in the study.

The main limitation was that the FPE projects had been rolled out all over the country and for one to come up with a proper representation of the projects, proper sampling needed to be done. To capture the national representation, the study opted to cover various primary schools, both public and private to clearly find out the disparities within Nairobi County. This was decided based on the findings of the study carried out by Uwezo (2011) that highlighted disparity in performance of the pupils in public and private primary schools.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter comprises the literature reviewed on m-learning. It also contains m-learning games studied, analysis of mobile learning games and the proposed learning game for literacy and numeracy.

This chapter will also serve as an insight of the findings with regards to mobile learning by many different researchers. Being a relatively new research area, most researchers are yet to agree on a comprehensive definition. The study sought to elaborate on how to develop content suitable for access from handheld devices. It also intended to discuss related research studies in the recent past; enumerating their strengths and weaknesses in relation to m-learning. The work is arranged in sections i.e.

1) M-Learning Technology
2) M-Learning in comparison with other modes of learning and their relevance to the study
3) Related Work

2.1 Mobile Learning Technology

Mobile learning is "the exploitation of ubiquitous handheld technologies, together with wireless and mobile phone networks, to facilitate, support, enhance and extend the reach of teaching and learning (MoLeNET, 2010)

(Sharples and Vavaula, 2007) define mobile learning in three dimensions – looking at it from the location perspective, e.g. it can take place either at workplace or home; it is mobile in terms of social status of the user e.g. leisure or work demands; and finally with regards to the fact that it is not time bound i.e. anytime, both day or night.

M-Learning mode of delivering teaching and learning activities has taken the education sector by a storm, thanks to the invention of cell phones, smart phones and tables and generally handheld devices which have expanded the learning boundaries to anywhere, anytime. The technological capacity of the handheld devices has tremendously been amplified in the past decade. Most of them come with bigger screens, clarity, larger storage capacities and multimedia capabilities.

2.2 Justification and making a case for m-Learning

Uwezo (2011) identified several detrimental issues the primary education is faced with some of which include low literacy and numeracy levels, extensive absenteeism by both teachers and learners, deficiency of teachers and inadequate supplementary resources. All these have resulted into a huge disparity in quality of education between private and public schools. Private primary schools tend to perform much better than public primary schools. According to UNICEF (2008), there are rampant rate of dropouts, mixed, pupils repeating classes leading to having over-age pupils in schools, among others. Despite all these being quite diverse and complex issues, m-learning attempts to address some of them e.g. the issue of supplementary materials is addressed by the available interactive learning content accessible to the pupils, anywhere and anytime for access. The teachers can also administer continuous assessment test and notes whenever they are away from classroom setup.

Attewell (2004), made the following observations on a European Union supported m-learning project; Mobile learning can:

i) Support both independent and collaborative learning experience.
ii) Help learners improve their literacy and numeracy skills
iii) Enable learners identify their weak areas and seek assistance
iv) Combat resistance to adoption of ICT and foster gap bridging between mobile literacy and ICT literacy.
v) Improve learners self confidence
vi) Boost the learner's concentration levels.

C. Shuler (2009), through her famous report "Pockets of Potential" highlighted five opportunities to seize mobile learning's unique attributes to improve education. These include:

i. Encourage "anywhere, anytime" learning to allow students gain access and process information outside classroom.
ii. Reach underserved early grade learners through relatively low-cost, accessibility; advance digital equity and population inspiration.
iii. Improve 21st Century social interactions by fostering collaboration and communication
iv. Enable personalized learning experience

Mobile devices fit more naturally with various learning environments.

2.3 Concerns and Challenges of m-Learning

Brown and Haag (2011), identified the following concerns, which needed to be addressed:

i. Battery life - This can vary greatly depending upon use and connections. There are considerations to conserve battery life in development as well as optional charging options until battery life improves.
ii. Connectivity - See Connectivity & Bandwidth in Design Considerations for details.
iii. Cost - Device costs continue to drop, whereas capabilities increase.
iv. Data charges - These costs vary greatly among carriers and can rise significantly during international travel.
v. Device ownership - Will devices be furnished to the users?
vi. Screen size - See Displays in Design Considerations for details.
vii. Security - Depending upon sensitivity of content, this may be the most difficult challenge. There are available solutions, but trainers need to work with their information systems team for the best solution.

viii. Technology changes - The global mobile industry is now the most "vibrant" and "fastest growing industry" on the planet. Expect improvements and changes.

In addition to the above concerns, Shuler (2009) outlined the following five critical concerns that needed to be addressed in order to unleash the educational potential of mobile technologies:

i. Negative aspect of mobile learning encompassing cognitive, social, and physical challenges presenting disadvantages including potential for distraction or unethical behavior, physical health concerns and data privacy issues.

ii. Cultural norms and attitudes are a stumbling block despite the significant potential of mobile devices in transforming early grade learners' learning, parents and teachers apparently are still apprehensive (Ganz, 2008)

iii. No mobile theory of learning are currently accepted for mobile technologies has been established, thus hampering the effective assessment, pedagogy, and design of new applications for learning.

iv.

v. Differentiated access and technology have a wide diversity among mobile technologies thus presenting a challenge for teachers and learners who wish to accelerate academic outcomes as well as the producers who seek to facilitate such learning. Limiting physical attributes due to poorly designed mobile technologies adversely affect usability and can distract early grade learners from learning goals. Physical aspects of mobile technologies that may prevent an optimal learning experience include: restricted text entry, small screen size, and limited battery life.

2.4 Comparing Mobile Learning to other Modes of Learning

According to Glen (2007), Distance learning is a general term used to wrap the broad range of teaching and learning activities in which the learner is geographically separated from the instructor, or his fellow learners prompting the acquisition of knowledge and skills through mediated information and instruction, encompassing all technologies and other forms of learning at a distance (USDLA, 2007).

E-learning is distance learning using an electronic device e.g. television, computers, videos, video games and laptops.

Mobile learning is an approach of e-learning that utilizes mobile phones. It presents unique attributes compared to conventional e-learning: personal, portable, collaborative, interactive, contextual and situated, it emphasizes "just-in-time-learning" as instruction can be delivered anywhere and at anytime through it. Moreover, it is an aid to formal and informal learning and thus holds enormous potential to transform the delivery of education and training. It is viewed as the intersection between mobile computing (use of small portable devices) and e-learning by use of ICT (Corbey, 2007).

Face to face learning is viewed as the basis to all forms and methods of learning. The hierarchy of the mode of delivery is best elucidated in the following diagram.

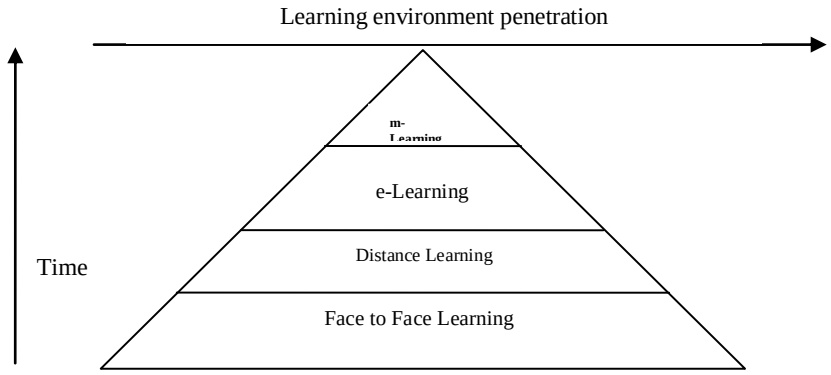


Figure 1: Hierarchy of learning methodologies (Uwezo, 2011)

2.5 Related Work

Considerable research has been conducted in the area of mobile learning. Hence, in this section, we will first discuss work that has been done in this area general before we get to what has been done specifically in the interactive games for mobile learning.

2.5.1 SMS-Based Mobile Learning:

This allows teachers to prepare automated response system for multiple choice quizzes using an SMS authoring tool. The teachers use this tool to present their questions in a variety of ways using posters, paper handouts or even websites. The learners use SMS text messaging to answer the multiple choice questions.

Despite having contributed so much in the mobile learning arena, the SMS-Based Mobile Learning systems have a number of challenges such as cost implications of sending interactive SMSes, non-delivery or delayed delivery of SMS either due to problems of bulk SMS gateway provider or service hitches at the mobile service providers. It has also been noted that most users of the messaging services tend to short-forms of words that not well understood by the systems unless otherwise trained on such words.

2.5.2 WAP-Based Mobile Learning:

A number of researchers and proponents of WAP-Based learning argue that it should be considered as the future of learning or as an integral part of any other form of educational process in the future. It is a new and dynamic domain in terms of leveraging education sector.

UniWap Project was a mobile learning project that used WAP technology to train teachers on creation of course materials via WAP enabled devices.

UtraLab M-Learning Project was responsible for the development of a prototype micro-portal layer (m-Portal) for providing M-Learning materials for people with literacy and numeracy knowledge deficiency (Collette M., 2002). This was delivered via WAP enabled gadgets.

Despite the wonderful contributions in the Mobile learning arena, the WAP-Based mobile learning initiatives are faced with numerous challenges such as connectivity issues, cost of accessing the WAP services.

2.5.3 Adaptive Mobile Learning System:

This is an artificial intelligence technique to mobile learning that offer learning platform that is adaptive to students' learning styles. The AM-LMS proposes an architecture and prototype quiz system based on XML/XSLT technologies. This system works on both PCs and mobile devices. However, it is a dynamic quiz system which does not support off-line learning.

2.5.4 Augmented Reality Games

Augmented reality simulations engage people in games that combine real-world experiences with additional information supplied to them by location-aware handheld computers. The first of these games, Environmental Detectives, was an outdoor game in which players using GPS-guided handheld computers tried to uncover the source of a toxic spill by interviewing virtual characters, conducting large-scale simulated environmental measurements, and analyzing data. This and other augmented reality games have been run at sites ranging from zoos and nature centers to schools and cities. Research has shown that this mode of learning is successful in engaging university and secondary-school students in large-scale scientific investigations, and is particularly appropriate for investigating socio-scientific issues such as those involving environmental and public health concerns. These however are not appropriate for little early grade learners. Also they pose a bigger challenge since not so many people posses GPS-guided handheld devices due to their cost and usage complexity.

2.5.5 Game Based Learning

Game-based mobile learning programs such as BrillKids allow teachers to create snap quizzes, multiple choice quizzes that are able to track and check answers by learners. These kinds however, outputs Flash files which are mainly appropriate Pocket PCs but do not support other handheld gadgets that lack a flash runtime system.

2.6 Types of Mobile Applications

Mobile applications, commonly referred to as mobile apps are programs or application software that run on mobile devices such as Smartphones and tablet computers.

There are three types of mobile apps i.e. Native mobile apps, Mobile Web apps and Hybrid apps.

2.6.1 Native Mobile Apps

These are mobile applications developed for use on a specific platform or device. They are Operating System (OS) specific. Native apps can also be referred to as apps designed and coded in a specific programming language such as Java for Android OS and Objective C for iOS devices.

These apps provide fast performance and high reliability since they have direct access to the phone hardware devices such as camera, phonebook, etc without internet connection.

Native apps are however expensive to develop since they are tied to one specific type of OS, forcing the developers to make the app then recode or custom it for the other different OS platforms.

2.6.2 Mobile Web Apps

Mobile-web apps are typically virtual apps due to the fact that they are just websites that look and feel like native apps. They are stored on a remote server and delivered via a browser.

Mobile web apps are typically developed in HTML5 and run on browsers and are generally designed to run well via any smart mobile web browser and in that regard, they are browser and internet connection dependent.

2.6.3 Hybrid Mobile Apps

Hybrid mobile application combines both features of native apps and mobile web apps. They are coded in web technologies such as HTML5, CSS and JavaScript. These apps typically run within a native container and leverage the device's browser engine (but not browser) to render the HTML5 and JavaScript locally.

A web-to-native abstraction layer enables access to device capabilities that are not accessible in mobile web apps e.g. accelerometer, camera and local storage.

Hybrid apps are popular because they allow cross-platform development i.e. the same source code can be reused and deployed on multiple mobile OS platforms, hence significantly reducing the development costs.

The tools employed in the packaging of this type of app include Sencha, PhoneGap and Mosync. For this project, tool of preference was PhoneGap and was used to package the app for Android, iOS, Windows mobile, Blackberry and Symbian.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter discusses both the research and system development methodology.

The system development methodology that was used to complete the proposed project was based on the ADL 6 D's for mobile learning application development. It is an appropriate software development methodology for delivery on mobile devices for use by learners. ADL suggests 6D for mobile learning development from the planning stage, design, development, deployment and evaluation of the learning application.

The study adopted Action Research model in research methodology. This involved five main stages i.e. preliminary findings, data collection, design, evaluation and results analysis and interpretation. The research design involved six research assistants who doubled up as proxy respondents to help in filling in the questionnaires since the early grade learners were not proficient enough to complete the questionnaires. Twenty six (26) participants were sampled from a school within Nairobi County.

Questionnaires, interviews and observations were used as the main data collection instruments. Finally the evaluation involved the use of the SUS tool which is in form of Likert scale for evaluation of usability and user experience as well as user satisfaction.

3.1 System Development Methodology

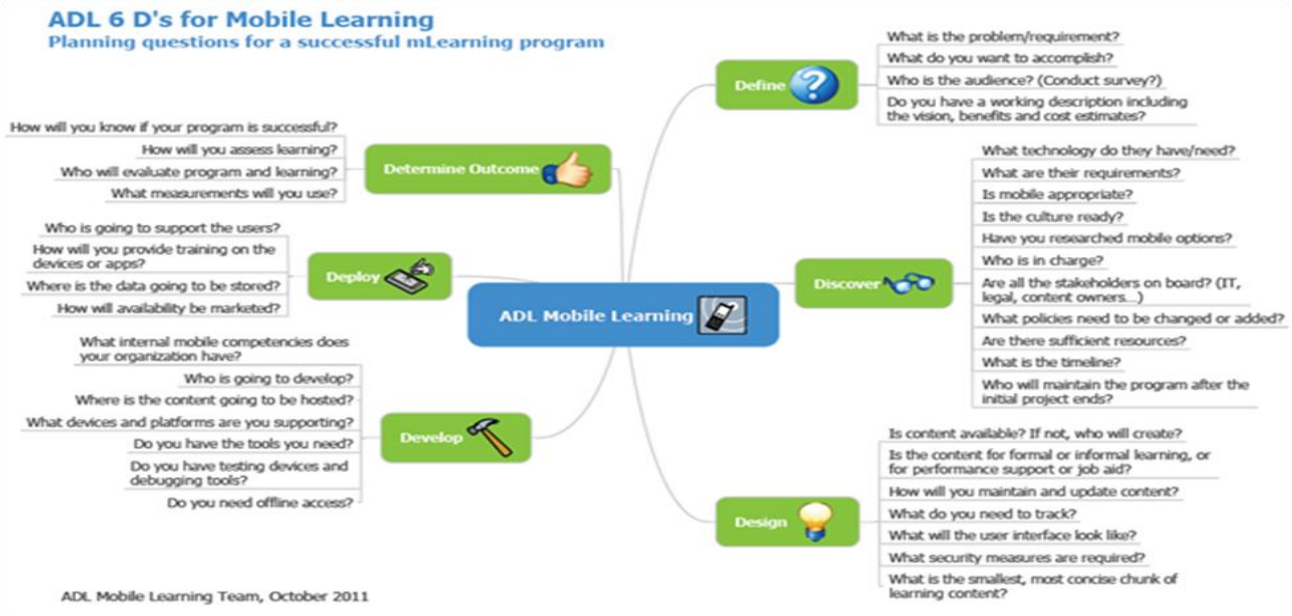


Figure 2: ADL 6 D's for Mobile Learning Application Development

3.1.0 Application of ADL 6 D's for Mobile Learning Project:

Generally ADL 6 D's has 6 main stages, these being Define, Discover, Design, Develop, Deploy and Determine Outcome. In this project we applied this methodology as explained below.

3.1.1 Define

We sought to identify the problem as well as the user requirements for this study. In the process of problem identification, we involved a number of stakeholders in activities such as:

i) Problem identification and requirements analysis
ii) Detailed definition of the aim of the project
iii) Identification and definition of targeted audience
iv) Working description – vision of the project

From expositional studies conducted in education sector, the researchers showed that early learning approaches have a great and positive impact on the learners' success in education and life pursuits. Findings from studies conducted by TrustAfrica

Foundation indicate that early grade learners are faced by the challenge of access to quality education in most parts of African continent (TrustAfrica, 2012). In our preliminary studies, we found out that majority of pupils in public primary schools in Kenya are grappling with challenges of inadequacy of learning resources despite the introduction of FPE by the government, which led to growth in enrollment. This however presented a new challenge – huge numbers of pupils enrolled in the public primary schools, hence compromising the quality of education due to few disparities and inadequacy of teachers to offer the much needed personalized support for learning.

The study involved various stakeholders in the preliminary studies in which we learnt the need to develop a mobile learning game for teaching pupils competencies in Numeracy and Literacy. It was found necessary to involve the Montessori curriculum approach of education in solving the challenges of the traditional modes of teaching and learning. Montessori curriculum tends to offer an interactive approach to teaching the early grade learners.

The decision to implement the teaching and learning on a mobile platform was informed by studies and surveys previously conducted indicating an increasing adoption of mobile technology in Kenya.

The vision of this project was to develop a hybrid mobile learning game to enable pupils learn anywhere and anytime. The mobile app targeted many different mobile Operating Systems such as Android, Windows Mobile, Bada, iOS, thus making platform independence.

3.1.2 Discover

This stage involved discovering the technical and technology required, appropriateness of the gadgets, user readiness, stakeholders, resources and maintenance requirements.

The technology required for this project success included smartphones and handheld gadgets. These despite being considered high-end mobile phones were found to be well suited for the app's optimal operations. The requirement analysis presented advantages of hybrid mobile app that enable smooth installation and operation across different mobile platforms.

Most of the smartphones have properties such as touch sensitive screens, wide screen-sizes, and multi-directional touch screens. Culture readiness has facilitated the need for targeting these types of phones and handheld gadgets as demonstrated by an upward trend of acquisition of the high-end gadgets with many functional capabilities. The successful implementation of this project involved brainstorming with some of the content developers, schools administration and education authorities. My Programming skills enabled me to develop and make decisions for maintenance of the mobile app after the initial project end.

3.1.3 Design

This involved:

i) Content availability/content development & developed by whom?

The development of learning content involved consultations with stakeholders in early learning and early childhood development fields. We sought guidance from teachers of the group of learners in the age group between 5 to 11 years in the selected primary schools. We also gained a lot of insights from literature as well as engagement with professionals in the Montessori Learning curriculum.

Scrounging from the Montessori curriculum that tends to support the idea of practical involvement of the pupils in the learning process; it became apparent that we had to develop an app that incorporates images and pictorials in the learning contents to enhance the retention of knowledge by the early learners. This approach to learning process involves interactivity, participatory and practical in various subjects. These are proven to be best practices which yield better results, especially knowledge retention in early learners.

From literature, most mobile learning applications have greatly made use of Montessori approach in the development of learning content. We considered this approach due to the fact that we were able to access a lot of material online which acted as a benchmark for our learning content.

In essence, the mobile learning system we developed sought to stir up the learners' imagination and interests through the use of objects and items they can easily relate with for purposes of teaching them both English and Math.

ii) How to maintain and update content

The mobile learning app that we developed is hybrid in nature and targets multiple OS platforms from a single source code. This ensures that whenever there is need for maintenance or update, it will be done cost effectively without having to maintain and update source code for each OS platform.

Being hybrid also brings with it the advantage of rapid response to evolving market requirements without interrupting the normal operations of the app. All the changes, maintenance and source code improvements can be done once from a source code editor then uploaded to the Adobe PhoneGap Build Apps store thus updating the whole App. The Adobe PhoneGap Build Apps store is secured by a username and password created by the developer. The app can however be downloaded by the potential users who have been given the express rights to download and install it onto their handheld gadgets. The developer created a QR code for ease of downloading the app from the Adobe PhoneGap Build App store.

iii) What will you track

The design of this app was aimed at making a learning game that is easy to learn and use. This has been demonstrated during the evaluation of the app's learnability, adaptability and usability by SUS evaluation tools.

iv) What will the UI look like?

PhoneGap is a cross-platform application and UI framework. It eliminates the constraints of being tied to a single platform; you develop your application once and deploy to multiple platforms without rewriting the source code. We designed a very easy to use User Interface that ensures effortless navigation by learners through the mobile app.

Basically, the mobile learning game was designed to have two broad categories namely; Literacy and Numeracy. These were also drilled down into sub-categories to enable learning of specific topics under the Literacy and Numeracy respectively.

v) Need for security?

The Adobe PhoneGap Build Apps store is secured by a username and password created by the developer. A QR code created by the developer can however be supplied to the selected potential app user. The QR code points the users to the hosting app store which allows them to download and install the app onto their handheld gadgets.

The security put in place is mainly to regulate downloads and prevent malicious interference and possible obliteration of the app through introduction of bugs into the source code. On the other hand, we chose not to put any security measures on the already installed app. This is due to the fact that it was targeted at the early learners. We did not find it appropriate to enhance any security levels. Our motive for this was to allow for easy access by the learner without necessarily seeking the intervention of the adults or parents. It also enables the learners to access the learning content at their free time.

3.1.4 Develop

This involved:

i) Mobile competencies among potential users

The development of this learning game took into account numerous competency requirements of the potential users. These were established during the requirements analysis which revealed that a great majority of the potential learners and users of the app were very quick to learn and adopt technology especially game playing on mobile platform. There were instances where we found out that a good number of the potential users had never had prior access to mobile gaming but when they were given a little coaching, they were quick to learn. Most of them progressively learnt intuitively.

ii) Mobile capabilities

The mobile devices used in the study ranged from Qwerty key button handsets as well as Smart, touch-screen mobile devices running different OS ranging from Android, Symbian, BlackBerry, Windows Mobile and iOS. With the advancement of mobile technologies, most handheld gadgets have superbly enhanced functionality in terms of

screen sizes, screen responsiveness, quality display and audio capabilities which we took advantage of for the optimal functionality of this mobile learning game.

iii) Who to develop the app'?

I developed this mobile learning game for purposes of study geared towards fulfilling the requirements of the degree of Masters of Science in Computer Science.

iv) Where the content will be hosted

Hosting and storage of the learning content in this project fully utilized the Local Storage, commonly referred to as HTML5 Storage which is based on named key/value pair that is supported by JavaScript. The data is actually stored as a string and retrieved by the same key. This technology was settled on given the fact that it has been used previously in a number of successful projects such as Mozilla Firefox, Symbian Smartphones, and Skype among others.

This technology is very light as compared to other database technologies; thus making it convenient and efficient for usage on mobile platform without hanging or malfunction of the devices due to huge chunk of data being retrieved.

v) What devices and platforms are you supporting?

This app runs on all types of handheld devices and various mobile operating systems such as iOS, Android, Symbian and Windows Mobile. This is the major advantage of having the app as a hybrid mobile app.

vi) Tools needed for development

For successful implementation of this project, we made use of HTML5, JavaScript and CSS for development of the interactive mobile app which was then wrapped inside a thin native container used for creating a hybrid mobile learning apps and enabled native APIs used from JavaScript.

The development optimized JavaScript pushing CSS to create beautiful layouts and writing compliant HTML5 codes that work across different platforms, hence the development and creation of this sophisticated mobile learning app that doesn't sacrifice the cool nature capabilities.

The development also employed the use of PhoneGap, an Open source framework for creating mobile apps using standardized web APIs and UI framework. It is a cross-platform Apps and UI framework that eliminates the constraints of being tied to a

single platform; it allows for development of the app once and deploying it to multiple platforms without rewriting the source code.

vii) Do you have testing devices and debugging tools?

We acquired 6 mobile devices for testing and debugging. We also installed the app on ten (10) other mobile phones with the specifications and capabilities that supported the optimal functionality of the app.

viii) Do you need offline access?

The mobile learning game app supports both online and offline access given the fact that it is a hybrid mobile app with both the native, mobile web and a combination of the two features.

3.1.5 Deploy

This stage sought to address issues related to user support, training, data storage and the ultimate marketing of the mobile learning app.

i) User support

The mobile learning game is a hybrid app built using PhoneGap for ease of maintenance and deployment on different mobile platforms. It allows for software update without interference with the operation of the app.

The developers are charged with the responsibility of creating and updating the learning content upon. Once the new features are implemented, the entire source code is incrementally updated at the Adobe PhoneGap Build AppStore. Occasional update prompts will be given to the users in case of development of new features done by the developers. The users will only be required to allow the update to experience the newly added features.

ii) How will you provide training on devices and app

We found out from the study that the users were able to quickly learn the operation of the mobile devices as well as the mobile learning game. This was demonstrated in cases where the learners were able to intuitively make correct moves during the game playing sessions.

The mobile learning game is also built in such a way that it facilitates the positive learning process through instructional scaffolding strategies such as modeling tasks,

suggesting options, compelling tasks and guidance on the development of cognitive skills.

iii) Where will the data be stored?

Storage of the learning data was broadly managed in two ways; first, the mobile learning app is stored within the Adobe PhoneGap Build AppStore from which the users can download and install it on their mobile devices.

Second level of storage of the learning content utilized the LocalStorage (HTML5 Storage) technology which is a very simple (but powerful) type of data structure called dictionary. It is an industry-standard technology that allows an app to store and retrieve data much faster. It allows storage of large amount of data without affecting the performance of the app. Data is stored locally in key/value pairs. The data is not included with every server request but used only when asked for.

iv) How will availability be marketed?

The mobile learning app will be marketed through the Kenya Institute of Education who are the institution charged with the vetting and approval as well as the dissemination of learning content for use in schools.

3.1.6 Determine Outcome

This stage involved the probe into application success, learning assessment, evaluation of the app.

i) How will you know that your app is successful?

After the completion of the development process, we took the app to the prospective users of the mobile learning app to determine their experience. We also went and demonstrated the app to the KIE staff charged with the responsibility of vetting and approving learning contents and dissemination to schools as part of learning curricula. We got very good comments from the KIE team.

ii) How will you assess learning?

Assessment of learning was done by subjecting the pupils to tests related to the topics learnt through the mobile learning game. The tests were confined under the Literacy and Numeracy categories.

iii) Who will evaluate program and learning?

Twenty six (26) participants were involved in the evaluation of the mobile learning game. To achieve this task, we adapted SUS questionnaire which used a Likert 5-point scale format.

3.2 PROGRAMMING LANGUAGES

3.2.1 HTML5, JAVASCRIPT & CSS

Hybrid development combines the best of both the native and HTML5 worlds. This app was primarily built using **HTML5, CSS** and **JavaScript**, that was then wrapped inside a thin native container that provides access to native platform features. **PhoneGap** was the container used for creating the hybrid mobile learning app and enabled native APIs used from javascript.

The development sought to optimize JavaScript, pushing CSS to create beautiful layouts, and writing compliant HTML code that works on any platform hence the creation of this sophisticated mobile learning application that don't sacrifice the cool native capabilities.

PhoneGap is a free and open source framework that allows you to create mobile apps using standardized web APIs for the platforms you care about.

PhoneGap is a cross-platform application and User Interface (UI) framework. It eliminates the constraints of being tied to a single platform: you develop your application once and deploy to multiple platforms without rewriting the source code.

Advantages of Hybrid Mobile App

i. Target multiple platforms from a single source code
ii. Shorter development time – faster time to market
iii. Reduced maintenance expense
iv. Avoid OS-subgroups in development organization
v. Enjoy true platform independence and remain insulated from platform changes – targeting a new platform is measured in days or weeks, not months or years
vi. Rapidly respond to evolving market requirements
vii. Hybrid delivers real, lasting competitive advantage

viii. It increases the productivity of developers by making C++ programming faster, easier and more intuitive

ix. PhoneGap development tools eliminate common bottlenecks in the development process:

- ✓ GUI Design & Layout - PhoneGap Designer
- ✓ Translation/Localization - PhoneGap Linguist
- ✓ Documentation – PhoneGap Assistant
- ✓ Cross-platform build system – PhoneGap Build

x. Full access to complete source code on all platforms enables development teams to adapt and extend PhoneGap to meet their unique needs, expediting the development process.

3.3 DATABASE LANGUAGES

Local Storage/HTML5 Storage

This project fully utilized Local Storage which is based on named key/value pairs. You store data based on a named key, then you can retrieve that data with the same key. The named key is a string. The data can be any type supported by JavaScript, including strings, Booleans, integers, or floats. However, the data is actually stored as a string. If you are storing and retrieving anything other than strings, you will need to use functions like parseInt() or parseFloat() to coerce your retrieved data into the expected JavaScript datatype.

Local Storage has been used in many large projects like Mozilla Firefox, Symbian smartphones, Skype, Solaris, PHP, Mac OS, among others.

3.3.1. SAMPLE SOURCE CODES

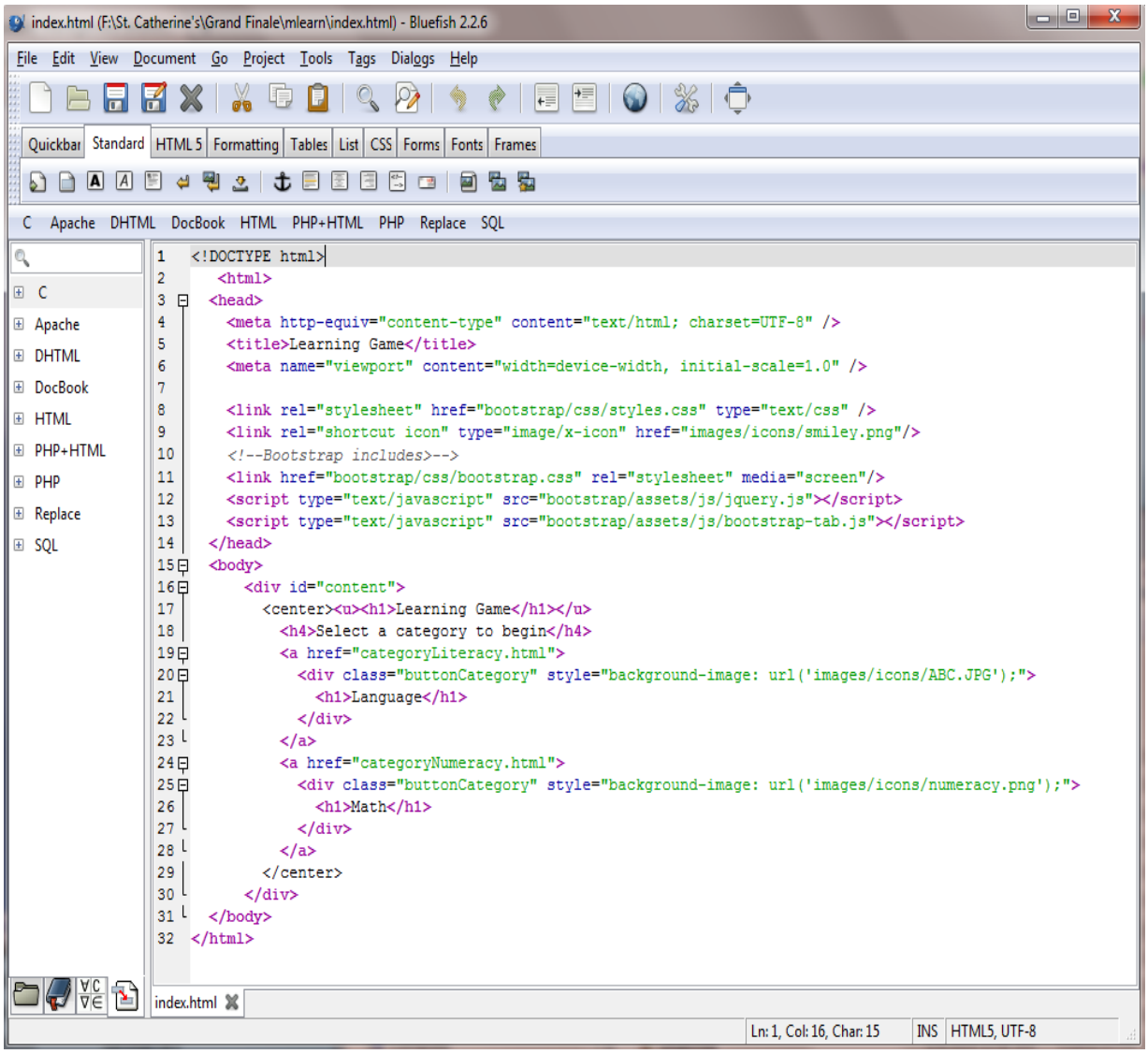


Figure 3: Sample Code 1

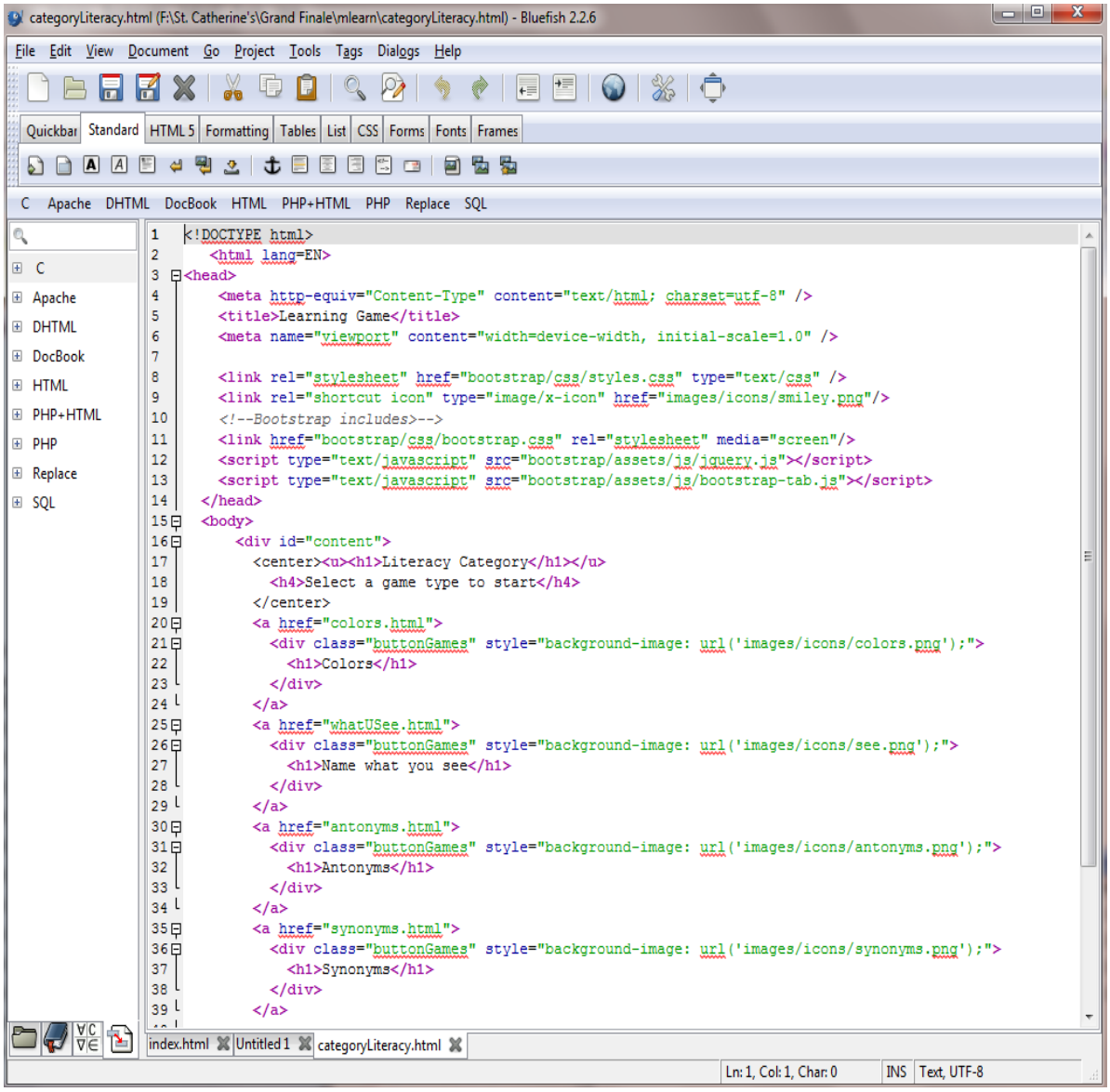
The source code above is responsible for the display of the Home page of the app with the main menus of the Learning Game. It allows the user to navigate from the main menu to the learning categories.

The Learning Game has two main categories namely;

i) Literacy Category

ii) Numeracy Category

Literacy Category




```
<!DOCTYPE html>
  <html lang=EN>
<head>
    <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
    <title>Learning Game</title>
    <meta name="viewport" content="width=device-width, initial-scale=1.0" />

    <link rel="stylesheet" href="bootstrap/css/styles.css" type="text/css" />
    <link rel="shortcut icon" type="image/x-icon" href="images/icons/smiley.png"/>
    <!--Bootstrap includes>-->
    <link href="bootstrap/css/bootstrap.css" rel="stylesheet" media="screen"/>
    <script type="text/javascript" src="bootstrap/assets/js/jquery.js"></script>
    <script type="text/javascript" src="bootstrap/assets/js/bootstrap-tab.js"></script>
  </head>
  <body>
     <div id="content">
       <center><u><h1>Literacy Category</h1></u>
         <h4>Select a game type to start</h4>
       </center>
       <a href="colors.html">
         <div class="buttonGames" style="background-image: url('images/icons/colors.png');">
           <h1>Colors</h1>
         </div>
       </a>
       <a href="whatUSee.html">
         <div class="buttonGames" style="background-image: url('images/icons/see.png');">
           <h1>Name what you see</h1>
         </div>
       </a>
       <a href="antonyms.html">
         <div class="buttonGames" style="background-image: url('images/icons/antonyms.png');">
           <h1>Antonyms</h1>
         </div>
       </a>
       <a href="synonyms.html">
         <div class="buttonGames" style="background-image: url('images/icons/synonyms.png');">
           <h1>Synonyms</h1>
         </div>
       </a>
```

Figure 4: Sample Code for Literacy Category

The source code above is charged with the navigation within the Literacy Category of the Learning game. It allows the users to select sub-categories under the Literacy Category.

Literacy Category has 4 sub-categories namely;

i) Colours
ii) Identifying objects (Name what you see)
iii) Antonyms
iv) Synonyms

Numeracy Category

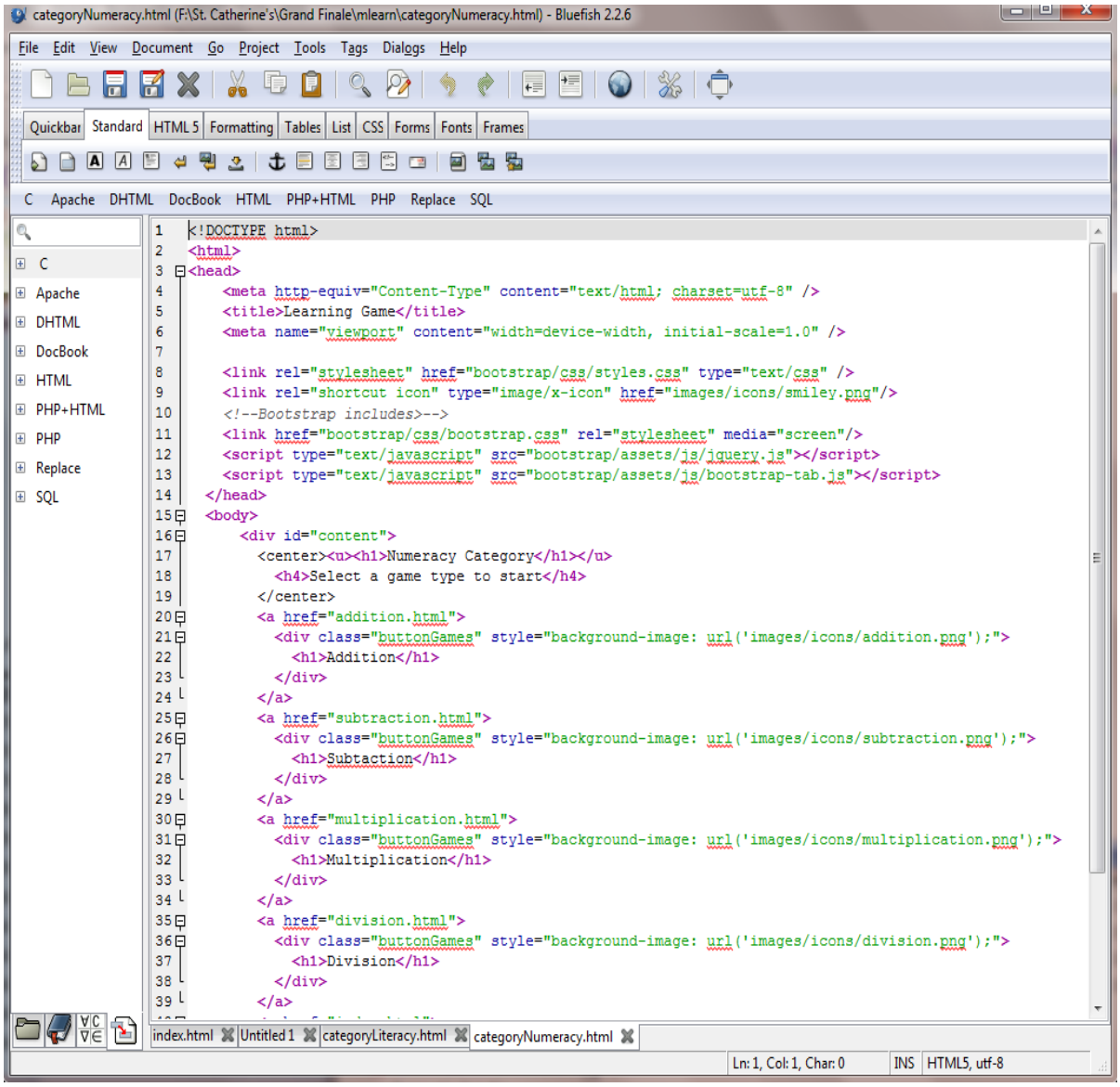


Figure 5: Sample Code for Numeracy Category

The source code above is responsible for the navigation within the Numeracy Category of the learning game. It allows the user to choose the sub-category of the Numeracy Category.

Numeracy Category has 4 sub-categories namely;

i) Addition
ii) Subtraction
iii) Multiplication
iv) Division

3.4 EVALUATION METHODS

3.4.1 GOAL-BASED EVALUATION

The aim of goal-based evaluation is to investigate whether the project has achieved its goals. This question is posed at the end of the project process, often within the context of a summative evaluation.

In this study we focused, the main goal was to foster an innovative learning approaches and environment for early learning. The evaluation revealed that the objective was attained by the ultimate successful development of the hybrid mobile learning game for teaching pupils of age group between 5 to 11 years old on the proficiency in both literacy and numeracy.

Findings from the usability evaluations of the mobile learning game have consistently shown that learners appreciated the interactive nature of the learning system. It was evident that it helped the learners to stay focused and engage in the learning process since most of them found it interesting and enjoyable. Additionally, the learners expressed their delight for the fact that the app allowed them to learn anytime and anywhere hence allowing them to manage their studies well (Abas et al, 2009).

3.4.2 PROCESS-BASED EVALUATION

Process-based evaluation was aimed at answering the following questions;

i) **What was required to deliver the innovative mobile learning game in terms of resources, products and services?**

In this project we required knowledge in mobile programming especially both native and mobile web programming. I took it upon myself to familiarize myself with the mobile app developments and the necessary features required for the mobile learning app development.

Programming resources required included the software such as Text editors for HTML5, Hosting facilities such as the Adobe PhoneGap Build App Store. All these were obtained under Open Source License. It also required the mobile devices for testing the app.

ii) How were individuals implementing the project trained?

Have a Computer Science background and programming skills, I was able to quickly embark on the mobile app development without difficulty. It however required me to learn some new technologies especially the mobile technologies such as native, mobile-web and hybrid technologies and how to implement.

iii) How were the participants selected and trained?

This study required involvement of research assistants who doubled up as proxy respondents to mitigate prejudice that would have resulted from having the early learners (of age groups 5 to 11 years old) fill in the questionnaires.

We selected six (6) research assistants, all affiliated to C4D Research Lab of the School of Computing and Informatics owing to their involvement in related researches in mobile learning. Despite their exposure, it was necessary to train them for three days.

iv) What were the innovation's strengths and weaknesses?

The evaluation gave us a clear picture on the strengths of this innovation such as the ability to run on various mobile platforms (platform independence) due to its hybrid feature. It was also noted that the development process involved developing the source code once and deploying it to multiple operating systems without any trouble. Updates on the source code were also found to be easy and convenient without interruption of the normal app operations.

The weaknesses noted during this evaluation included the fact that most of the learners do not own mobile phones due to their tender ages.

v) What were the feedback from participants and partners and stakeholders about the implementation of this project?

The successful implementation of this project solicited very positive feedback. Among them being the Kenya Institute of Education (KIE) staff members whose feedback upon the presentation were that the application was fit for use in teaching and learning in early education due to its content. KIE is the institution charged with

the mandate of vetting and approving learning contents and syllabi for use in schools countrywide.

The learners also gave very impressive with regard to the user experience and general usability of the mobile learning game. This was well illustrated in **Table 4** and **Figure 13.**

3.4.3 OUTCOMES-BASED EVALUATION

Outcomes-based evaluation was aimed at measuring any changes immediately after the project implementation and to establish that the changes due to the innovation. We witnessed enhanced learning processes in terms of knowledge retention among the learners, perceptions/attitudes or skills of the learners were also boosted as demonstrated the eagerness to continue playing the learning game. Also it was noted that the learners demonstrated fast learning intuitively which helped improve the learners' cognitive psychology.

3.5 Mobile Learning Game

The mobile learning game was aimed at teaching the pupils of age group between 5 - 11 years how to perform numeracy and learn literacy. The app was developed to depict the two areas of study i.e. Math and English. These were made as the two main Categories of the learning content. They were further sub divided into 4 subcategories each.

3.5.1 Development of Learning Content:

This involved consultations with stakeholders in early learning and early childhood development fields. We sought guidance from teachers of the group of learners in the age group between 5 to 11 years in the selected primary schools. We also gained a lot of insights from literature as well as engagement with professionals in the Montessori Learning curriculum.

Scrounging from the Montessori curriculum that tends to support the idea of practical involvement of the pupils in the learning process; it became apparent that we had to

develop an app that incorporates images and pictorials in the learning contents to enhance the retention of knowledge by the young learners.

In essence, the mobile learning system we developed sought to stir up the pupils' imagination and interests through the use of objects and items they can easily relate with for purposes of teaching them both English and Math.

3.5.2 Screenshots of the Mobile Learning Game

Home Screen

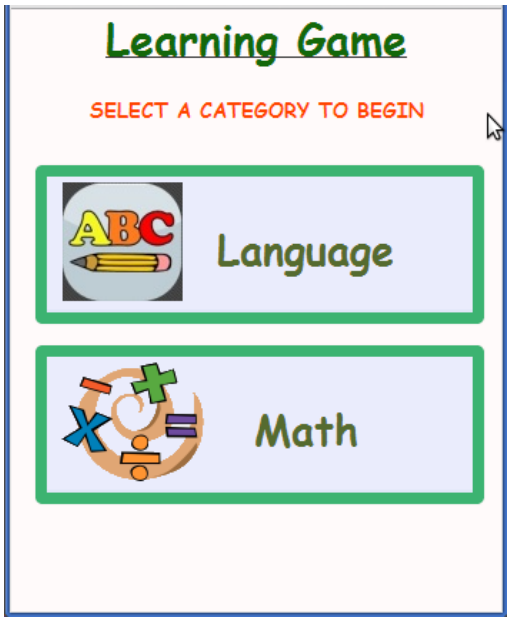


Figure 6: Home Screen

Home Screen has two Categories of the game:

i) Literacy (Language)

ii) Numeracy (Math)

Literacy Category:

Figure 7: Literacy Category Screenshot

Literacy category has 4 subcategories: Colors, Name what you see, Antonyms and Synonyms

i) Name what you see

Figure 8: Feedback upon submitting the answer

Numeracy Category:

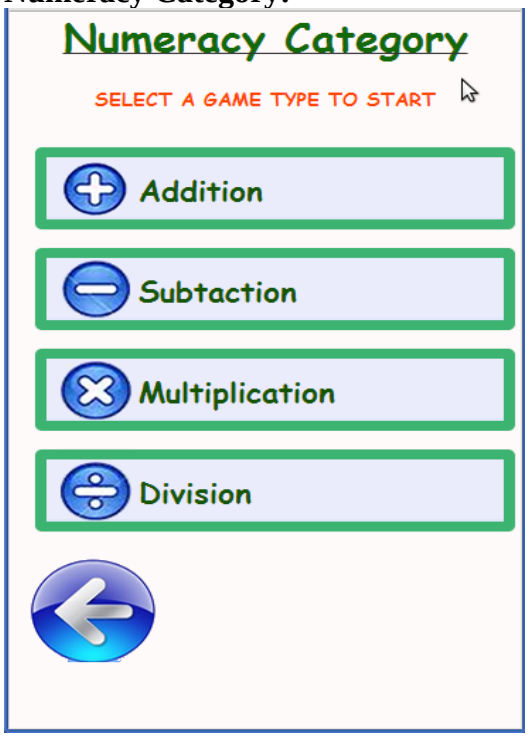


Figure 9: Numeracy Category Screenshot

Numeracy category has 4 subcategories: Addition, Subtraction, Multiplication and Division

i) Addition

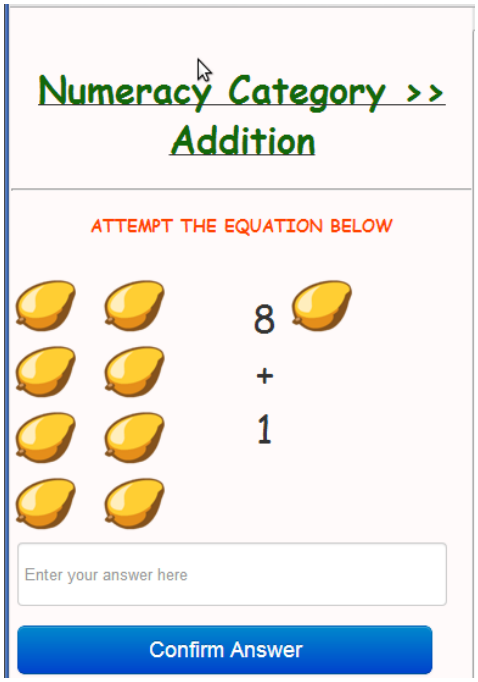


Figure 10: Screenshot of Addition Subcategory

3.6 Research Methodology

Kothari C. R (2008) defines research design as the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. It therefore gives the structure in which the research is conducted and it contains the collection, measurement and analysis of data.

3.6.1 Research Design

The research design followed Action Research model which entailed the following five steps:

i) Preliminary findings

This involved literature review, observations and interviews with the stakeholders in a bid to understand the domain of the study. At this stage we managed to identify the mobile devices that would support the mobile learning app.

ii) Data collection

This was aimed at conducting diagnosis and action planning. Employing the three main data collection instruments; Questionnaires (adapted the SUS questionnaire), Interview questions and Observations.

iii) Design stage

Also referred to as Action taking, involved the use of ADL 6 D's approach for Mobile Learning Projects.

iv) Evaluation stage

The prototype was evaluated to determine its learnability, adaptability and usability

v) Results analysis and interpretations

Analysis of the data was conducted using the SUS analysis formula, interpreted and presented in form of charts.

3.6.2 Detailed Research Design

Conducting research study in the early education domain is quite a complex activity especially when it revolves around mobile technology in early education. This is more complex especially when the targeted population is a group of learners aged between 5 to 11 years old. The early grade learners might not be able to fully understand how to properly fill in the questionnaires which formed one of the main data collection

instruments in this study. Owing to this fact, we found it difficult to administer questionnaires to such young learners.

Being such a complex activity for early grade learners of age group between 5 and 11 years old, we decided to co-opt six (6) research assistants affiliated to the C4D Research Lab of the School of Computing and Informatics. This was arrived at by virtue of the fact they were also involved in mobile gaming research within the Research Lab and this would expose them to actual research in the educational arena. The research assistants doubled as proxy respondents in this study to mitigate the complexity of having early learners fill the questionnaires.

3.6.3 Proxy Respondents Training

All the six (6) research assistants were taken through a three (3) days rigorous training on the key issues to look for during the study. The training was designed to depict some features of the Theory of Planned Behavior (TPB) model, which is one of the most preferred theories for linking beliefs, attitudes, behavioral intentions and behaviors (Ajzen, 1991). The following steps informed the training guidelines for the research assistants:

i) Definition of the population of interest – The population for this study was carefully selected from St. Catherine's Primary School. These included a total of 26 participants; 22 being pupils of age group between 5 and 11 years old while 4 were teachers of the said age group.

ii) Careful definition of the behavior and attributes under study (adopted from the SUS evaluation questionnaire) from which the relevant questions were constructed. (See Appendix B). The research assistants were expected to note, record, every feedback they got from the respondents, either by interview responses or observations made.

iii) Decide on the best methods for measuring the attributes such as Learnability, Adaptability and Usability. For this study, we adopted the Likert scale, commonly used for psychometric ratings. Likert scale being a bipolar scaling method that measures either positives or negatives ranging from 1. Strongly disagree, 2. Disagree, 3. Unsure, 4. Agree and 5. Strongly agree. **Part Two** of

the Adapted SUS Questionnaire for evaluation of the m-Learning Game clearly illustrates this (See Appendix B).

3.6.4 Significance of Proxy Completion of the Questionnaires

The validity of responses by individual pupils in the study was threatened by a number of biases and prejudice due to their tender age cadre sighting incompetence to properly fill in the questionnaires. Taking note that most of the learners involved in this study were early grade learners of ages between 5 and 11 years, we found it fit to have the research assistants help in filling the SUS Questionnaire upon noting the users' response to the questions on learnability, adaptability and usability of the mobile learning app. Apart from the 10 standard SUS questions, the research assistants also made observations on the user experience and behavior during the learning sessions.

3.7 Sampling Technique and the Targeted Population

This study involved 26 participants who were randomly sampled from St. Catherine's Primary school in Nairobi County. The twenty six (26) participants were solicited from both lower primary and upper primary classes. Of the 26 participants, only 21 returned validly filled questionnaires, 17 being pupils and while 4 were teachers.

St. Catherine's primary school was purposely sampled due to logistical considerations and a modest budget. It is a public school with a population of 317 pupils.

The research assistants involved in the study were well trained on the operations of the mobile learning game. The mobile app was installed in six (6) mobile phones used by the research assistants in testing the learnability, adaptability and usability of the learning game. They were also taken through the attributes to look for in observation as well as the two parts of the adapted SUS questionnaire with **Part one** being the interview questions to establish the participants' exposure and experience using computing devices and particularly handheld mobile devices such as mobile phones. **Part two** composed of the typical psychometric scale questions commonly known as the Likert scale, universally used in evaluation of new technologies. This included the 10 SUS questions adapted for this study.

The table below illustrates the distribution of the sampled participants. It also depicts the distribution of the participants from Lower and Upper primary classes respectively.

	Class	No. of Pupils	No. of Teachers	Cumulative
1	Lower Primary Classes (Class 1 – 4)	Participants: 1, 3, 4, 7, 13, 16 & 19 (i.e. 7 pupils)	Participants: 9 & 14 (i.e. 2 teachers)	9
2	Upper Primary Classes (Class 5 – 8)	Participants: 2, 5, 6, 8, 10, 12, 15, 17, 18 & 21 (i.e. 10 pupils)	Participants: 11& 20 (i.e. 2 teachers)	12
3	Invalidated	5 pupils	-	5
Total Participants				**26**

Table 1: Distribution Table of Sampled participants

3.8 Data Collection Instruments

The following research instruments assisted in the collection of data while carrying out the study.

3.8.1 Questionnaires

The main data collection method used was questionnaires. This is because they could be used to reach a large number of respondents. They were cost effective and could be used to curb biasness. Questionnaires did not require respondents to provide their identity thus encouraging them to give more reliable information.

The questionnaires based on the Systems Usability Scale (SUS) developed by John Brooke in 1986. In this study the SUS questionnaire was adapted to fit the nature of the system under evaluation which was a mobile learning game application. The SUS questionnaire was modified to consist of two (2) parts. **Part Two** of the questionnaire particularly addresses learnerbility, adaptability, and usability of the mobile learning game.

Twenty six (26) questionnaires were administered to the 26 participants. Out of the 26 only 21 were validly filled, 5 were spoilt.

3.8.2 Interviews

To gain more insight into the participants' level of exposure and experience using computing devices such as computers and mobile phone, all the participants were interviewed. The SUS questionnaire was modified and divided into two (2) parts; **Part One** being the interview questions to establish the user exposure and experience with computing gadgets. This was aimed at establishing whether there was a necessity and extent of training the participants on the usability of the mobile learning game. Interviews were used because they provide an opportunity to collect more information through probing that could not be collected by using questionnaires alone. This helped in soliciting the sentiments of participants.

The interview sessions were recorded and later transcribed to help in filling in the SUS questionnaires.

Participant ID: _____ Site: _____ Date: ____/____ /____

System Usability Scale

Instructions: For each of the statement in **Part Two**, mark one box that best describes your reactions to the mobile learning game today. **[**1st, 2nd, 3rd, 4th and 5th boxes representing: Strongly Disagree, Disagree, Unsure, Agree and Strongly Agree, respectively**]**.

PART ONE

Have you ever used a computer before? Yes ☐ No ☐

Have you ever played a computer game before? Yes ☐ No ☐

Have you ever used a mobile phone? Yes ☐ No ☐

Have you ever played a game on a mobile phone before? Yes ☐ No ☐

PART TWO:

This part is based on the observation and judgement of the learner "in action" (while playing the learning game) and aims at evaluating factors pertaining to the functionality/ logic of the game. It's aimed at evaluating the Learnability, Usability and Playability of the m-Learning game.

		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
1.	The m-learning game was enjoyable and I'd like to play often	☐	☐	☐	☐	☐
2.	The m-learning game was too complex to play	☐	☐	☐	☐	☐
3.	The m-learning game was easy to play	☐	☐	☐	☐	☐
4.	I needed assistance to play this m-learning game	☐	☐	☐	☐	☐
5.	I found it easy to navigate through the m-learning game	☐	☐	☐	☐	☐
6.	The m-learning game was very inconsistent	☐	☐	☐	☐	☐
7.	The m-learning game was easy to learn	☐	☐	☐	☐	☐
8.	The m-learning game was too cumbersome to play	☐	☐	☐	☐	☐
9.	I felt very confident playing the m-learning game	☐	☐	☐	☐	☐
10.	I needed to learn many things before playing the m-learning game	☐	☐	☐	☐	☐

This questionnaire is adapted from the System Usability Scale (SUS), which was developed by John Brooke while working at Digital Equipment Corporation. © Digital Equipment Corporation, 1986.

Figure 11: Adapted SUS Questionnaire for Evaluation of the m-Learning Game

3.8.3. Observation

This was done to assess the way the learners interact with the mobile learning game for learning both numeracy and literacy. It was aimed at gaining insight on the learner's ability learn, play, and use the m-learning game. This aided the evaluation of the perceived user satisfaction to ascertain whether they enjoyed interacting with the app. This was done and a video recording done of some sessions which were later

watched to draw some conclusions with regards to the perceived satisfaction of users and the usability of the mobile learning game.

3.9 Data analysis

In order to establish whether the objectives of this study were attained, the collected data was analyzed. This was done by use of the standard SUS formula for analyzing usability. The analysis sought to establish the user experience and satisfaction in using the mobile app for learning purposes. This was geared at gaining insight on the success level on bridging the gaps identified in this study as indicated in the research problem that showed that there was need to facilitate and foster innovative and interactive methods for enhancing teaching and learning of numeracy and literacy among the pupils of the age group between 5-11 years.

Evaluating usability was aimed at giving insight on how easy it is for the learner to learn by means of the m-learning game. It also would give an indication of the level at which the app addressed the pedagogical aspects in early grade learning of literacy and numeracy.

Generally SUS analysis aimed at addressing all aspects of usability and user experience as well as user satisfaction since it tends to determine the following system attributes:

i) Effectiveness
ii) Efficiency
iii) User satisfaction
iv) User perception

3.9.1 Analysis Stages/Explanation

SUS yields a single number representing a composite measure of the overall usability of the system being studied. Note that scores for individual items are not meaningful on their own.

To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1, 3, 5, 7, and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position.

Multiply the sum of the scores by 2.5 to obtain the overall value of SU.
SUS scores have a range of 0 to 100.

- **Equation 1: SUS formula for one respondent**

$$2.5 \sum \left((x^{+ve} - 1) + (5 - x^{-ve}) \right)$$

This calculates usability of an individual respondent based on their feedback.
Since usability by use of SUS is meant to be one value on a scale of 0-100, an average of all the individual respondents SUS value is calculated as follows;

- **Equation 2: SUS Formula for 21 respondents**

$$\frac{\sum_{i=1}^{21} 2.5 \sum \left((x^{+ve} - 1) + (5 - x^{-ve}) \right)}{21}$$

The average acceptable usability is SUS score of 68% (Sauro, 2012) - values above 68% being considered as above average while those that are less than 68%are considered below average.
In this research, 26 respondents were involved and each of them was expected to give 10 responses as structured in SUS questionnaire. These summed up to 260 responses. Out of the 26 participants, only 21 participants gave valid responses thus the total responses were 210 which was derived by multiplying the number of users by the number of structured SUS questions, i.e. 21 by 10. The table below shows the frequency distribution of usability scores based on SUS calculations. A detailed SUS results are found in appendix C table (5). The average SUS score was found to be 78.45% rounded off to 78.5%
The arrival at this average SUS is illustrated in the table below.

	Question Response Distribution									
	50 - 55	56 - 60	61 - 65	66 - 70	71 -75	76 - 80	81 - 85	86 - 90	91 - 95	96 - 100
Frequency	1	2	0	0	2	4	8	4	0	0

Table 2: Frequency of SUS for each respondent

3.9.2 Qualitative Analysis

Qualitative analysis was used to analyze data that could not be quantified, which includes data collected using open-ended questions and interviews. This assisted in analyzing data collected from different respondents in a systematic way in order to arrive at useful conclusions and recommendations. Phrases or words from different respondents were studied to identify similarities and differences and establish a pattern. All the participants were interviewed using the interview questions in **Part One** of the adapted SUS questionnaire and analyzed by excel spreadsheet as shown in the table 3 below:

Interview Question	Response		% Positive	% Negative
	Yes	No		
Have you ever used a computer before?	7	19	26.9	73.1
	Yes	No		
Have you ever played a computer game before?	12	14	46.2	53.8
	Yes	No		
Have you ever used a mobile phone?	23	3	88.5	11.5
	Yes	No		
Have you ever played a game on a mobile phone before?	20	6	76.9	23.1

Table 3: Analysis of Interview Question Responses

Interesting observations were made from the analysis of the interview question responses above. It was evident that only 26.9% and 46.2% of the participants had been exposed to computers and computer games respectively. On the other hand, 88.5% and 76.9% of the participants have been exposed to mobile phones and played games on mobile phones respectively.

3.9.3 Testing the Prototype

The testing was aimed at determining the mobile application's functionality aspects which include its usability and the user experience. Initially a mockup prototype of the game was taken to one of the sampled schools. The pupils together with their teachers were shown the operations of the system. They were given a chance to contribute what they would like to be included in the final app.

A fully developed mobile learning game was then taken to a public primary school in Nairobi. The app was installed in a number of phones that we had. Given the platform independence nature of this app, it was very easy to install it in phones running on

different Operating Systems such as Android, Windows Mobile OS, Symbian. The most common OS we used were Android and Windows Mobile in this study.

The testing involved investigating the functionality of different modules of the app such as the launching of the app, the navigation from one category to the other. The app has 2 main categories; Literacy and Numeracy. These also have subcategories drilling down to the various learning contents.

The app performed reasonably well with regards to its functionality and 78.5% of the users expressed great level of satisfaction and user experience.

CHAPTER FOUR

RESULTS DISCUSSION AND FINDINGS

4.0 Introduction

The main reason of carrying out data collection was to test the validity of the proposed mobile learning game and evaluation of the m-learning game developed. The collected data was tabulated in a SUS format and computed by SUS analysis tool. The results of this study were mapped to the research objectives which were as follows:

i) To develop a hybrid mobile learning game for teaching pupils between 5 to 11 years old how to do Math and English

ii) To enhance the learning process and boost the knowledge retention among the pupils of age group between 5 and 11 years.

iii) To increase flexibility of learning offered to early learners

iv) To encourage and support ubiquitous learning (just in time, anytime, anywhere) via mobile technologies.

v) To evaluate the usability of the mobile learning system

The questions 1, 3, 5, 7 and 9 of the SUS questionnaire sought to find out the level of user satisfaction with regards to Usability, Playability and Mobility of the game. The responses were positive and shows a high level of user satisfaction as illustrated in the table (4) below and the graph (figure 12) below

Learnability, Usability & Playability of the Mobile Learning Game

Questions	Average Score Per Question	Percentage Response
1	4.48	89.5
2	1.76	35.2
3	4.48	89.5
4	2.33	46.7
5	3.95	79.0
6	2.14	42.9
7	4.38	87.6
8	2.05	41.0
9	4.33	86.7
10	1.95	39.0

Table 4: Usability of the Mobile Learning Game

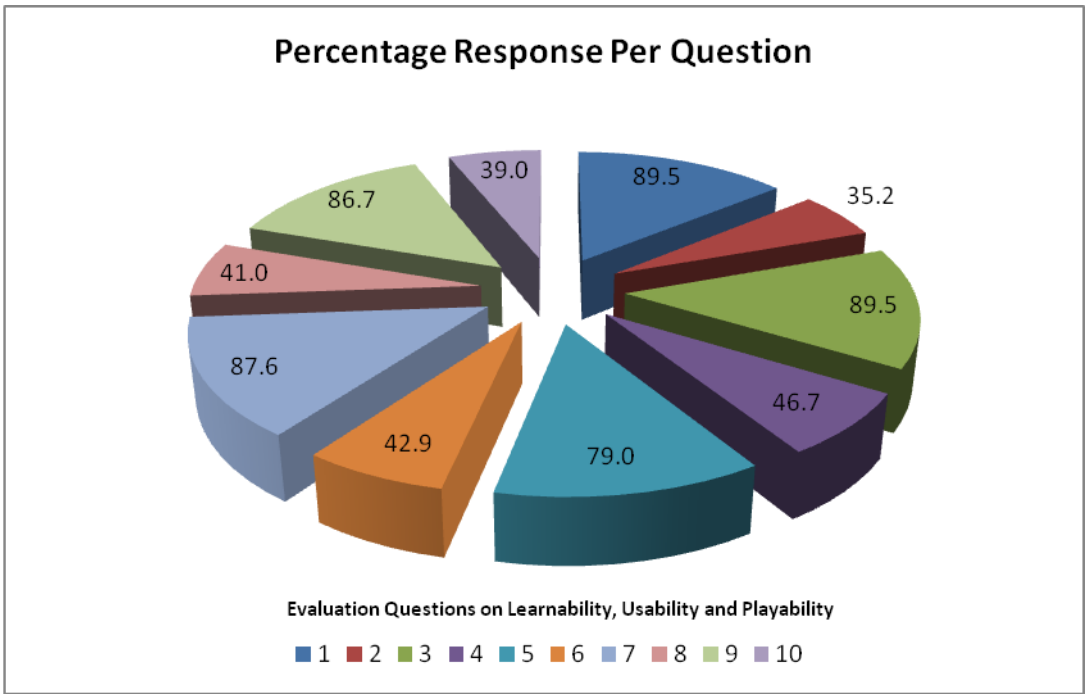


Figure 12: Graph Representing the Analysis of Learnability, Usability & Playability of the Mobile Learning Game

4.1 Reliability Testing

During data analysis, the first step to be carried out was to test the reliability and validity of the instruments used to collect data.

Reliability Testing

The reliability of the instruments to be used was measured to determine the consistency of the results. For examples, using the questionnaires, answers to the same questions were analyzed to establish the consistency. SUS tool is one of the most widely adopted for perceived usability evaluation of software/products (Tullis & Albert, 2008; Sauro 2012)

4.2 Results

Handheld devices such as mobile phones and tablets seem to be appropriate devices to use in the learning particularly in early education, yet a requirement to use them in a course would deprive a small percentage of early grade learners who do not own or use a mobile phone. The objectives were measured using ten closed-ended questions

as in table (4). The table shows the percentage of the descriptive statistics for the effectiveness of mobile learning. Responses to each of the indicators on effectiveness of mobile learning were measured on a SUS Likert Scale of 1 to 5, ranging from "Strongly agree" to Strongly disagree"

According to Sauro (2012), the average acceptable usability is SUS score is 68%; hence any values above 68% are considered as above average while those that are less than 68%are considered below average.

In this research, 26 respondents were involved and each of them was expected to give 10 responses as structured in SUS questionnaire. These summed up to 260 responses. Out of the 26 participants, only 21 participants gave valid responses thus the total responses were 210 which is derived by multiplying the number of users by the number of structured SUS questions i.e. 21 by 10. The table below shows the frequency distribution of usability scores based on SUS calculations. A detailed SUS results are found in appendix C table (5). The average SUS score was found to be 78.45% rounded off to 78.5%

4.3 Discussion

Data in table 5 provides an overview of the relative importance of these indicators. Mean scores of the sample indicate that more than 78.5% of respondents strongly support mobile learning as an effective method for learning. This data indicates that mobile technologies are more flexible and facilitate pupils' greater freedom of learning any place, any time. Respondents did, however, report apprehension regarding the quality of peer networking presently available to them. Mobile technologies such as mobile phones can be used to enrich pupils' learning environment by providing timely information.

In survey on the use of different handheld devices such as smartphones, mobile phones and tablets, results show that, less than 50% of the respondents owned these mobile devices.

4.4 Findings & Interpretation

The study revealed that mobile learning involves varied learning contexts such as user experience, user attention and ergonomics. It was also evident that mobile environment would be most suitable in supporting learning to complement the curricula outside the fixed context of institutions and timetables. However, we realized that mobile learning presents the challenge of blurring the distinction between formal and non-formal learning.

The study also established the fact that mobile learning would reinforce the learning process as it was evident that the early grade learners would use the mobile learning devices to play learning games within the syllabi and curricula to revise concepts learnt in class hence boosting learning outcomes.

The mobile learning games tend to demystify the notion that early grade learners waste time playing after the normal class hours. The mobile learning games help in ensuring that the pupils invest their "free time" in playing educational games that in many ways help even the "academic weak" to develop interest and improve their overall academic performance.

During the mobile learning game evaluation, a crucial observation was made that despite majority of early grade learners having had very little prior or non-exposure to computing devices such as computers, it was evident that they quickly learnt and some were able and eager to even teach their colleagues how to play the mobile learning games. Majority also demonstrated intuitive attributes especially on navigation of the games on touch screen Smartphone. The ability to learn the navigation intuitively demonstrated a positive attribute of handheld mobile learning devices in development and improvement of pupils' psychomotor skills. This forms a firm indication that through use of mobile learning games, the pupils would develop cognitive psychology, thus enhancing their mental models, attention, memory, perception, thinking and problem solving skills.

Generally, the project met the set out objectives. The hybrid mobile app addresses the issues of portability and access across different platforms. It also bridges disparity amongst learning outcomes of the learners in public and private primary schools.

The high mobile phone penetration and adoption in Kenya, has brought forth opportunities of using the mobile technology in education sector among others.

The analysis of learners' perception on m-learning points to the fact that mobile learning is widely preferred by the learners' community. The majority of participants supported the notion that the mobile phones increase the flexibility of access to resources in learning and that they could work independently of variable resources like lab or library PCs.

The Mobile technologies are perceived as an effective tool in improving learning. In developing countries like Kenya, mobile learning technologies are not yet popular due to the cost involved in owning and using such higher-end mobile technologies, less expensive.

Findings from the usability evaluations of the mobile learning game have consistently shown that learners appreciated the interactive nature of the learning game. It was evident that it helped the learners to stay focused and engaged in the learning process since most of them found it interesting and enjoyable. Additionally, the learners expressed their delight for the fact that the app allowed them to learn anytime and anywhere hence allowing them to manage their studies well (Abas et al, 2009).

Usage of images and imageries in the learning content and context, especially in Math enhanced the retention of knowledge among the early grade learners.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Summary

This study was based on the development of an interactive Hybrid mobile learning game for teaching pupils both literacy and numeracy. Being hybrid means that it possessed platform independence feature enhancing the capability of being deployed on different mobile devices operating systems i.e. iOS, Android, Symbian, Blackberry, Windows Phones, etc.

The game has been adapted for pupils between the age of 5 – 11 years; mainly targeting kindergarten and elementary schools.

The game proved interesting and more appealing to the learners who showed more interest in playing the game over and over again.

Adaptation of mobile learning game for the early grade learners involved high level user interaction underscoring and qualifying the methodology used as suitable and most appropriate.

Obtaining the user requirements involved observation of the learners' activities during the typical math and language (numeracy and literacy) lesson in classrooms.

5.1 Achievements

This project is deemed successful as depicted in the following reasons:

i) The mobile learning game proved suitable for teaching both numeracy and literacy and still was quite interactive and enjoyable to the pupils targeted.

ii) Taking advantage of the popularity of portable gadgets and their entertainment features as well as learning tool.

iii) Involvement of users in the development of the mobile learning game made it quite easy to gather requirements, design, development and testing of the system – a strong point of usage of ADL 6 D's for Mobile Learning Application Development.

5.2 Limitation

The study revealed that despite the great potential of mobile learning, majority of up to 79% of the early grade learners have no access nor own mobile devices to use for purposes of learning.

It was also evident that most education stakeholders are still apprehensive about the adoption of mobile devices for learning.

High cost of the mobile devices proved to be a hindering factor in the use of mobile devices in education sector.

5.3 Recommendations

Despite the success in the implementation of the project, the study recommended further research in this area and address the following concerns;

i) Many smartphones and handheld devices with different mobile Operating systems are in the increase and there is need for researchers to consider development of hybrid mobile apps as opposed to the common practice of native mobile apps to aid learning across different mobile platforms.

ii) Most mobile game developers make games void of the learning essence. It would be prudent to involve curriculum developers in the mobile learning game development process.

iii) Despite being a complex matter, development of a mobile learning game should be beyond the initial "wow" effect associated with technology. The development should focus on the bigger picture of supporting learning process.

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APPENDICES

APPENDIX A: Sample Source Codes

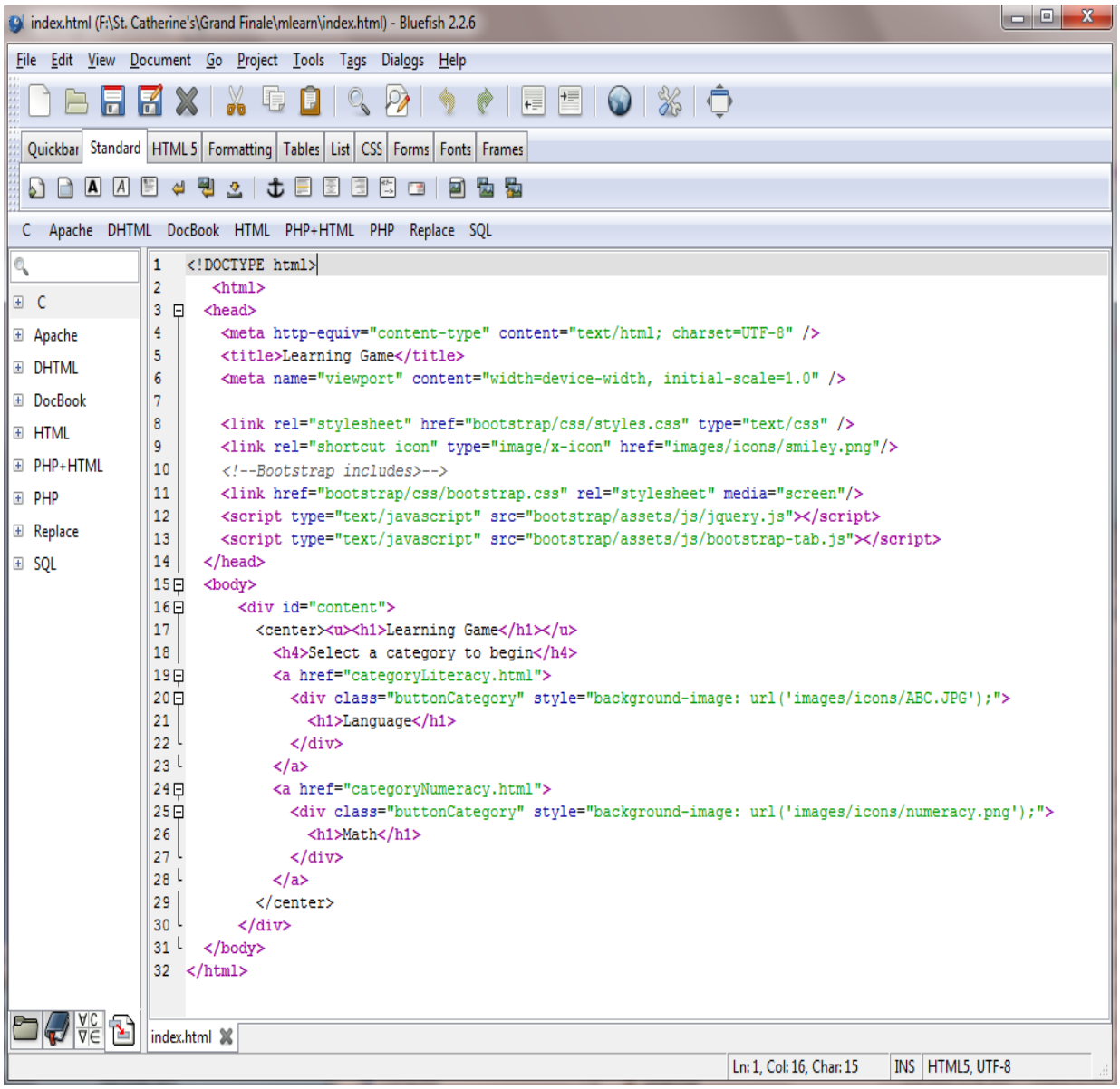

Figure 13: Sample Code 1

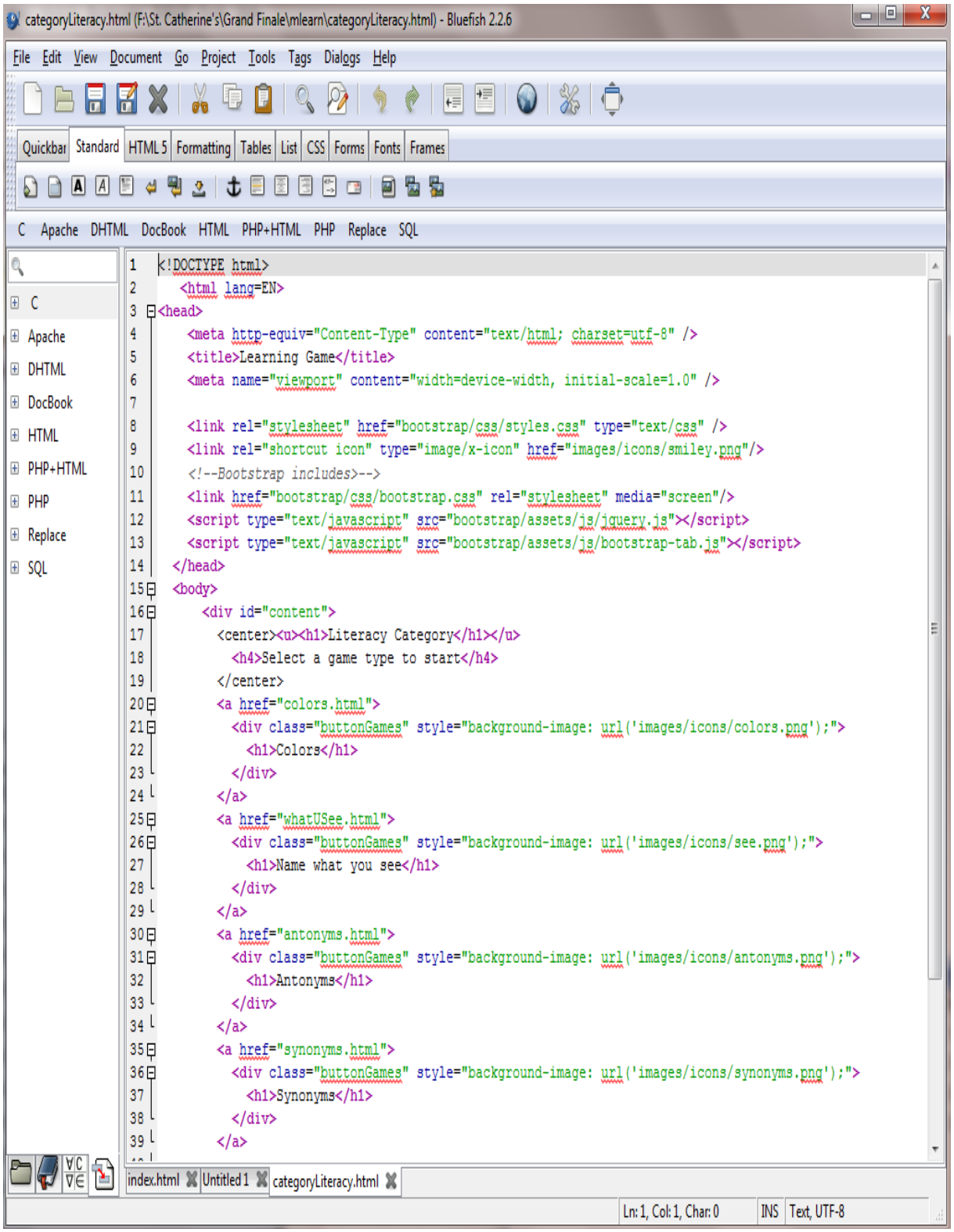

Figure 14: Sample Source Code 2

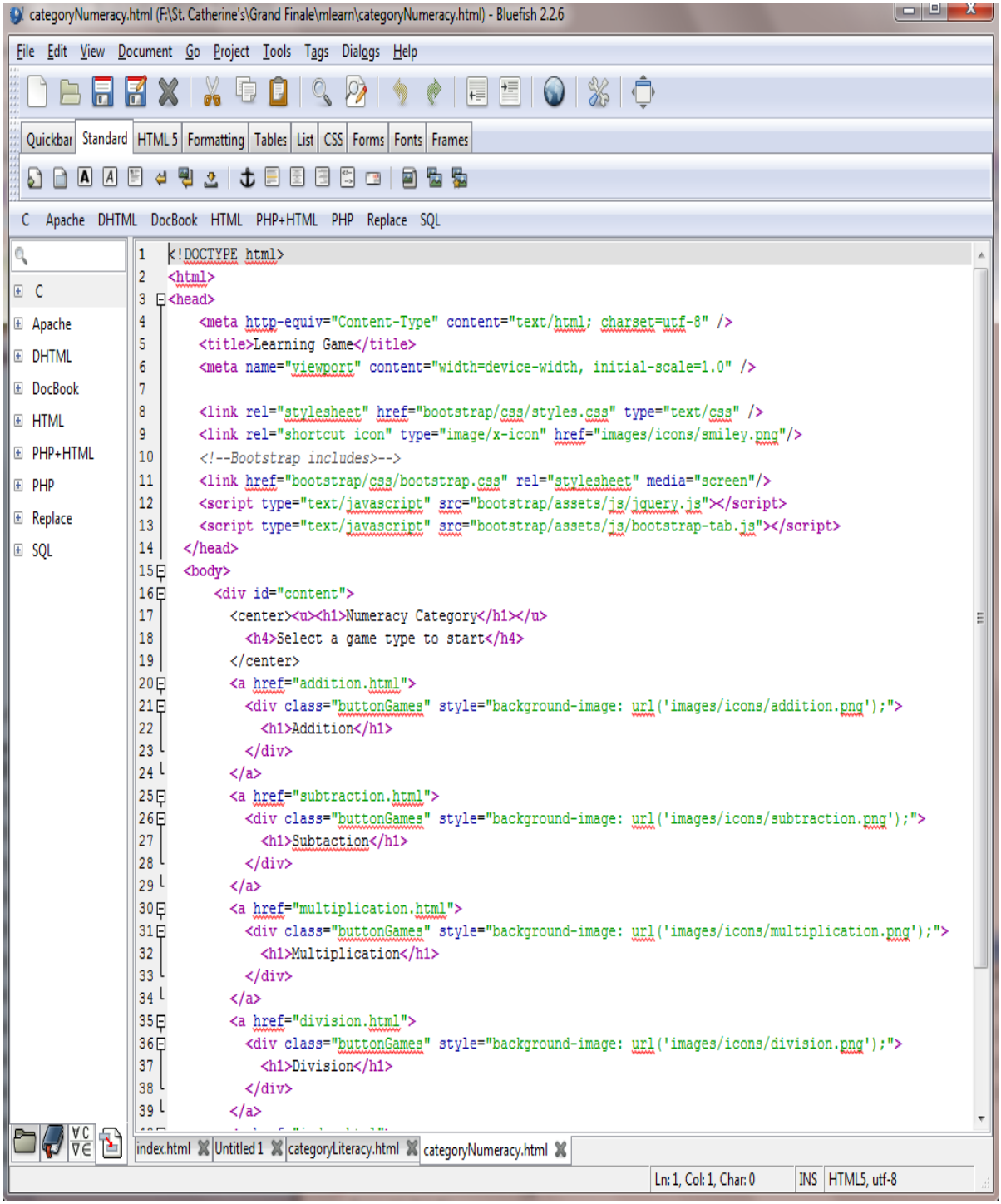

Figure 15: Sample Source Code 3

APPENDIX B: Adapted SUS Questionnaire for Evaluation of the m-Learning Game

Participant ID: _____ Site: _____ Date: ____/____/____

System Usability Scale

Instructions: For each of the statement in **Part Two**, mark one box that best describes your reactions to the mobile learning game today. **[**1st, 2nd, 3rd, 4th and 5th boxes representing: Strongly Disagree, Disagree, Unsure, Agree and Strongly Agree, respectively**]**.

PART ONE

Have you ever used a computer before? Yes ☐ No ☐

Have you ever played a computer game before? Yes ☐ No ☐

Have you ever used a mobile phone? Yes ☐ No ☐

Have you ever played a game on a mobile phone before? Yes ☐ No ☐

PART TWO:

This part is based on the observation and judgement of the learner "in action" (while playing the learning game) and aims at evaluating factors pertaining to the functionality/ logic of the game. It's aimed at evaluating the Learnability, Usability and Playability of the m-Learning game.

		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
1.	The m-learning game was enjoyable and I'd like to play often	☐	☐	☐	☐	☐
2.	The m-learning game was too complex to play	☐	☐	☐	☐	☐
3.	The m-learning game was easy to play	☐	☐	☐	☐	☐
4.	I needed assistance to play this m-learning game	☐	☐	☐	☐	☐
5.	I found it easy to navigate through the m-learning game	☐	☐	☐	☐	☐
6.	The m-learning game was very inconsistent	☐	☐	☐	☐	☐
7.	The m-learning game was easy to learn	☐	☐	☐	☐	☐
8.	The m-learning game was too cumbersome to play	☐	☐	☐	☐	☐
9.	I felt very confident playing the m-learning game	☐	☐	☐	☐	☐
10.	I needed to learn many things before playing the m-learning game	☐	☐	☐	☐	☐

This questionnaire is adapted from the System Usability Scale (SUS), which was developed by John Brooke while working at Digital Equipment Corporation. © Digital Equipment Corporation, 1986.

Figure 16: Adapted SUS Questionnaire for Evaluation of the m-Learning Game

APPENDIX C: Detailed SUS Data Analysis Table

		Question Response										
	Participant	**q1**	**q2**	**q3**	**q4**	**q5**	**q6**	**q7**	**q8**	**q9**	**q10**	**SUS Score**
1	User 1	5	1	5	3	5	2	5	2	5	1	**90**
2	User 2	4	2	5	1	4	3	5	1	5	1	**87.5**
3	User 3	5	1	5	2	4	1	4	3	3	3	**77.5**
4	User 4	3	4	3	5	2	3	5	3	4	1	**52.5**
5	User 5	4	2	4	2	4	1	5	2	5	2	**82.5**
6	User 6	4	1	5	1	3	1	4	3	3	2	**77.5**
7	User 7	4	2	4	4	4	2	4	2	4	1	**72.5**
8	User 8	5	2	4	4	2	3	3	3	5	4	**57.5**
9	User 9	5	1	5	1	4	2	5	2	4	2	**87.5**
10	User 10	5	2	4	2	5	2	4	1	5	3	**82.5**
11	User 11	4	2	5	1	4	3	5	1	5	1	**87.5**
12	User 12	5	1	4	4	5	1	5	2	5	2	**85**
13	User 13	5	1	5	1	4	1	4	3	3	2	**82.5**
14	User 14	4	2	5	1	5	3	4	2	4	2	**80**
15	User 15	5	1	4	2	5	2	3	2	5	1	**85**
16	User 16	4	1	5	2	4	3	4	1	5	2	**82.5**
17	User 17	5	3	4	3	5	2	5	2	4	2	**77.5**
18	User 18	5	1	5	2	4	3	5	2	5	2	**85**
19	User 19	3	2	4	3	3	2	4	3	3	4	**57.5**
20	User 20	5	3	5	2	3	3	4	1	4	2	**75**
21	User 21	5	2	4	3	4	2	5	2	5	1	**82.5**
								Average SUS Score				**78.5**

Table 5: Detailed SUS Data Analysis Table