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Smart education: an event framework for cognitive blended learning

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SMART EDUCATION: AN EVENT FRAMEWORK FOR COGNITIVE BLENDED LEARNING

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Declaration and Approval

Declaration

I declare that this work has not been previously submitted and approved for the award of a Master Degree by this university or any other university. To the best of my knowledge and belief, this dissertation contains no material previously published or written by any other person except where due reference is made in the dissertation itself.

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Abstract

Digital learning has increasingly been adopted around the world, evidenced by large scale deployment of online learning platforms. More specifically, the use of hand held devices such as mobile phones and tablets has disrupted learning as we traditionally knew it. Blended learning, which extends classroom learning with computer mediated learning, is increasingly being adopted by education systems around the world. However, the two (blended learning and traditional classroom learning) have not been well integrated. For example, there is limited or no information sharing between digital learning mostly carried out by an automated tutor and the traditional classroom conducted by a human instructor. This leads to fragmentation in the overall teaching and learning experience.

Existing blended learning platforms have tried to address this issue by focusing on performance management. This approach ignores the bigger challenge in public and private schools: the large number of students to teacher and the inability to offer personalised learning that is essential for students to excel academically. Understanding how personalized technical interventions can be designed requires understanding of where issues intersects. We present the overall architecture and design of event framework. The first version supporting a core set of capabilities for blended learning has been implemented as mobile applications for teachers and students. We conducted a limited pilot to test the technology in an actual classroom setting. We also report on a usability study of the event framework that demonstrates user awareness and support for data-driven cognitive decision-making in education.

Keywords: Digital learning, blended learning, mobile technology, knowledge models

Dedication

This dissertation is dedicated to all parties involved in digital learning and education research; these include academic educators, digital learning adopters, parents, ministry of education and education research scientists.

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Profound appreciation and gratitude to my supervisor Dr. Vitalis Ozianyi for his continuous guidance throughout the duration of this dissertation. He has always provided me due and prompt direction on my research study.

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Abbreviations and Acronyms

CAK	–	Communication Authority of Kenya
CRUD	–	Create, Read, Update and Delete
DBaaS	–	Database as a Service
GPS	–	Global Positioning System
HTML5	–	Hyper Text Mark-up Language 5
ICT	–	Information Communication Technology
JSON	–	JavaScript Object Notation
MOOC	–	Massive Open Online Courses
NoSQL	–	Non Standard Query Language
OER	–	Open Education Resource
RAVE	–	Rapid Adaption Visualization Engine
RSS	–	Really Simple Syndicate
SAI	–	Student Activity Information
SSA	–	Sub-Saharan Africa
UI	–	User Interface
USB	–	Universal Serial Bus

Definition of Terms

Smart planet – is a corporate initiative by IBM that seeks to highlight how forward-thinking leaders in business, government and civil society around the world are capturing the potential of smarter systems to achieve economic growth, near-term efficiency, sustainable development and societal progress.

Chapter 1: Introduction

1.1 Background

Recently, education institutes in Africa have witnessed adoption of mobile-based digital learning with content accessed through personal devices such as personal computers and hand held mobile devices (Ebner & Schiefner, 2010). This has made it possible to learn from anywhere at any time. Having computer mediated learning to extend traditional classroom learning is increasingly being adopted by the education systems all over the world. However, according to Ashridge Business School (2012) blended education involving human instructor on one hand and online systems on the other are often disconnected from other learning activities or disintegrated at best.

The smart planet is highly instrumented, interconnected and increasingly intelligent. In smarter education domain, there is increasingly a rise in application that capture and analyse fine-grained data for example page flipping forward and backwards, rewinds of video content, pause, forward, user sentiments (sad or happy), etc. All these interactions are tagged with a timestamp or location by the device sensors. Collected data can latter be consumed by educational applications to support personalised and adaptive learning. For example, this data can be used to infer learners' engagement, understanding and progress; to infer effectiveness of content, popularity of content, learners' sentiment, learners' context, learners' affective states, etc.

In resource-constrained environments, this approach can pose challenges due to intermittent or lack of Internet connectivity, as well as limited storage capabilities on the device. Such situations are mostly common in emerging markets such as Africa and India (Thorne, 2003). Access to tablet computers is now quite common in our schools (procured by learners/ donated by government or other organisations). These tablet computers are mostly pre-loaded with educational content.

However, such development does not come without a challenge. Intermittent Internet connection, low memory storage and inconsistent supply of battery power are some of the constraining factor. As a result, some of the user interaction data may not be stored beyond a certain point. In such a scenario these applications fail to collect new data generated by user interaction, or the application delete already existing data. In such a situation this missing data could lead to lose of valuable user and content interaction insights. Thus, there is a need for an events framework that intelligently stores, manages and analyses learning interaction data in a blended environment where resource are constrained.

1.2 Research Problem

Adoption of blended learning presents multiple unique sets of problems due to the weak inside and outside classroom connection. Majority of the existing e-learning systems focus on performance management, ignoring the bigger challenge in public school system (Udell, 2014). The large number of students per teacher makes it hard for teachers to design appropriate interventions. There is a need to understand how technical interventions can be designed for personalised learning. This requires understanding of where a student encounters issues in the learning process. Moreover, with ICT flagship programs being rolled out in schools, there lacks measures to combine learning in school and at home into one view that ultimately helps students become more robust and teachers more thorough.

1.3 Objective of the Research

The purpose of this research is to discover challenges teachers and students face, often arising due to the rising student to teacher ratio. The main aim is to find out how we can exploit portable device sensors used in blended learning using an event framework that collects user context and interaction data so as to make students more robust and teachers more dutiful. The research will focus on the following broad objectives:

i) To investigate adaptive learning technologies in blended learning environments.

ii) To analyse the existing applications for adaptive learning technologies in a blended environment and schemes for fine-grained data collections as well as events sources.

iii) To design a configurable events framework that enables collection of fine-grained sensor and contextual data.

iv) To perform validation on the event framework in a blended learning system.

1.4 Research Questions

i) What are the existing adaptive learning technologies in blended learning environments?

ii) What are the existing applications for adaptive learning and schemes for fine-grained data collection as well as events sources?

iii) How can the existing mobile architectures, designs and frameworks be used to develop a configurable events framework that enables capturing learners' data in a blended learning environment?

iv) How can the requirements and performance of the event framework be measured?

1.5 Hypothesis

Performance in public and government school suffers from disconnect between teachers and students because there is less or no instrumentation and technical intervention to provide learners' feedback to teachers.

1.6 Assumption of the Research

During this research 22 pupils in grade 5 were provided with a tablet computer with the student application preinstalled to facilitate blended learning setting. Teachers used a tablet computer running the blended learning system with the event framework ported in it to conduct lessons. Students receive learning materials, assignments and assessments through the tablets. In this study we assume that the students have the tablets during class time at school and outside classroom, during breaks and when at home.

1.7 Scope

The research mainly targets users in upper primary, standard 5 from public government schools. However, a general research approach will be adopted since also a substantial number of private schools suffer the same disconnect problem as their counterparts in public schools. The research will be conducted in two select schools from Nairobi county namely Kibera Primary School; a public government school and Riara Primary School, which is privately owned. At the end of the research duration, expected deliverables were as follows:

i) A functional event framework ported in an existing blended learning system.
ii) A function web management platform to help in content uploading and other management needs.

1.8 Significance of the Research

It was expected that this research would make various contributions to blended learning. Majorly, the event framework would draw insights for policy makers by making analysis on collected data thus assisting in solving challenges within the education system. Secondly the teachers would get to know the weak areas that a learner is struggling in and give personalised intervention.

1.9 Limitation of the Research

There are various limitations that the research faces. First, the field of blended learning is still new in Kenya. According to Martin Mungai in an article published by ICTWorks (2011) this is attributed by various challenges which include: lack of qualified teachers to teach ICT in schools, lack of computers/tablets, computers/tablets are costly, fear of teachers being rendered redundant, intermittent or no network connectivity, burglary of these devices, etc. Due to these challenges most pupils are computer illiterate and thus not able to use the tablet computers provided for the research.

1.10 Justification

The education sector is at the cusp of a technology-enabled transformation. Content is increasingly becoming digitized; there is greater usage of technology in classrooms; and outside of school, mobile/tablet and other personal devices are easily making learning an anytime, anywhere activity. These advances are resulting in learning becoming increasingly blended where a student learns, at least in part, at a brick-and-mortar facility and partly through online learning, with some student control “over the time, place, path, and/or pace” (Brosvic, Epstein, Cook, & Dihoff, 2005). Extending this further, new models of education delivery are being experimented with such as the flipped classroom (Larry, Zsolt , & Gabor, 2006), which encourages self-learning outside the classroom through access to quality digital content, and more hands-on problem-solving time with the teacher inside the class.

1.11 Conclusion

With technology, education has clearly been revolutionised in the way learning contents are being disseminated, used and shared within and outside classrooms. The ultimate goal of mobile based blended leaning system is to give its users, immediate, easy and relevant content with teacher intervention in class and away from the class. The development of the event framework will leverage on mobile devices and teachers’ remote intervention to provide interested learners an elevated level of experience by providing interactive, engaging and timely feedback.

As a result, the researcher finds this as a viable topic to conduct an in-depth research. As depicted in the fourth chapter of this dissertation, the research seeks to establish the actual connection between learners’ performance and their engagement as affected by their immediate environment.

Chapter 2: Literature Review

In this chapter we investigate adaptive leaning technologies in blended learning environment and review some of the existing application in adaptive learning. The aim is to identify drawbacks in these systems, identify metrics used to measure performance and review how instrumentation to capture fine-grained user interaction data is done.

2.1 Background Information

Most of Sub-Saharan African countries are extremely poor; Kenya is among them. 67% of the population lives below the poverty line, which means that they have an income of less than 2 dollars a day (World Bank, 2013). Primary school education in Kenya has been free since 2003, however the reality is that a big number of the population remain uneducated due to lack of essential resources required in a school setting (the main one being low number of trained teachers). On average the richest quartile goes to school for 8 years, while the poorest quartile goes for only 6 years before dropping out (World Bank, 2013).

Recently, digital technologies have been adopted in schools complimenting the normal brick-and-wall learning in the form of blended learning. However, this program faces some challenges. Access to Internet and Internet connected devices is still low but steadily growing at an encouraging rate.

Therefore, the combination of widespread poverty, low teacher to student ratio, fees for uniforms and other learning amenities contributes to high dropout rates. For these reasons there arises the need for cognitive technological solution to increase access to quality education for all learners in Kenya. On the other hand, number of mobile devices with Internet access is increasing gradually opening possibilities to reach and utilise mobile and web-based education solutions. This research looks to explore feasible cognitive ways to provide access to guided learning improving learners' experience and at the same time increasing teachers' efficiency, thus reducing dropout rates.

Furthermore, existing research in the area of education (blended learning, non-formal leaning and M-Learning) in developing countries mainly focuses on higher education and/or teacher education. Examples of such efforts in higher education and teacher education for Open Educational Resource (EOR) in Africa is research by Ngugi (2011), Sapire and Reed (2011), Murphy and Wolfenden (2013), etc. Thus, there lack research specifically looking at how learning activities can be designed to adapt in response to an individual learner's environment using cognitive computing capabilities.

2.2 Adaptive Learning Technologies in Blended Learning Environments

Adaptive learning can be described as using what is known about a learner, or through interaction to alter how the learner's experience unfolds progressively with the aim off improving the learning experiences (Larry, Zsolt , & Gabor, 2006). It involves using learning activities of different kind to achieve some set objectives. There exists research that looks to use technological infrastructure that support online leaning, where the activities are designed to adapt to an individual learner. However, most lack coordination between classrooms based learning and outside-class learning.

Blended learning refers to synchronous learning activities, such as face-to-face interaction with teachers, mobile-based learning, distance learning, open learning, and other social-active collaboration. In the formal education setting, learning has largely consisted of classroom-based learning with a little complement from outside class delivered through homework and assignments. While outside classroom work (i.e. assignments and homework) remain vital, there is loss of immediacy in terms of feedback since such work must await human instructor evaluation and subsequently be returned to the learner for deliberation. Due to this time shifting there are implications both for learner's self-assessment and instructors' ability to collectively respond to misconceptions among learners. Figure 2.1 show a deliberate approach to the design of technology-enhanced learning experiences, that are crucial for the success of blended learning.

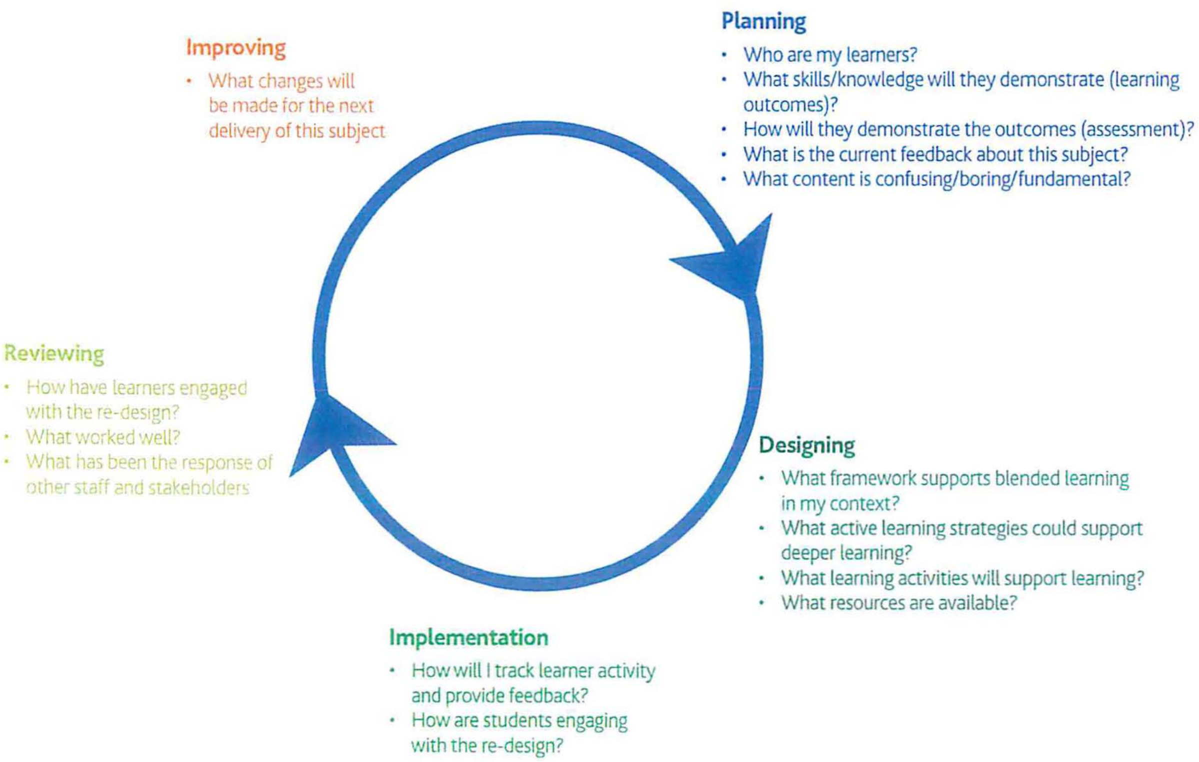

Figure 2.1: Blended Learning Cycle (Brosvic et al, 2005)

There is significant improvement in retention when students are immediately provided with feedback on performance rather than when it is delayed or none is given at all. There is even greater retention when a learner is provided with multiple attempts on the initial encounter (Brosvic et al., 2005). Kulik and Kulik (1988) earlier meta-analytic review substantially agrees with this notion, in which immediate feedback was found to be useful compared to delayed feedback.

With modern technology its now possible to provide immediate feedback to learners during a learning activity within a technology supported learning environment (Larry et al., 2006). Technology brings an important aspect of potential to be responsive to learners as they progress through their learning activities. This is what is being referred to as adaptive learning. The fundamental quality of this model is that it uses known information about a learner or through interaction, to alter the flow and content of a learning process. Adaptive learning is largely motivated by being responsive to learners as individuals rather than as a group.

There are some attempts to address the lack of adaptive learning on blended learning environments. This lack of adaptive learning is limiting the generation of integrated and interlinked views about students' knowledge, interest and interaction models, that can be drilled down by their teachers for effective feedback. Taking a blended learning approach in teaching a subject can be used to support face-to-face teaching, self directed learning, small and large group learning, communication between and with team members (JCU Blended Learning Policy, 2014). This research examines some of the work done around adaptive blended learning and the challenges and opportunities that are yet to be explored.

2.2.1 Open Educational Resource

OERs are defined as educational resources (including course materials, textbooks, streaming videos, podcast, multimedia applications and any other materials designed for use in teaching and learning), which are open and available for use by learners and instructors without the need to pay some royalties or license fee (Neil, 2011). OER has great potential in supporting educational transformation, with its power laid in the ease with which such resources, when digitized, can be shared via Internet (Neil, 2011). Its good to note that OER is not the same as e-learning although people make a mistake of using the terms interchangeably. OER are mostly designed as printable unlike the E-Learning resources which are digitized.

2.2.2 M-Learning

This refers to the use of mobile, wireless and handheld devices as additional devices to access conventional learning materials. Mobile technologies are adaptive substitution for desktop technologies (Traxter, 2007). Mobile learning activities continue to take place on mobile devices, which were initially not intended for educational use. To support usability there is need for continuous adaptability to create seamless access to educational resources regardless of the device (Kukulska-Hulme, 2007). According to Traxler (2007) in a research carried out in South Africa and Kenya, learning is a technology-driven mix, where potential for mobile devices was regarded as very high and portability was key.

2.3 Mobile Technologies

Mobile devices are the most common mode of communication in developing countries and are ubiquitous in Kenya. The mobile market in Kenya has maintained an upward trend standing at 37.8 million subscribers, and mobile penetration has grown to 88.1% of Kenyan population (CAK, 2015). Internet access in the country is about 27% of the the subscribers and is increasing tremendously, 15% of these access the Internet via smartphones or tablets (Kenya ICT Board, 2015). In this time and age, day-to-day operations have become almost impossible without the help of mobile handsets that have access to the Internet. Governments have embraced the Mobile-computing concept gracefully, and so have sectors such as health, energy and education just to mention a few. The driving force behind these revolutionary devices is to provide efficiency and effectiveness in service delivery.

According to Satyanarayanan (1996), the increasing social acceptance of the home or any other location as a place of work is a further motivation for the development of mechanisms for mobile information access. These considerations imply that data from shared file systems, relational databases, object-oriented databases, and other repositories must be accessible to programs running on mobile devices. The increasing growth and acceptance of mobile devices has led to a revolution as more and more people are resorting to do business using such devices and hence creating viability for development of mobile applications to provide fast and reliable solutions to consumers. Through this technology, distant learning, offsite working and ubiquitous banking options are now possible.

In adaptive learning the applications of mobile devices are limitless. Due to their portable nature these devices are used in classes and outside class to compliment the normal brick-and-wall learning. This has solved the issue of lack of textbooks and other learning materials. Going forward it would be easier to personalise learning to a particular student provided they are assigned a dedicated mobile device.

2.3.1 Mobile Penetration Across Sub Saharan Africa

According to a report published by GSMA intelligence (2014), Sub-Saharan Africa (SSA) has been the fastest growing region over the last five years, in terms of both unique subscribers and connections. By June 2014, there were 329 million unique subscribers, equivalent to a penetration rate of 38%. Consumers, governments and businesses across Sub-Saharan Africa are rapidly adopting mobile computing, not only as a basic communication tool, but also to access information and a growing range of new applications and services. Figure 2.2 shows the increase in number of subscribers in the region within the last one year. The trend from the figure depicts a steady growth in the use of mobile phones in the region.

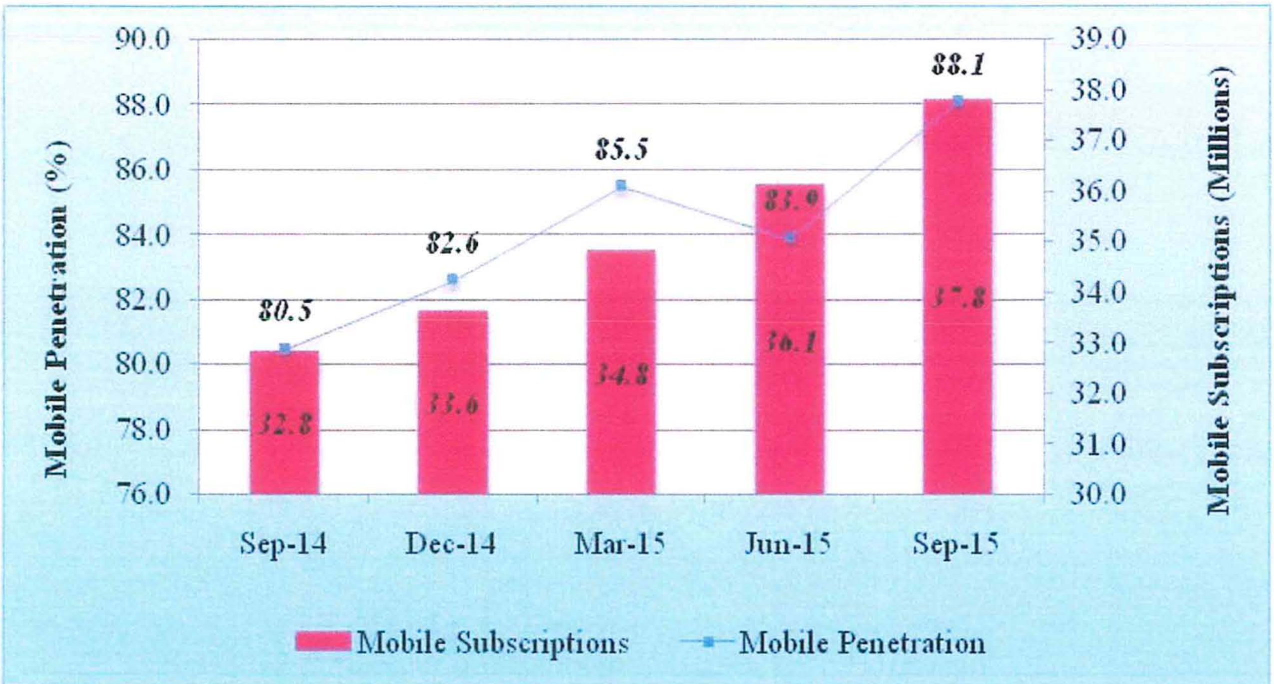

Figure 2.2:Mobile Subscriptions (Communications Authority of Kenya, 2015)

2.3.2 Mobile Network Technologies

Mobile network technologies have evolved from analogue through to Long Term Evolution (LTE) as show in Table 2.1. For each transition, motivation is driven by the need to meet requirements identified between that generation and its predecessor. For example, transitioning from 2G to 3g was driven by the need to enable mobile Internet on consumer devices.

Table 2.1: Evolution of Mobile Technologies (GSMA Intelligence, 2015)

Generation	Primary services	Key differentiator	Weakness (addressed by subsequent generation)
1G	Analogue phone calls	Mobility	Poor spectral efficiency, major security issues
2G	Digital phone calls and messaging	Secure, mass adoption	Limited data rates - difficult to support demand for internet/e-mail
3G	Phone calls, messaging, data	Better internet experience	Real performance failed to match hype, failure of WAP for internet access
3.5G	Phone calls, messaging, broadband data	Broadband internet, applications	Tied to legacy, mobile specific architecture and protocols
4G	All-IP services (including voice, messaging)	Faster broadband internet, lower latency	?

a) First Generation

First generation (1G) technologies were introduced in 1981 and supported speed up to 2.4kbps. However, it has low capacity, unreliable handoff, poor voice link and no security since call were played back in radio towers, making these calls susceptible to unwanted eavesdropping by third parties. It was characterised by technologies such as Advanced Mobile Phone System (AMPS) in North America, Total Access Communication (TACS) in UK and Nippon Telegraph and Telephony (NTT) (Amit & Peter, 2001).

b) Second Generation

In the second generation we had technologies like Global System for Mobile Communication (GSM), Code Division Multiplexing Access 2000 (CDMA2000), High Speed Circuit Switching Data Technology (HSCSD). 2G emerged in 1990s and was mainly used for voice communication, supporting speed of 64kbps.

c) Third Generation

Then later came in 2.5G and third-generation 3G technologies characterised by General Packet Radio (GPRS), Enhanced Data Rate for GSM Evolution (EDGE) and Universal Mobile Standards (Amit & Peter, 2001). GSM is a second generation standard for mobile communication, developed by the European Telecommunications Standards Institute (ETSI) and now owned by the Third Generation Partnership Project (3GPP). Operating in the 900 MHz and the 1800 MHz frequency band, GSM is the most widespread mobile standard in use across Europe and Africa (Amit & Peter, 2001).

GSM offers three major services; tele services which is subdivided into bearer services, tele services and supplementary service; data service comprising of internet services sending data at rates up to 9.6K bps, to user on POTS (Plain Old Telephone Services), Short Messaging Services (SMS) which is a bidirectional service for short alphanumeric (limit 160 bytes) messages; Facsmile, sending and receiving fax messages using a GSM phone and laptop computer; and finally secure corporate services which include call forwarding, call barring, caller identification, call waiting and conference conversations. However, GSM is technologies are limited due to its low data transmission speed.

d) Forth Generation

To solve limitations of 3G, 4G was evolved in 2011. It makes use of higher Layer Protocol (IP) as transport medium which offers intelligence at every stage within the network relative to a service. 4G features next generation applications such as e-leaders, mobile marketing, geo-targeted advertising, etc. The two top technologies in this generation are LTE and WiMAX. 4G is way faster and more efficient when it comes to audio and video streaming and thus the proposed application will be supported by 4G technologies for better performance.

2.4 Mobile Application Architectures

It is the desire of any designer of a mobile application to achieve optimum capabilities and output of their application. However, this is usually hindered by several factors owing to limitation of the mobile phone such as memory, network and battery life. Therefore, it is important to have a comparative analysis of all relevant contemporary approaches in designing mobile applications. The choice between these architectures is determined by application requirements and system capabilities (Krešimir et al., 2002). A mobile application will normally be structured as a multi-layered application consisting of three major components; the presentation, business, and data layers as shown in Figure 2.3. Multi-layered approach is beneficial as it provides users with flexibility, maintainability, reusability and scalability (Miller, 2014).

The presentation layer contains components used to implement and display the user interface. According to Patterns (2009) this layer contains two main components, which have distinct functions, the user interface and the user process. User interface is a means for users to interact with the mobile application. The user process component has a role of ensuring synchronization of the user interaction and processing of user input events (Ibrahim, 2009). Common services provided by the presentation layers include user authentication, rendering of data and maintaining session data.

The business layer is responsible for implementation of processes necessary for flow of data to and from the backend of the mobile application (Lee, Schell & Schneider, 2004). This layer implements the business rules needed in the application. This layer also acts as an intermediary between the presentation layer and the data access layer.

The data access layer is used for managing connections with the data source. There are various kinds of data sources used which include but not limited to web services, flat files, RSS feeds and databases (Logi Analytics, 2015). The data access will retrieve and perform storage of data in accordance to the specifications of the business layer.

Mobile application architectures are broadly classified into two; mobile web and native application. Development of applications for mobile phone involves considerations for both high-end smartphones and tablets to low-end feature phones. With the increase in smartphone use and their extensive capability, many developers and users are geared towards smartphone applications.

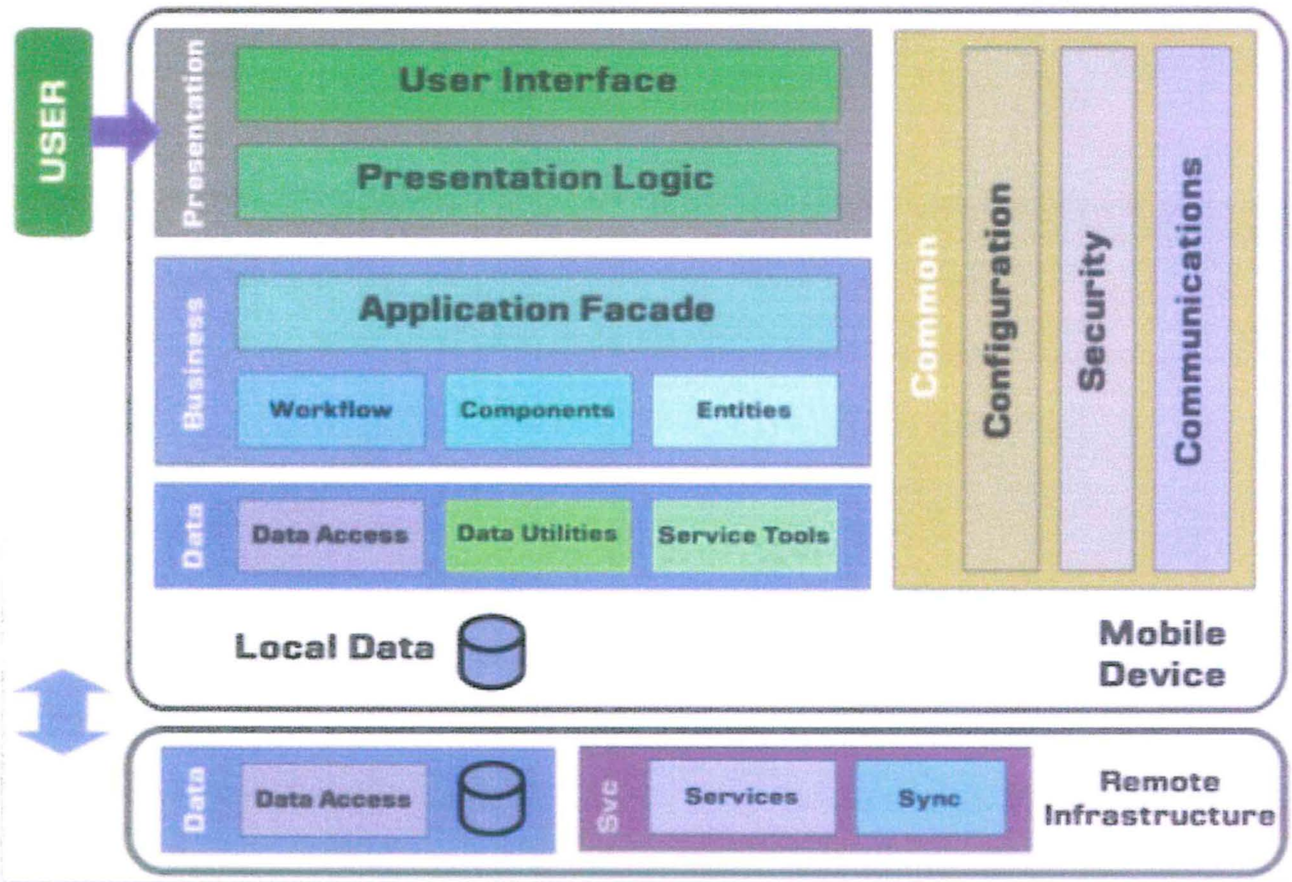

Figure 2.3: Common Mobile Application Architecture (Microsoft Patterns & Practices Team, 2009)

2.4.1 Mobile Web Architecture

Mobile web architecture as shown in Figure 2.4 is one of the most common approaches. This architecture is for browser-based applications; this means that it uses the web browser of the mobile phone in order to gain access to the application. The most popular language used in development of mobile web applications is HTML5. The browser will usually host the presentation layer of the architecture (Mehta, 2002).

Mobile web applications are platform independent; this means that the mobile application can be accessed using any phone that has a web browser irrespective of its operating system (Patterns, 2009). Mobile web applications thus will have a wider reach as opposed to native applications. Mobile web applications have a major limitation of not having the ability to utilize the hardware features of the mobile device; this affects the user interface of the applications developed. The other drawback of mobile web applications is that they always require an Internet connection in order to work.

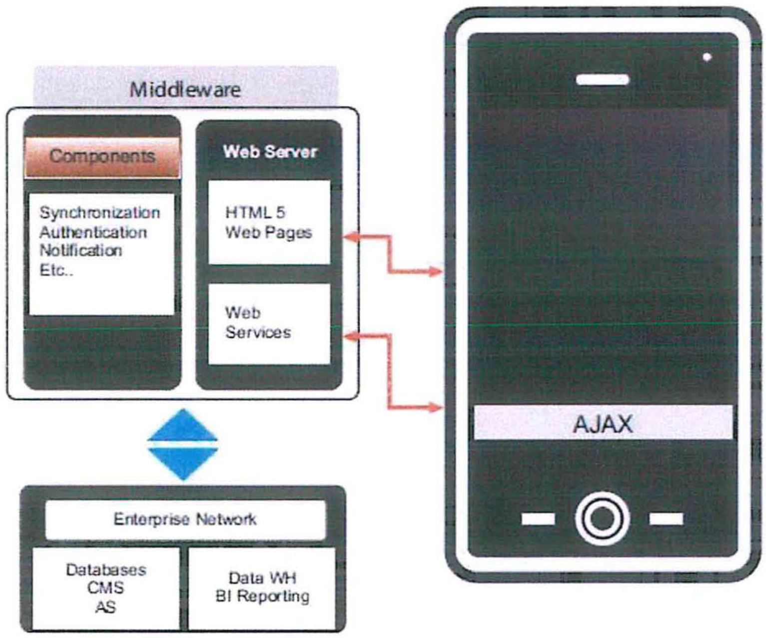

Figure 2.4: Mobile Web Architecture (Mehta, 2002)

2.4.2 Native Application Architecture

Native application architecture as illustrated in figure 2.5 involves custom development of applications for a specific mobile phone operating system (Patterns 2009). The most common operating systems used in development of native applications include java for android, objective C for iPhone, C# for windows applications and JavaME for low end devices. In order to use native applications a user needs to download them from the various application stores where they are deployed for example Google play, iTunes, Safaricom and Samsung app stores.

There are several benefits associated with native applications. One of the major advantages is that these applications can utilize the phone hardware providing access to features such as camera and Bluetooth (Microsoft Patterns & Practices Team, 2009). Native applications have a good user experience and increased performance because of optimization; the optimization is realized because the executable is compiled and run directly in the operating system (Mehta, 2002). If a native application does not use data stored on servers then it can run independent of the Internet; a user does not have to worry about being always connected to the Internet to enjoy the services provided by the application.

Native applications have been associated with a number of drawbacks. One of the major shortcomings is that these applications are platform dependent (Mehta, 2002). This means that a phone cannot run an application developed for another operating system that it does not operate on. If an organization or individual want to avail the application to different platforms, then they have to use extra resources which include time to develop the application on a new platform and training employees on the programming language to use (if they do not have skills in other programming languages). Operating systems for mobile devices are constantly being updated with new releases. This provides a challenge to developers because they have to keep their mobile applications up to date with extra maintenance, testing and developing so as to accommodate for the changes (Robbie, Heather, & Valentino, 2014).

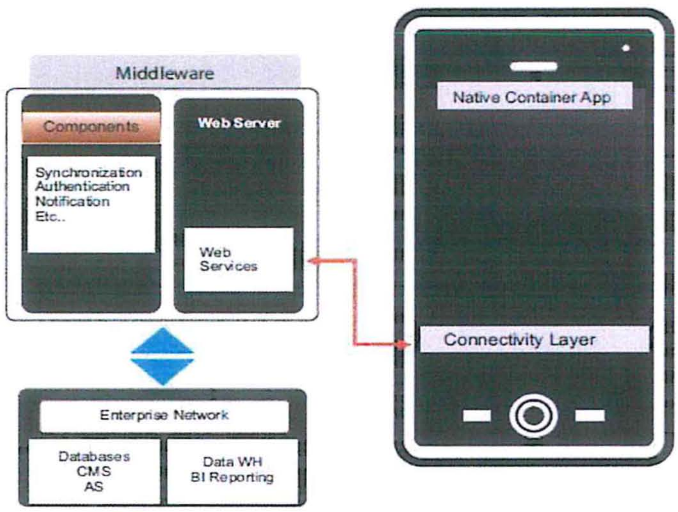

Figure 2.5: Native Application Architecture (Mehta, 2002)

2.4.3 Considerations for Selecting the Right Mobile Application Architecture

There are various considerations that one should make before deciding whether to develop mobile web applications or native applications. The first consideration is the user; one should consider the kind of users of the applications and if the mobile device that majority of the users in the target group have is able to support the application developed.

The other consideration is the kind of features one would like to have in the application. Mobile web applications have limited capabilities as opposed to native applications, which have full access to the hardware of the phone that provides a better user experience/user interface and enhanced performance.

If the target is to utilize mobile device hardware, then native mobile architecture is the option to consider. The other important consideration is the skillset that the developers have. The researcher settled for native application due to its ability to leverage on the hardware resources.

2.5 Built-in Mobile Phone Sensors

In daily life, it is commonly agreed that mobile devices such as mobile phones, smart phones, and tablets have become ubiquitous. As shown in figure 2.6, these devices are equipped with numerous in-built sensors that can be leveraged for a great variety of applications. The usage of mobile phone takes place in the context of real world surrounding the user and the device. Thus, they offer potential range of new services (Karin, Alexander & Enrico, 2005).

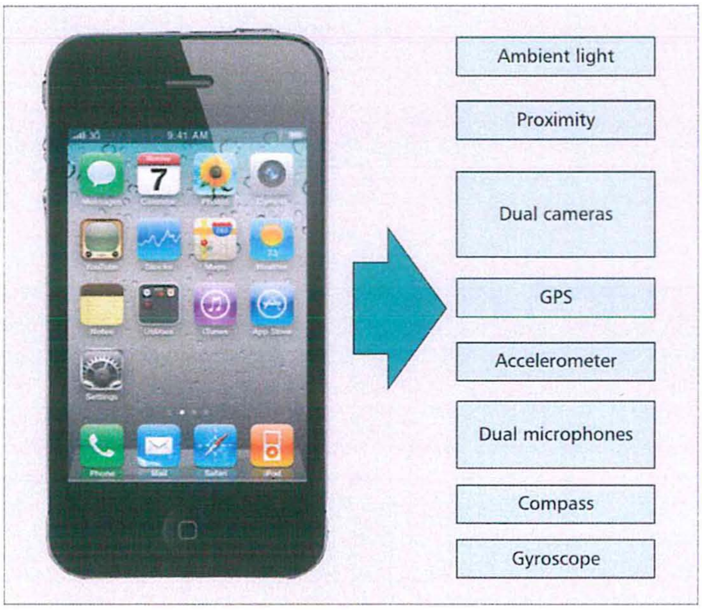

Figure 2.6: An off-the-shelf iPhone, representative of growing class of sensor enable mobile devices (Nicolas et al., 2010)

Sensor enabled mobile devices are going to be at the centre of next revolution in green applications, global environmental monitoring, personal and community healthcare, sensor augmented gaming, virtual reality, smart transport and education systems (Khan et al., 2012). In this study the researcher gives an overview of some sensors and how each of them can be used for a number of application as highlighted above.

As the mobile device matures as a computing platform, it has acquired richer functionality more often paired with introduction of new sensors. Take for instance, accelerometer, which was initially introduced to enhance the camera and user interface. They are used to determine screen orientation in which user is holding the device. This information is used to re-orient the display to either landscape or portrait during view, for example when viewing pictures. Other sensors include gyroscope, compass, proximity sensors, ambient lighting sensor, global positioning systems, WiFi and camera.

Proximity and light sensors allow devices to perform simple form of context recognition, such as when the user brings the phone close to the face to speak the touchscreen and keys are disabled preventing accidental pressing. Light sensors are used to adjust brightness of the screen. Not only are these sensors used to drive user interface and provide location based services, they can also be used to gather data about people and their environment (Nicolas et al., 2010).

2.5.1 Personal Sensing Scale Architecture

Application of sensing scale is designed for a single individual user, often focused on data collection and analysis. The typical use case scenario includes tracking user exercise routine. Although this information is for personal consumption, it can be share with medical professionals for healthcare application. However, there is little or no consensus on the sensing architecture for the mobile devices (Nicolas, et al., 2010). Common methods for collecting and sharing data therefore need to be developed. Figure 2.7 illustrates a simple mobile phone sensing architecture.

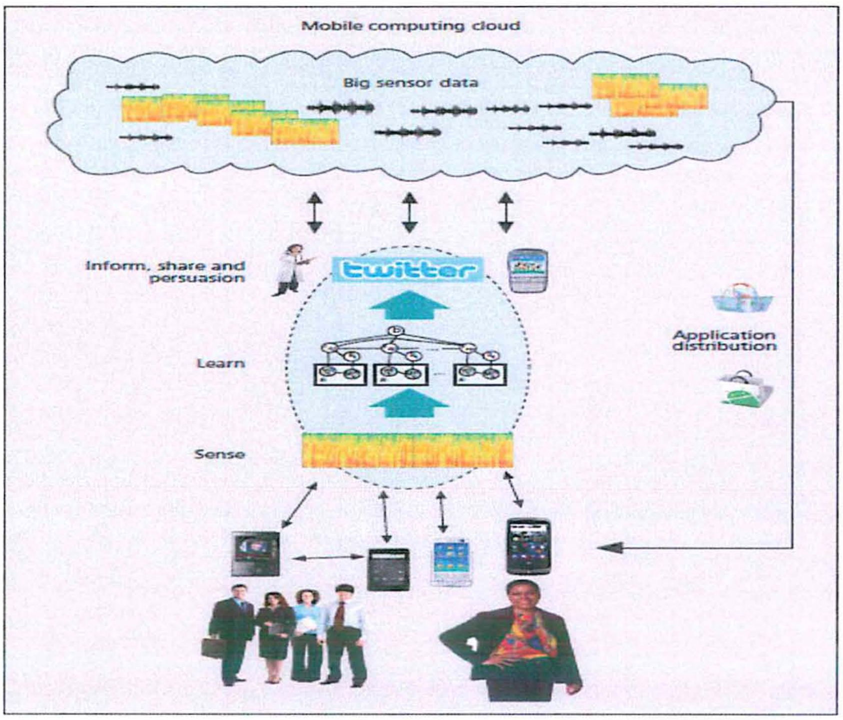

Figure 2.7: Mobile phone sensing architecture (Nicolas et al., 2010)

2.6 Applications of Adaptive learning Technologies in Blended Environments

According to a report done by Griffith University (2010), student's achievement is enhanced when they go beyond the passive task of listening, reading or viewing. Active engagement with subject material is vital for effective learning. This can be facilitated through individual or collaborative work as well as formative and summative tasks to support students in attaining the subject learning outcomes. Figure 2.8 outlines the range of outcomes from Bloom's Taxonomy that are possible when using active learning strategies.

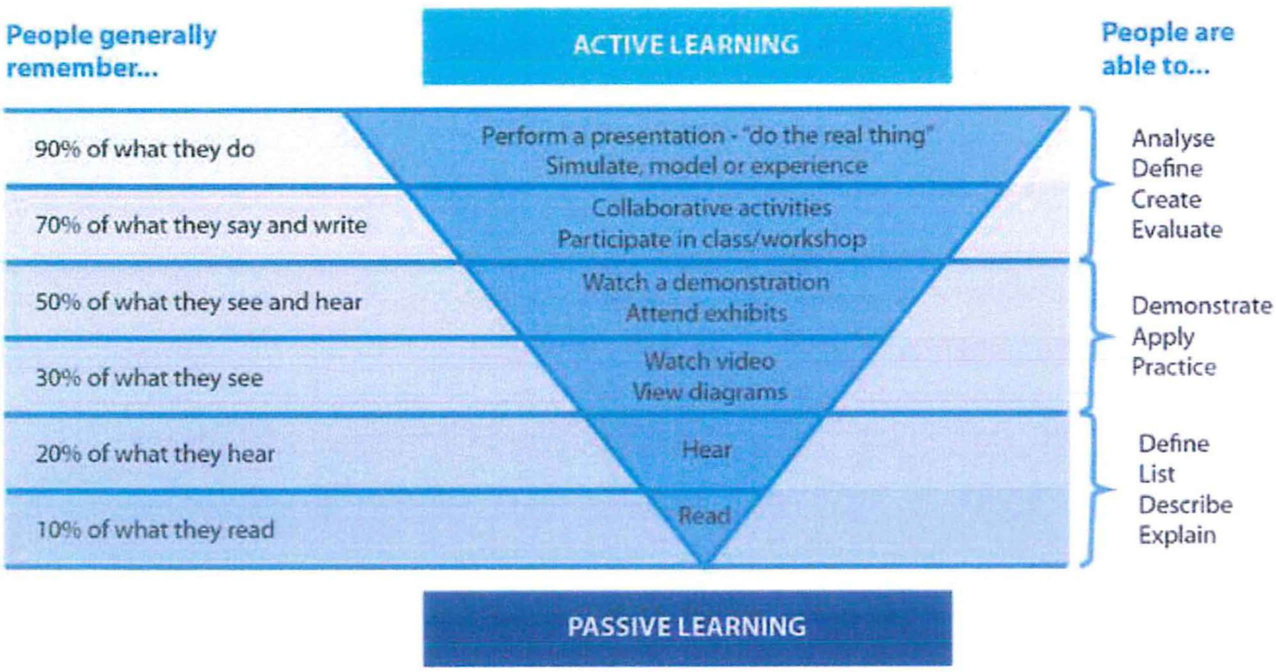

Figure 2.8: Interaction between active and passive learning strategies and the degree to which learners are engaged with their learning through various activities (Royce, 2010)

Numerous research studies have been done in blended learning that try to achieve the range of outcomes from Bloom's Taxonomy. However, a little has been done towards achieving adaptive learning in a blended learning environment. Below the researcher outlines some of the efforts done towards adaptive learning in blended environment.

2.6.1 MAGADI: A Blended-Learning Framework for Overall Learning

The Magadi framework is a suit of applications consisting of adaptive intelligent system, authoring tools and learning management system to provide the best teaching and learning in a blending learning environment (Ainhao et al., 2009). It provides a guide process for instructors to build instructional plans through rule-based planner algorithms, which infuse the use of authoring and learning at the same time. For students, Magadi provides various capabilities such as content viewing and personalised schedule. The contents are adaptively and hierarchically organized based on prior knowledge about a student. Furthermore, Magadi tried to implement knowledge representation model about student's knowledge, course, as well as pedagogical knowledge using domain ontology.

This work presents a good basis towards adaptive learning. However, the researcher did not outline comprehensive methods on how to achieve adaptive learning. The knowledge model is purely based on test performances yet there are other metrics that contribute towards a student's achievements or failures. This research goes an extra step in collecting users' interactions and environmental data that is vital in adaptive learning.

2.6.2 SIgBLE

L. Jun and Z. Ling (2011) in their case study, they discussed an approach to design instruction to support learning flexibility with open course structure, self-pace learning resource, learner-centred learning strategy, technology-mediated interaction, online learning community, technique tool support, and integrated assessment method in the course. Furthermore, an approach that tracks student's evolution in blended learning environment and provides feedback to teachers is discussed (Martin, 2011). In this approach, a blended learning process comprises of students, teachers and e-learning platform. For example, data such as reading activities and assessment results, gathered by the platform is used by the teacher's application to derive some useful insights/recommendation (e.g. teaching strategies selection).

While the above approaches claimed to adapt to students' needs for content interaction, the teacher has to define and configure the controlling variable (i.e., adaptation criteria) for the system. The proposed systems also claim that in a blended learning environment information sharing between online and offline modes of operation can enhance the teaching and learning experience (M. Martin, 2011). However, the system is not designed for collecting fine-grained data from learners, analysing data to derive actionable insights for the teacher, as well as no support for dynamically updating the knowledge, interest, and preference models of the student.

2.6.3 LearnBop Tangerine

LearnBop is a web-based adaptive platform for mastering mathematics. It simulates a one-on-one tutoring experience by allowing students to learn fundamental mathematics concepts sequentially. A student can interact with LearnBob to ask for help or answer a question. In case of incorrect response, it breaks down the initial problem into smaller, more manageable steps for the student to understand better the sequence of steps by applying tutoring techniques. LearnBob also uses prior knowledge of the learner to assess the missing knowledge aligned with standard concept and also provides insights to the teacher about the missing prerequisite concepts of a student.

While this system claims to adapt to a student's learning outcome, it lacks diversity. Mathematics is not enough to draw conclusions towards a student's learning model. The system is also not designed to collect fin-grained data from the student.

2.6.4 Knewton Adaptive Platform

Knewton (2015) developed an adaptive learning platform that continuously adapts and responds in real-time to each individual's performance and activity by processing thousands of data points (such as concepts, structure, difficulty level, and media format). It further applies sophisticated algorithms to personalize and recommend learning contents based on the insights. Moreover, Knweton (2015) implements advanced theories such as Item Response Theory to quantify the difficult level of a question, Knowledge Graph, Probabilistic Graphical Models and Hierarchical Agglomerative Clustering to represent, analyse and correlate the skill, knowledge and understanding of a student. However, this platform is solely based on individual performance. The learners' environment contributes highly in the students learning outcome and hence should also be considered in designing adaptive learning systems.

2.6.5 EduPAL

EduPAL is a plug-and-learn solution based on a low-cost USB flash drive as a portable learning platform. It attempts to track students' interaction with content in blended learning environment (The Alex Brown Centre for Entrepreneurship, 2014). Learners can use the EduPAL client installed in the USB to download and consume learning content. It tracks students' learning activities and allows students to take notes and ask questions to the teacher in remote mode. It captures data about learner's interactions with the content and uses it to device actionable insights for the teacher. EduPal system collects learners' data by tracking the mouse, keyboard events and movement of the eyes (Wang & Johnson, 2004).

This research extends the capabilities, scope and instrumentation of the event capturing and management described in EduPal. Collected data is later analysed and used to recommend learners' possible intervention areas. The events framework extends capabilities of EduPal by adding the students' context while they were interacting with a particular content item. The learner's context is captured using device sensors (location, ambient, noise levels etc.) and packaged together with personal sentiments the student had while consuming the content. The proposed system therefore, is able to use this data to adapt to a student by determining if the student is having difficulty understanding a given learning content.

2.6.6 Medupal

Medupal is a blended learning system that provide a suit of cognitive capabilities supporting multiple modes of learning namely school and remote modes. This system was design as a learning and teaching companion aiding the teachers in teaching and students in learning. The cognitive capabilities of this system enables it to move from one mode to the next seamlessly. As it moves from school mode to remote mode, it elevates its functionality from being teachers' assistant (in school mode) to a tutor (in remote mode). In school mode, Medupal recommends learning content based on curriculum to the teacher while in remote mode it facilitates between the teachers and student by escalating questions it fails to answer.

This system is by far an improvement to the above blended learning system. However, Medupal lacks a way to capture students' interaction activities at both content and device interaction levels. There is no correlation of what a student learns while in school mode and remote mode where this information could be useful in adapting learning to a student.

2.7 Gap from the Literature

The availability and growing popularity of rich, multimedia learning content (e.g. videos, games and simulations) and sophisticated interfaces (e.g. smart phones and tablets) promotes high content item interactions (Weldemariam, 2014). A single user learning session can potentially generate thousands of interaction events of different types. For example, Tangerine is a tablet-based application designed to collect data on early reading and mathematics assessments. It has been used in Kenya to generate school related operation survey questions and collect responses, which are analysed to generate policy recommendations. While Tangerine is reported to be effective for mobile data collection and helps in bridging the gap of facilitating adoption of early learning techniques, it does not address the chronic education challenges mentioned in section 1.2 of this research. Furthermore, it is a common trend by the major online education platforms, such as Massive Open Online Courses (MOOC), to monitor, track and collect learner's interaction with educational content at a fine grained level. Such fine-grained events can be made available for analysis and reporting applications. However, the generation, collection and aggregation of such data in a blended learning environment receive less priority or does not exist.

Many studies showed that learner's engagement is a key indicator for their understanding of a particular topic (Johnson, 2012). Johnson discusses the correlation between user engagement, content duration/length and production style. More specifically, the authors analysed using millions of viewed sessions from edX MOOC to measure how long students spend on viewing video contents as well as to understand whether they attempt to take follow up assessment. They reported that more engaging video contents tend to be shorter in duration/length.

A study by Guo and Reinecke (2014), showed how different students navigate through online content to amplify their success rate without effectively engaging with the content. As a result, the authors concluded that grades might not be enough to measure the academic progression of a student. Furthermore, they suggested that richer measures of participation and engagement should be considered while evaluating the level of understanding of a student. Similarly, students who begin active participation in the first week of their MOOC course are 35% less likely to drop out of the course (Carlson et al., 2014). The proposed system will address these gaps as highlighted here.

2.8 Conceptual Framework

The event framework is envisioned as follows:

i) To have event data collected from two major sources; device sensors events source (accelerometer, GPS, gyroscope, ambient light sensor, compass, camera, etc.) and application UI level event source (pdf, audio, video feedback, sentiments, etc.).
ii) The other part would be events collection; collected events were filtered, customised then passed to rule engine for immediate analysis.
iii) The generated JSON document were saved in a NoSQL database (Cloudant) interfacing to a backend system where map reduce and CRUD operations were performed.
iv) From the backend analytics were done using tools such as Rapid Adaptive Visualization Engine (RAVE) to draw insights and later display to the users to act on them.

2.9 Conclusion

Unlike the above discussed approaches, the research will generate several actionable insights from the fine-grained activity stream data by applying deep analytics (e.g. content interactions and engagement analytics, student data analytics) and cognitive algorithms. Unlike those approaches, the Event Framework will also generate personalised or group interventions/recommendations to improve the learning and teaching experiences. The backend algorithms will make use of various indicators including engagement, performance and sentiment to dynamically construct/update the knowledge, interest, and preference models of the learners and teachers. For instance, by using engagement, performance and sentiment, this approach is more deterministic as opposed to clustering techniques. This would also help in the determination of the appropriate interventions given a poor performance state of a certain student. Moreover, this research will indicate that the engagement of students is not the only factor to be used in determining their progress.

Chapter 3: Research Methodologies

This chapter describes the formulation of research design and methodology used to achieve the stipulated goals of the study. After consideration of the objectives of the study, the research questions, limitation and scope of the study the researcher felt that it was appropriate to adopt the waterfall development model. In figure 3.1 below, a basic waterfall model is illustrated which is one of the main system development models. In completing the tender selection system this chapter will cover waterfall system development methodology, research instruments, and data analysis techniques.

3.1 Proposed System

A learner-content interaction framework, to be integrated into a blended learning system was proposed to improve adaptive learning. The platform captures learner environmental data collected by mobile/tablet sensors and other contextual information from interaction with learning materials (e.g. forward or rewind of a video). The other source of data is from quiz/ tests issued by the teachers. The platform tracks number of attempts done on a question or a quiz in general and score for each attempt. From the collected data, insights and instrumentation can be generated.

This section discusses the event framework, which is the basis of data collection in a blended learning environment. The aggregation of fine-grained data forms the Student Activity Information (SAI) events, which will be consumed by corresponding analytics library to generate actionable insights such as engagement, performance, and sentiment.

3.1.1 The Event Framework Overview

An extensible and configurable event framework library instruments user interaction, feedback, and sentiment with respect to content and/or general level device content information. Application developers can easily integrate the library within their applications in order to capture fine-grained user events. The developers only need to set a few configuration settings that provide a high degree of flexibility to end-users (e.g. turn on/off certain events to be logged, logging frequency and storage destination). The framework has a client server configuration where the client resides on a mobile application and is responsible for all the data collection and generation. The server side resides on the cloud.

3.1.2 Database as a Service (DBaaS) Overview

Cloudant Database as a service (DBaaS) is a management platform that manages a variety of structured and unstructured data. Data collected from the event framework is highly unstructured, Cloudant is therefore the appropriate technology to store this kind of data. The framework uses a dictionary structure when logging received events, which allows for easy association of event. The framework takes advantage of the dictionary structure implemented within a JSON document. In the following section, we describe the various components of the event framework, which are instrumental in data collection.

3.1.3 Events Sources

The event framework collects data from three distinct types of interaction events: application event, sentiment and contextual event and sensor event. The application events are content dependent and mainly consist of user interaction data with learning content. There are three types of application event documents that can be generated: text (pdf, ppt, etc), multimedia (audio and video) and assessment/quiz. Each event document has a set of interaction events that can be captured in a given session as shown in table 2.1.

The other events are sentiment and contextual events captured from learners through a context logic engine. The engine is configured to capture three forms of sentiment: generic, content-centric and poll-based sentiments. Each of this collects emotional information from individual learners relative to the context of instrumentation. The sentiment engine uses two-level logic to determine the right sentiment question to be asked. The sentiments collection is based on past sentiment, engagement index and performance metric supplied from the analytics engine.

The feedback includes the well-being of student, understanding student opinion toward specific content, as well as their ability to adequately comprehend content within the specific mode of delivery. This also aims to provide use of historical sentiment data to create profiles used in identification of interventions for poor performing students and to better understand their learning styles and preferences for future content delivery.

The sensor events are collected via smartphones/tablets. The devices include device level sensors such as the accelerometer, microphone, light sensor and GPS that are used to capture raw data about the learner's context (dependent on the configuration settings). Summarization analyses are performed on the raw data generated by the sensors in order to derive information about the learner's environment. An example is where the event framework uses a three-axis accelerometer to determine the locomotive state of the learner.

Sensor data alongside application events is used to derive the relationship between student engagement and the environmental context. The sensor data can be used during engagement analysis to determine the root cause of anomalous behaviours (could be extremely high or low engagement).

Table 3.1: Metadata of event for the events types

MULTIMEDIA (VIDEO/AUDIO)	PLAY	time_location, time
	MOUSE_PRESSED_RELEASE	pressed_time, release_time
	STOPPED	stopped_time_location
	FORWARD	from_time, to_time
	REWIND	from_time, to_time
	MUTE	
	UNMUTE	
	PAUSE	
	CHANGEVOLUME	
	PLAY_SUB_TITLES	
	TOGGLE_FULL_SCREEN	
	CLOSE_VIDEO	time_location, total_time, time
	SENTIMENT	sentiment, comment, timeoffset, weight
	FEEDBACK	response, timeoffset
TEXT DOCUMENT	NEXT	page-number, time
	GOTOPAGE	page_number, time
	PREV	page_number, time
	ZOOMFIT	page-number, time
	CLOSE_DOC	page_location, total_page, time
	SENTIMENT	sentiment, comment, page-number, weight
	FEEDBACK	response, page number
ASSESSMENT	QUIZ_ATTEMPT	questionID, answerID, correct
	QUIZ_SAVE	timestamp
	QUIZ_SUBMIT	total_time
	QUIZ_GRADE	grade, total

3.2 Research Methodology

Waterfall model was selected as the preferred system methodology that was used in this study. This is because it allows returning to the previous when the need arises, however this provision should be used with care. This is because the waterfall method doesn't allow one to return to previous steps with the newfound requirements in later steps.

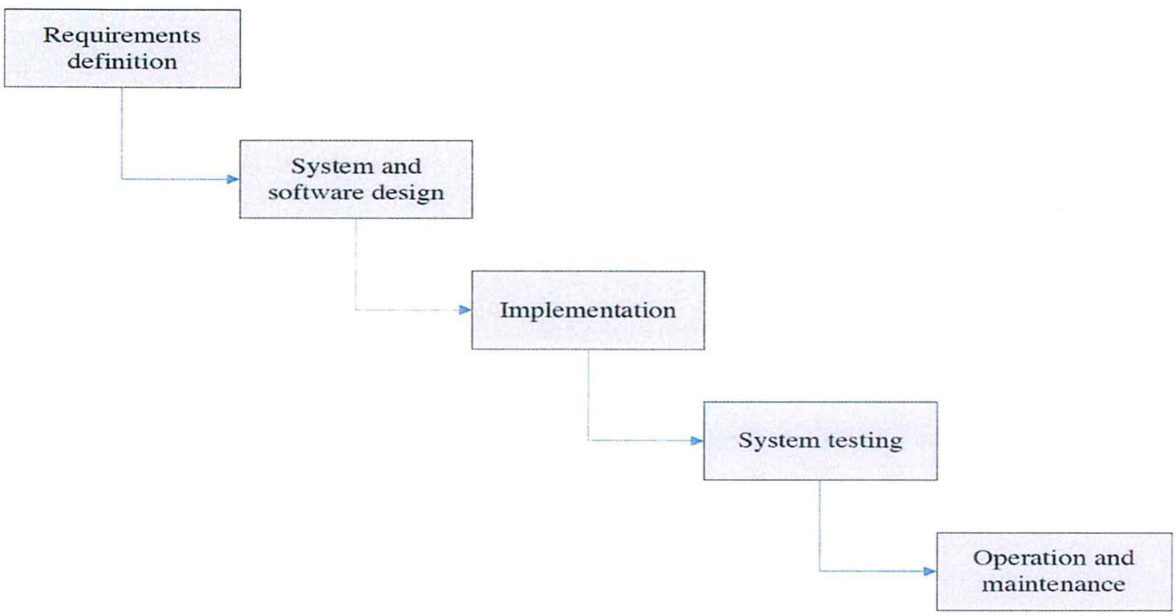

Figure 3.1: Waterfall model

(Sommerville, 2011)

3.2.1 Requirement analysis

This is the first stage in any system engineering process and software development process. It encompasses those tasks that go into determining the needs to be met for a new or altered product (Sommerville, 2011). In the requirements analysis stage the waterfall method allows for different data collection methods to be used. In this research study all the requirement for the system was gathered by employing techniques such as survey, questionnaire, interviews and observation. The data collected was meant to determine what constitute the developed system, the ease of use of the tender selection system and whether it performs its intended functionality. To undertake the survey a population sample was identified. The researcher used judgemental sampling (Westfall, 2008) to pick schools with capacity to deploy and utilise blended learning within their teaching system. By using random sample (Paula et al, 2001) a student population of 22 pupils was picked to conduct learning using the tablets for mathematics and science lessons. Judgemental sampling was also used to pick teachers from various schools from Nairobi county to get a total of 28 teachers especially ones with background in information technology, supporters of blended learning. Chow, (2008) derived the formulae that was used to get the sample size.

$$n = z * z[p(1 - p)/d^2$$

Where:

n = required sample size

z = Confidence level at 95%

p = 10% estimation of the need of sharing tool

d = Marginal error at 5%

Once a population sample had been identified data gathering began. The study proposed to use both observations and interviews administered to the target population on a one to one basis. The data collected was meant to determine what will constitute the system to be developed, the ease of use of the system and whether it performs its intended functionality. The following is a detailed discussion of the data collection techniques that was employed:

i. **Observation**

   Observation was mainly used for the pre-development data collection to understand the needs of the users who the tender selection tool is targeting, this data was used to determine the feasibility of the tool and the functionalities to be implemented.

ii. **Interviews**

   This technique was used because the research involves using the tender application and selection system and thereafter giving feedback on its usefulness. The data collected during the interview was intended to test the validity of the tender selection system.

iii. **Questionnaires**

Questionnaires provided more data points for the proposed system and was used to validate the requirements by providing useful statistics into the number of people who have the same sentiment on system features and elements. Questionnaires also provided useful means to test features without implementing them.

After data is collected it needs to be analysed. Data analysis can either be done through a quantitative approach or a qualitative approach (Creswell, 2013). Both approaches were employed in this study. Mean, standard deviation and variance will be used in the analysis of the data. Other visualization tools such as bar charts were also used to show the frequency of data received from the respondents of this study.

3.2.2 System Analysis and Design

In the system analysis and design phase of the project development, the Object Oriented Analysis and Design (OOAD) technique was used due to its capability to allow modularization of components. This has the benefits of reuse of classes and improves system quality and robustness of the code. With reuse, the developer only needs to connect the classes resulting into industrial-strength applications that run as intended, reducing cost of project, late project deliveries and eliminate errors in development.

According to Larman (1998) the Unified Modelling Language (UML) is a standard diagramming notation. The Unified Modelling Language was chosen to represent all actions and users of the system in a more comprehensive way. The following diagrams were chosen to represent the system: Use Case Diagram, functional diagram and Data Flow Diagram. The various design diagrams were created using Microsoft Visio and Argo UML tools.

3.2.3 System Implementation

Extreme programming methodology was used to implement the system. Extreme programming uses iterations so as to continuously improve the system based on feedback given (Parthasarathy, 2010). The benefit of using this methodology is that it allows for quick adaptation to change (Beck, 2000). Another reason for choosing extreme programming is that it allowed creation of a test-driven environment (Beck, 2000). This means that code needed to pass unit testing before another module of code is programmed.

To analyse, test and implement the system the researcher used several tools such as Dexter for analysis, Android Studio for development and JUnit for testing. System backend was implemented using Moodle (an open source course management system). Moodle was used to upload learning content that would be used in teaching, to the system. A MySQL database that was to be used together with Moodle was also configured. The mobile application frontend was developed using android operating system. Visualisations were created using RAVE (Rapid Adaptive Visualization Engine) framework integrated into the system.

3.2.4 System Testing

Testing methodology used in this research was V-model illustrated in figure 3.1. This kind of methodology involves several levels of testing associated with the systems, which include unit testing individual modules of the application, integration testing to test interoperability between the different modules and sections and acceptance testing to test functionality of the system (Software Testing Class, 2002). V-model was mapped into two kinds of tests that were conducted during the research; these tests are black box testing and white box testing.

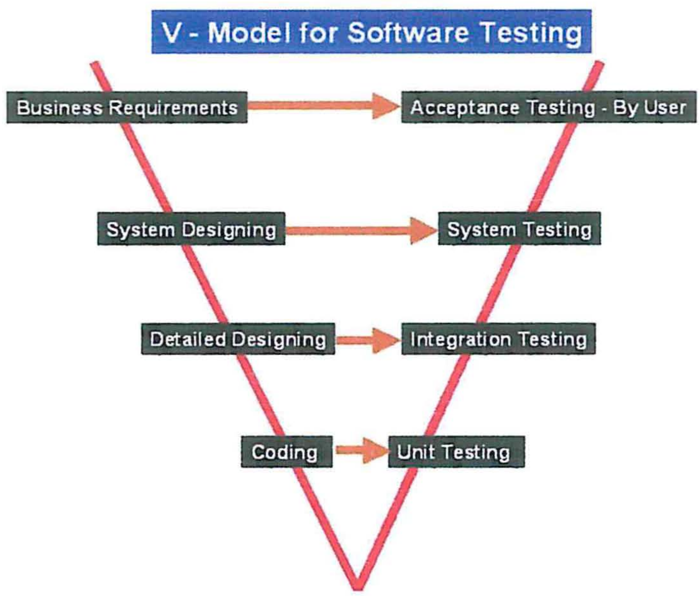

Figure 3.2: V - Model Testing Methodology (Software Testing Class , 2002)

Black box testing is done when the tester does not have knowledge of the interior working mechanism of the application (Desai & Srivastava, 2012). The tester performed this testing by interacting with the user interface and conducting user acceptance tests with the target population. The target population did this kind of testing during pilot. White-box testing involves investigating the logic associated with the code to ensure it is working as intended (Desai & Srivastava, 2012). Unit testing was done during application development by the researcher on individual modules of the application, system testing was done on the complete system and integration testing when the framework was ported to the blended learning application.

3.3 Research Design

To better understand any gaps in the existing blended learning platform that affects learning outcome and intervention design, the researcher employed prototyping research design. The main techniques used were semi-structured interviews, participant observation and secondary analysis. Secondly, in order to understand the pros and cons of using technology in class with teacher as an assistant to student and outside with teacher as a guide to student, the researcher narrowed the scope to the student population in standard five, Kenyan curriculum.

For the success of this dissertation two workshops will be held, one with a group of teachers and another with a group of students. The goal of the workshops will be divided in threefold: understanding the merits and demerits of using technology within the classroom and outside the classroom; understanding the teachers need which could be translated into use cases to develop a technological solution which could assist them to be thorough; finally, for user experience testing of the framework in a prototype implementation of the system on an android/iOS platform.

3.3.1 Study variables

This research had both dependent and independent variables. Independent variables are assumed to affect the dependent variables. Independent variables can be thought of as the presumed cause while dependent variables as the presumed effect (Collier, 2013). The dependent variable for this study was the experience of blended learning by main stakeholders (Teachers and Tutors), while the independent variables were the use of event framework in a blended system to enhance learners experience and improve teacher's efficiency.

3.3.2 Location of study

This study was carried out in two primary schools within Nairobi County in Kenya, which were picked based on their capacity to deploy a blended learning system. The other factors that lead to selection of these two schools was based on the fact that they are in the middle social class hence the results from the study can be adopted to scale downwards or upwards.

3.3.3 Population and Sample

The researcher used judgemental sampling (Westfall, 2008) to pick schools with capacity to deploy and utilise blended learning within their teaching system. By using random sample (Paula et al, 2001) a student population of 22 pupils was picked to conduct learning using the tablets for mathematics and science lessons. Judgemental sampling was also used to pick teachers from various schools from Nairobi county to get a total of 28 teachers especially ones with background in information technology, supporters of blended learning.

3.3.4 Research Instruments

Two workshops were held, one with the teachers and another with the students. During these workshops the researcher used interviews, questionnaires and observations as the main research instrument to gather data for this research.

a) Online Questionnaire

Online questionnaires supported by Google Docs were selected as data collection method for usability and acceptance testing. This is preferable as collected data is already digitized and easy to analyse. The questionnaires were distributed via the tablet computers that the users were using for blended learning and thus more motivating to complete the questionnaire.

b) Observation

The observation procedure should be non obstructive to enable the informants share their reality directly with the researchers (Annum, 2015). To conduct the observations an image processing application was used to collect video feed during the normal traditional learning and the blended learning lessons. The videos were later viewed to retrieve observation data. This was necessary to avoid interference with the normal learning sessions by having an outsider in the class.

c) Document Review

A review and analysis of documents on mobile technology, adaptive learning and blended learning was done. These documents provided a wider understanding on the concepts under study. The reference section highlight some of the documents and sources used in this research.

3.3.5 Data Collection Procedure

Two workshops were held, one with the teachers and another with the pupils. Discussions and observations were the 2 main research instruments used to gather data from these workshops. The teachers workshop employed user-centred design approach by focusing on practical activities organised in three sessions: brainstorming, design thinking and user experience testing sessions.

In the brainstorming session, teachers were asked to share their experiences in blended learning environment. In the design thinking session the teachers were divided in groups of five and asked to come up with a list of requirements for a system that would help them engage actively with learners, deliver learning materials and monitor students progress. In user testing session, teachers were provided with tablet computers running a prototype implementation of blended learning system. Participants were asked to interact with system features and then give feedback on the user interface, navigation flow and intuitiveness of the application.

For the students workshop the goal was to conduct a user acceptance test of the developed blended learning system and to understand sentiments and context of student during a learning session. In the first session we studied the interpretation of sentiments by the students. Table 3.1 a list of sentiments classified based on their semantic orientation. Students were divided into groups of four then provide with similar list of sentiments and asked to assign a popularity value to on scale of 1 to 5 on each sentiment. In session two the researcher conducted acceptance testing of the developed prototype. Each student was provided with a tablet computer pre-loaded with the blended learning system (Medupal). A science teacher was then asked to conduct a 35 minutes' lesson to simulate a blended learning environment. After the lesson the pupils were provided with a questionnaire attached in Appendix A and asked to give their feedback on use of the system.

Table 3.2: Example of Sentiments

Positive	**Negative**
Better	Alone
Blessed	Annoyed
Brilliant	Angry
Determined	Bored
Entertained	Confused
Excited	Frustrated

3.4 Research Quality

3.4.1 Validity

Validity of a study refers to how well data collection and analysis of research captures the reality of topic being studied. According to GreenField (1996), It can be said that a research is highly valid if it contains only what the researcher wants to study. From the usability and acceptance tests sessions done during the two workshop, the prototype was able to capture user sentiments data shown in Appendix C part a), contextual device-sensor level data illustrated in Appendix C part b) and performance data from the quiz done shown in Appendix C part d).

3.4.2 Reliability

Reliability of a study demonstrate that operations of a study, such as data collection can be repeated and yield the same outcome (GreenField, 1996). The objective of the study is to ensure that if another person repeats a specific research study, follows the same procedure as described by earlier researcher he should be able to arrive at the same result. To achieve reliability usability test and acceptance test done during the pilot was conducted in groups. Findings from the groups were compared and contrasted, however, no major discrepancies were identified.

3.4.3 Piloting

For experimental purposes the researcher carried out a limited pilot study in a standard five class with 22 pupils (Kenyan primary school, ages 11 and 12). A blended learning platform was used to conduct two lessons; one in science and another in mathematics. Two respective teachers who handle these subjects taught the lessons. The event framework was integrated and ready to collect all application, sentiment and sensor events data. The collected events stream data was stored using Cloudant DBaaS. The researcher then used MapReducer capability of Cloudant to manage and manipulate views, which are stored as secondary indices for later use in insight generation.

3.4.4 Ethical Measures

Permission was sought from the pupils' parents in the two schools where the study was being carried out. Further, it was clearly stated by the researcher that it was a research for this particular case study. Anonymity of the correspondents was explicitly adhered to and names revealed only at the correspondents' consent and wish. The correspondents were further clearly informed that they were at will to withdraw from the study if they so wished.

3.4.5 Data Analysis Procedures

Data analysis is an ongoing activity, which not only answers the research questions but also gives directions for future data collection (Bala, 2005). The analysis procedure employed was deductive qualitative approach. This approach would help put research project in perspective and help in testing the hypothesis. Statistical packages such as SPSS and Microsoft Excel were used to facilitate data analysis.

Since the research design adopted was mixed methods (experimental and prototype development), data analysis was done beginning from the time of data collection, during the observation phases and group discussion sessions. For further analysis, the researcher allowed the correspondents to elaborate further on their responses in the form of a discussion during the group engagements.

Further, qualitative data collected from the research was organised and summarised using Cloudant MapReduce functions illustrated in Appendix D and other statistical packages highlighted above. Later results were presented in the form of graphs, charts, comments, quotes and derived statements.

3.5 Conclusion

In conclusion this chapter has described: how the prototype was created and tested, how data for the study was collected and finally how it was analysed, thus making it clear to the reader how the research results were obtained. This chapter was presented under 14 main sections namely; research design, study variables, location of the study, target population, sampling strategies, research instruments, validity, reliability, piloting, data collection procedure, ethical measures, and data analysis procedures.

Chapter 4: System Design and Architecture

This chapter presents the design and architecture of events framework that was integrated in a blended learning system to collect interaction data. A detailed description of the framework is given to deepen understanding of the system. A greater part of the design was informed by findings gathered from workshops held with teachers and students. Through the findings, the researcher was able to incorporate the user requirements elicited in the requirement analysis stage.

4.1 Framework Architecture

The blended learning system comprises of three major components, the client side, server side and the database. The event framework integrates into two of the system components: a client server configuration where the client resides on a mobile application and is responsible for collecting fine-grained data and the server side of the framework resides on the cloud. Application developers can easily integrate with the library in their application to collect various events. Due to its flexibility, developers only need to add database configurations to capture the required events.

When the framework is integrated and well configured, the library will be ready to collect user interaction with content and the device. The library generates a JSON document, and writes it into the local Cloudant storage, which continuously synchronises with the online repository when an Internet connection is available. The framework uses a dictionary structure to log received events, implemented in the JSON document. Figure 4.1 shows an illustration of the events framework architecture.

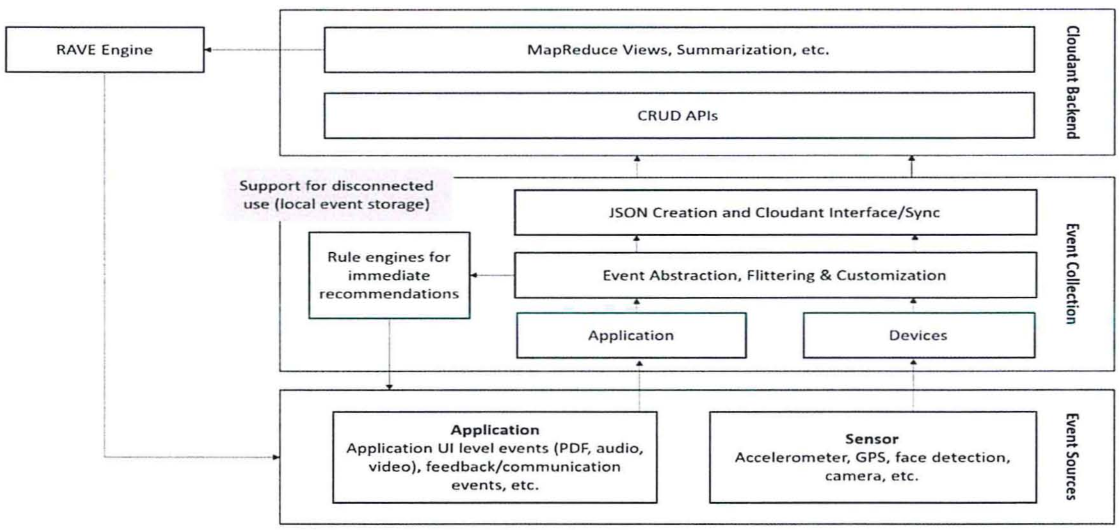

Figure 4.1: Events Framework Architecture

4.1.1 Event Sources

The library collects data from user interactions at various levels. However, these interactions can be categorised into three distinct types:

a) **Application events** – These are content dependent and mainly consist of user interacting with learning contents. These generated events are of three types: text (i.e. from pdf, ppt, etc.), multimedia (video and audio) and assessments (quiz and tests). Table 2.1 shows a set of events captured in each of the document on each session.

b) **Sentiment and contextual events** – Events captured from learners through contextual logic engine within the library. The engine can be configured to capture any of three forms of sentiments: generic, content centric and poll based. These events can either be implied implicitly by the engine based on user mode of interaction and historical fata or explicitly by asking questions to the learner. This is useful in shaping adaptive learning based on user profile.

c) **Device sensor-level events** – these events are generated from device level sensors such as the accelerometer, microphone, light sensor, GPS, etc. They capture raw data, which is used by the summarization algorithm to derive information about learner's environment. When the output is combined with application events we can derive relationship between student engagement and environment context and how they affect learning.

4.1.2 Events Collection

The event framework is highly configurable allowing application developers to decide which events to collect based on their system requirements. Due to its resource awareness the event framework is able to adopt so as to cope with the resource constrained nature of mobile devices. The resource manager is responsible for events abstraction, filtering and customization. This module monitors the resource levels, the current events generation rate, and estimates future events storage needs. The resource manager also monitors the network connectivity patterns to determine when to synchronise locally stored data to the cloud storage.

4.1.3 Cloudant Backend

Cloudant is a cloud based service for non-relational distributed database. It provides integrated data management, search and analytics engine using MapReduce technology. In the events framework Cloudant is used as the suitable mode of data storage to store SAI data due to its unstructured nature. MapReduce view are designed to perform summarization on collected data. To link the mobile client local Cloudant storage to the remote Cloudant we use CRUD APIs component.

4.2 System Design

4.2.1 Use Case Diagrams

Interaction by the users of the system with the various functionalities of the blended learning system integrated with event framework platform for data collection is illustrated in the use case diagram in Figure 4.2. This use case highlights all the major functionalities that the proposed system offers. All the external systems and users interacting with proposed framework have been highlighted.

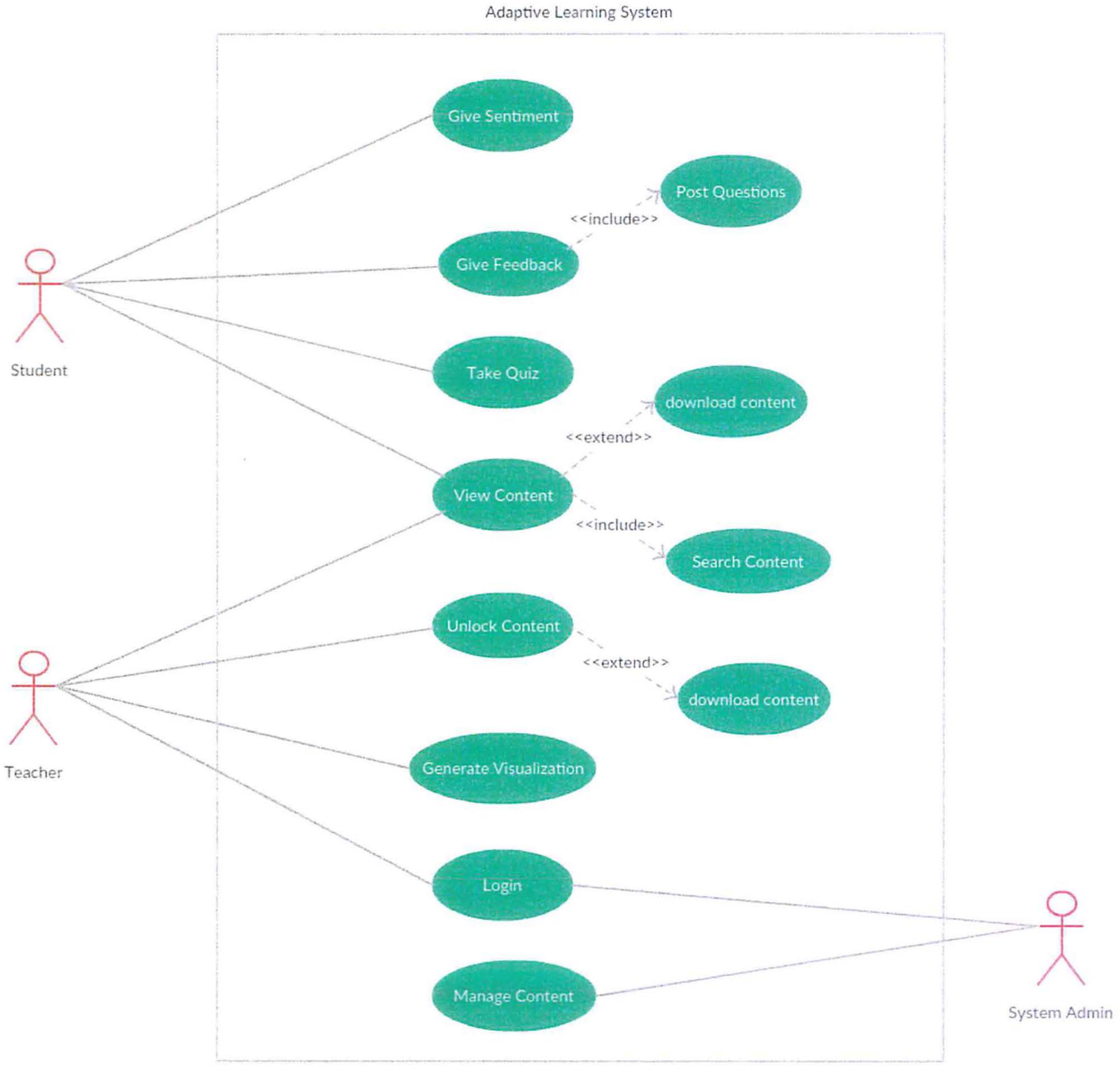

Figure 4.2: Adaptive Learning System Use Case Diagram

a) Give Sentiments Use Case Description

Table 4.1 shows the use case description for giving personal sentiment essential for collecting sentiment data. The table highlights the primary actors and triggers of the use case.

Table 4.1: View/Download Content Use Case

Generate Visualization Use Case Description	
System: Adaptive Learning System	**Group ID**: group A
Use Case Name: View Content	**UC ID**: 4
Primary Actors: Teacher, Student	
Goal: Collect user-content interaction events when reading through the content	
Trigger: Student /Teacher opens a content	
Relationships: include, extends	
Inputs: Content name, lesion	
Normal/Basic flow of events	
Actor	**System**
	1. System provide available contents
2. Student/Teacher searches for content to view	
	3. Show filter result base on user search input
4. Download content if not available in device	5. Retrieve content from server
6. Open the downloaded content	
Output: content-level interaction data	
Test Cases: Unit test (UT1)	

b) Generate Visualization Use Case Description

Table 4.3 show the use case description for generating insights from collected interaction and contextual data. The table highlights the primary actors and triggers for the use case.

Table 4.2: Generate Visualization Use Case Description

Download/View Content Use Case Description	
System: Adaptive Learning System	**Group ID**: group A
Use Case Name: View Content	**UC ID**: 6
Primary Actors: Teacher	
Goal: Create actionable insights from collected interaction and contextual data.	
Trigger: Teacher accesses the visualization menu	
Inputs: Students Active Interaction (SAI) data	
Normal/Basic flow of events	
Actor	**System**
2. Teacher selects a visualization to generate 3. Select SAI data to use. 6. Save/print/ mail the generated visualization	1. System provide available visualization templates 4. Process data and display visualization
Output: Actionable insights visualization	
Test Cases: Unit test (UT5)	

4.2.2 Activity Diagrams

The activity diagrams illustrate how information flows as a user interacts with each system function. In this study the researcher used activity diagrams to show the flow of information for each user module of the mobile application.

a) Content Preview Activity Diagram

The content preview activity diagram shows flow of information between the user and the system when a student or a teacher wants to preview content. Content can either be a document, a quiz or a video. Using navigation menu, the user selects subject and lesson number. The system returns a list of all available content, highlighting in yellow the ones that need to be downloaded. The user clicks on a content to preview. The system downloads the clicked content and opens it a content viewer. Figure 4.3 illustrates the flow of these activities.

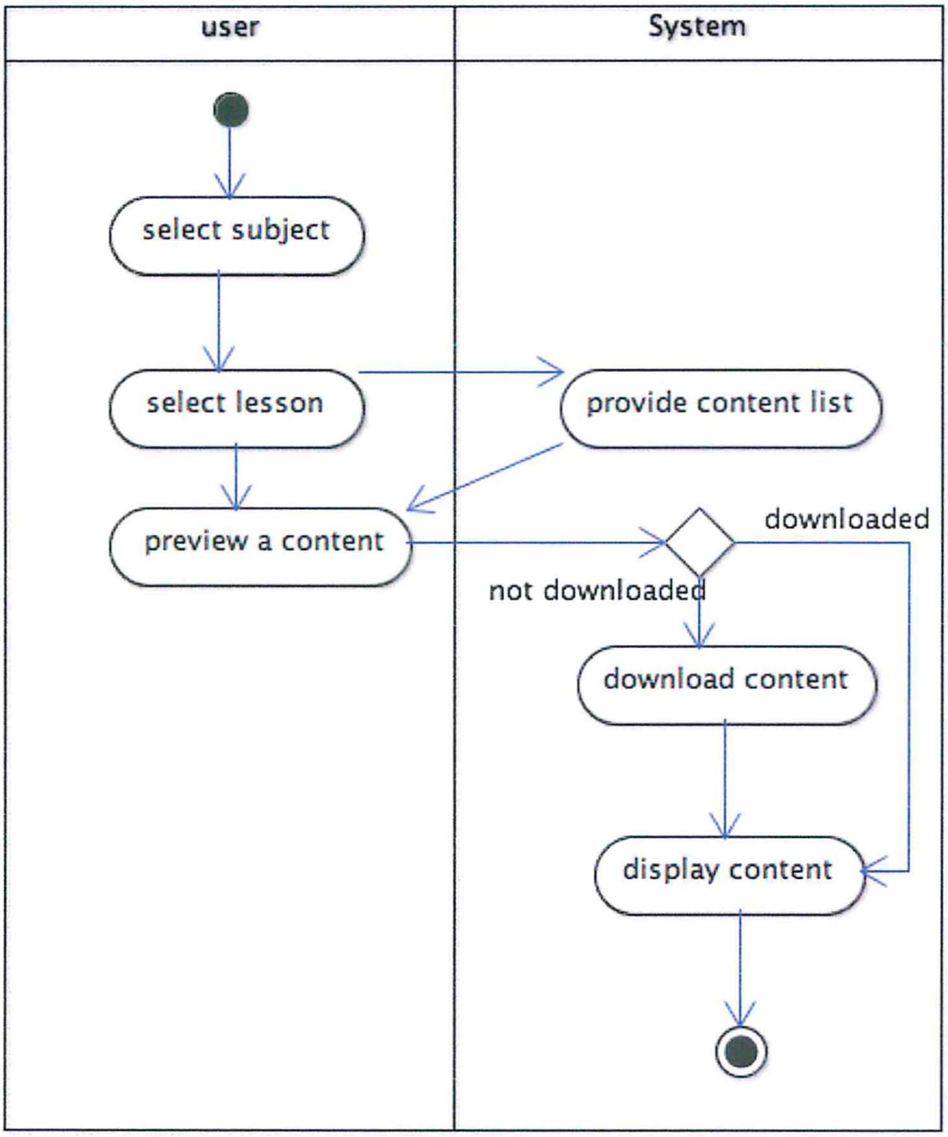

Figure 4.3: Content Preview Activity Diagram

b) Quiz Activity Diagram

The quiz activity diagram illustrated by figure 4.4 shows the flow of activities when a user takes a quiz/test. The student uses the navigation menu to select subject and lesson number under which they want to take a quiz. The system displays a list of available content distinguished using icons for quiz, video or reading documents. The user selects the quiz to take, then on completion submits for marking. The system marks the tests and returns a score to the student. Student can retake the quiz if they like and repeat the submission process.

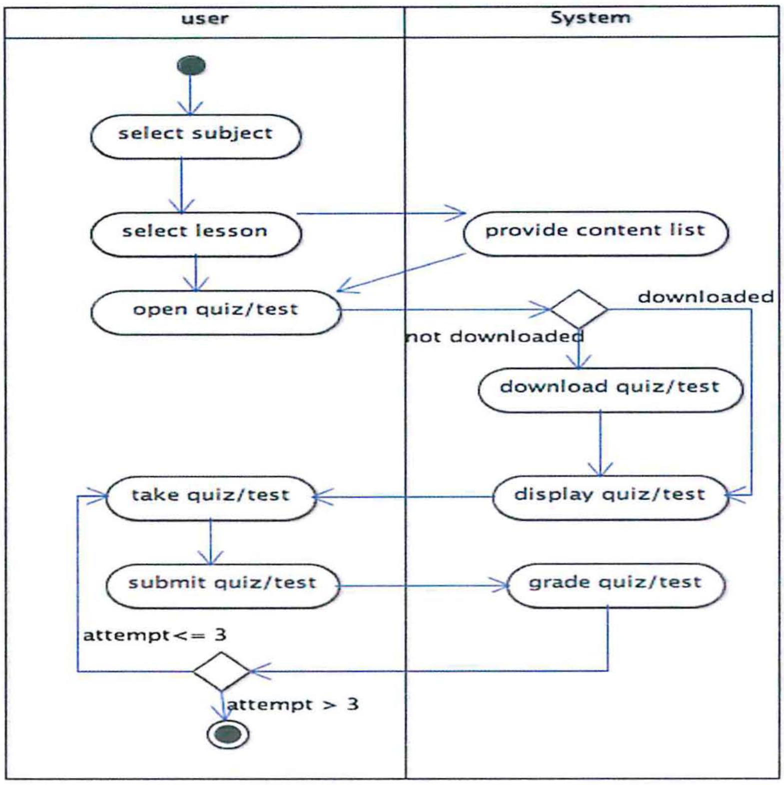

Figure 4.4: Quiz Activity Diagram

c) Question and Feedback Activity Diagram

Figure 4.5 illustrates the flow of activities that occurs when a student posts a question to the teacher. The student navigates to the discussion menu, then selects "new post" button to send a question. The system sends this question to the teacher. A teacher receives a notification, clicks on the notification to respond to the question. The system sends the answer back to the student.

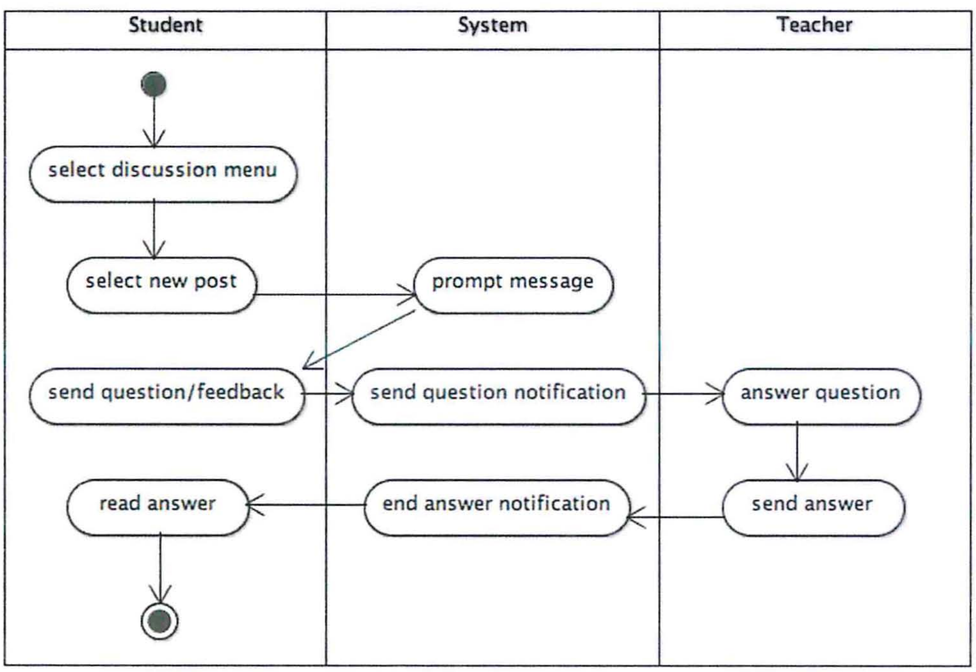

Figure 4.5: Question and Feedback Activity Diagram

4.2.3 Data Flow Diagrams

The data flow diagrams show how data flows in the system specifying the actual inputs and output of the process. The DFD diagrams used include: context diagram illustrated in Figure 4.6, level 0 diagram shown in Figure 4.7 and level 1 diagram represented in Figure 4.8.

a) Context Diagram

The context diagram plays an important role in system design. It gives an overall picture of how users interact directly with the system. The context diagram influences the system functionalities as it shows what exactly the user will be expecting from the system.

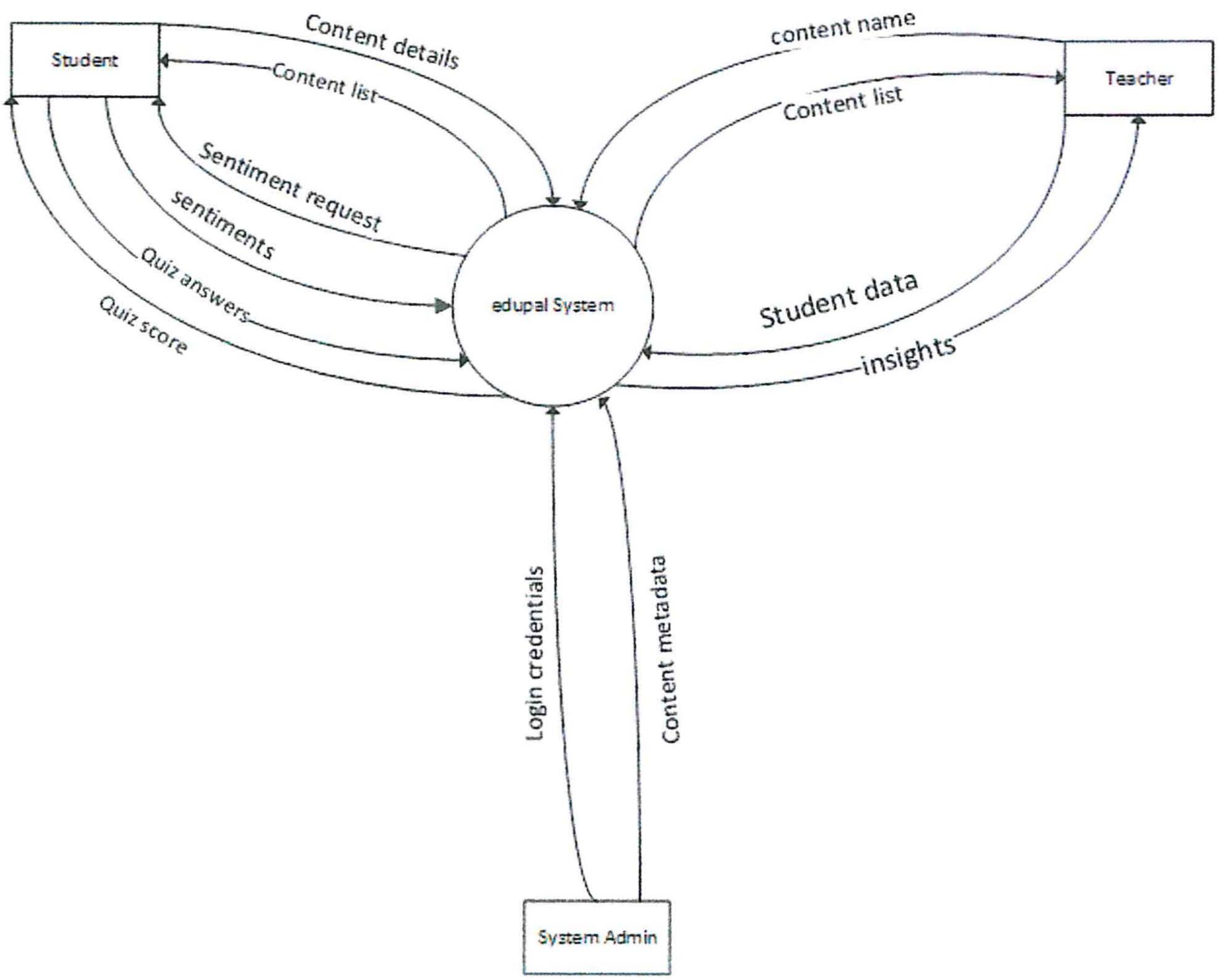

Figure 4.6: Context Diagram

b) Level 0 Diagram

Level 0 show the system's major processes that lead to generation of events by the user. These processes include: view content, manage content, among others as illustrated in Figure 4.7. Events data and uploaded content is saved in data stores as represented in the figure.

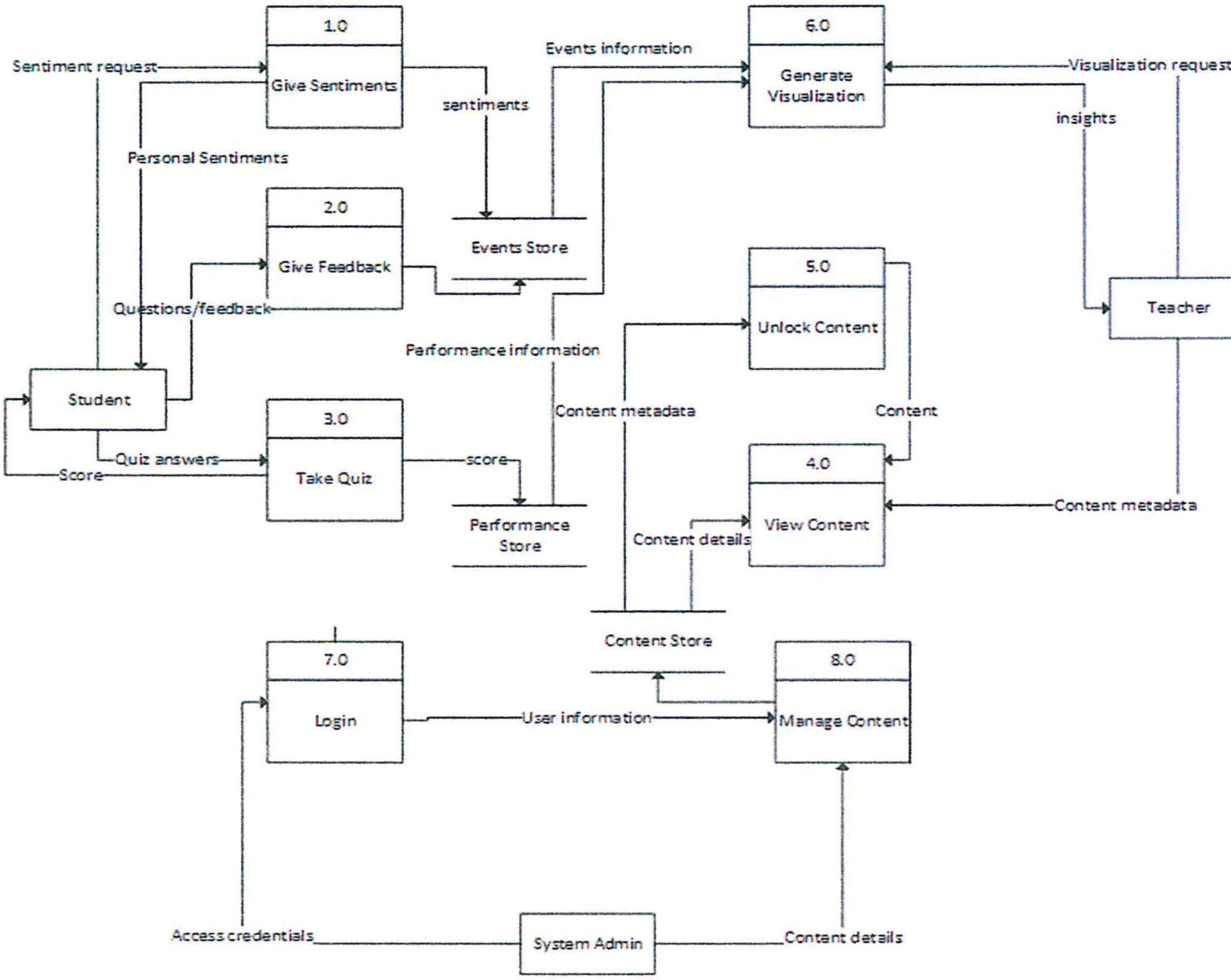

Figure 4.7: Level 0 Diagram

c) Level 1 Data Flow Diagram

The level 1 diagram shows internal processes of a major level 0 process after decomposition. In this case the researcher decomposed process 4 as shown in Figure 4.4. Process 4 in level 0 DFD shows a process that represents content viewing system function. The process comprises of various sub-processes namely: search content, download content and open content. To view a content these steps are essential to occur in the outlined order. Viewing content generates interaction level events which are stored in the events store.

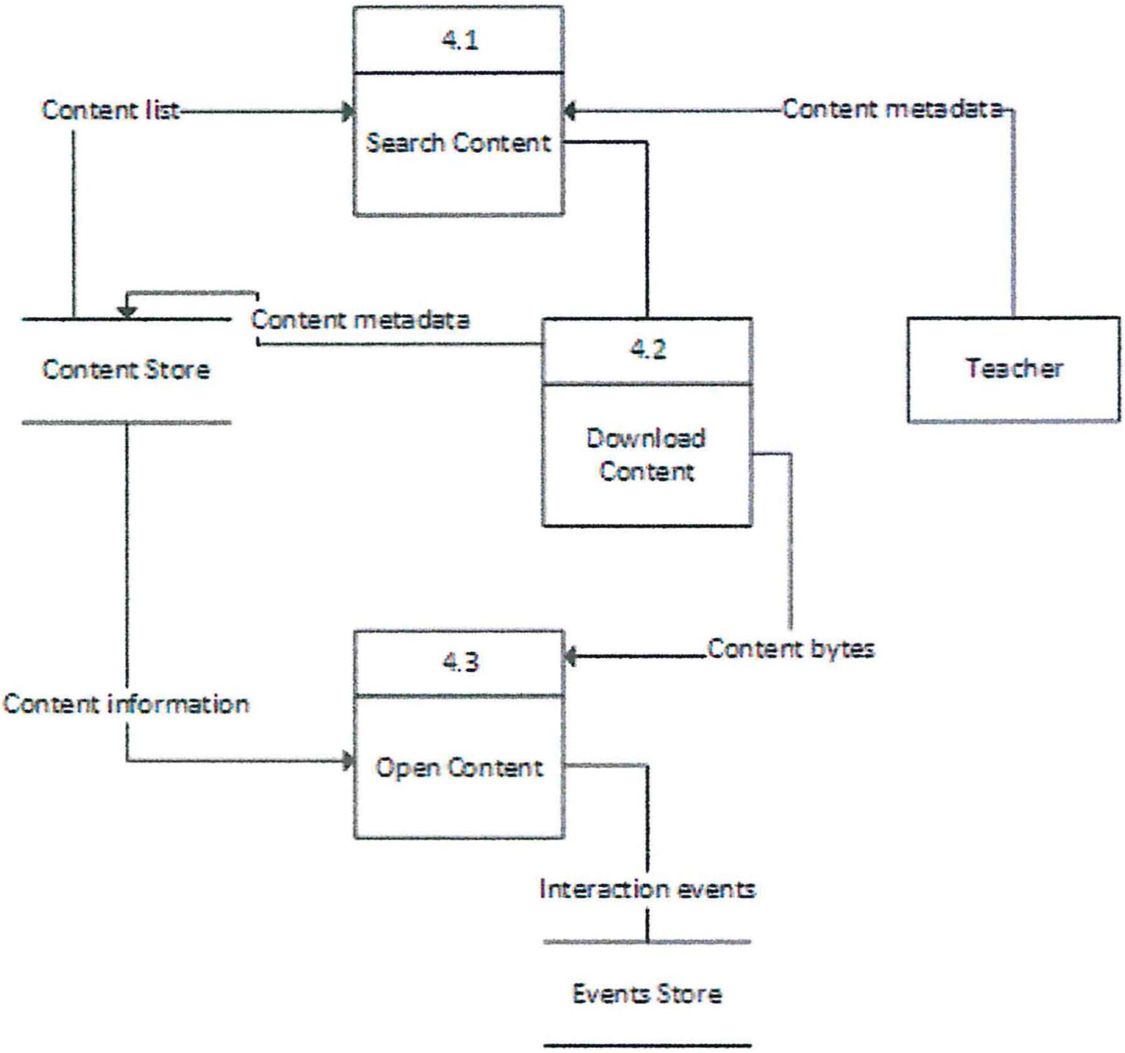

Figure 4.8: Level 1 Data Flow Diagram

4.2.4 Entity Relationship Diagram

Events collected from content interaction and device sensors was in large volumes and highly unstructured, hence, the selection of Cloudant NoSQL database. Cloudant is document database with documents containing many different documents key-pairs or even nested documents. For events the events framework collected contextual events, sentiments events and performance events as separate documents. However, for content and user management, a normal SQL database was used. Figure 4.9 illustrates all the tables used in the database to save data that can be accessed both from the mobile application and from the back end of the system. This diagram enabled the developer to normalize the database by organizing all the tables and their attributes to minimize redundancy.

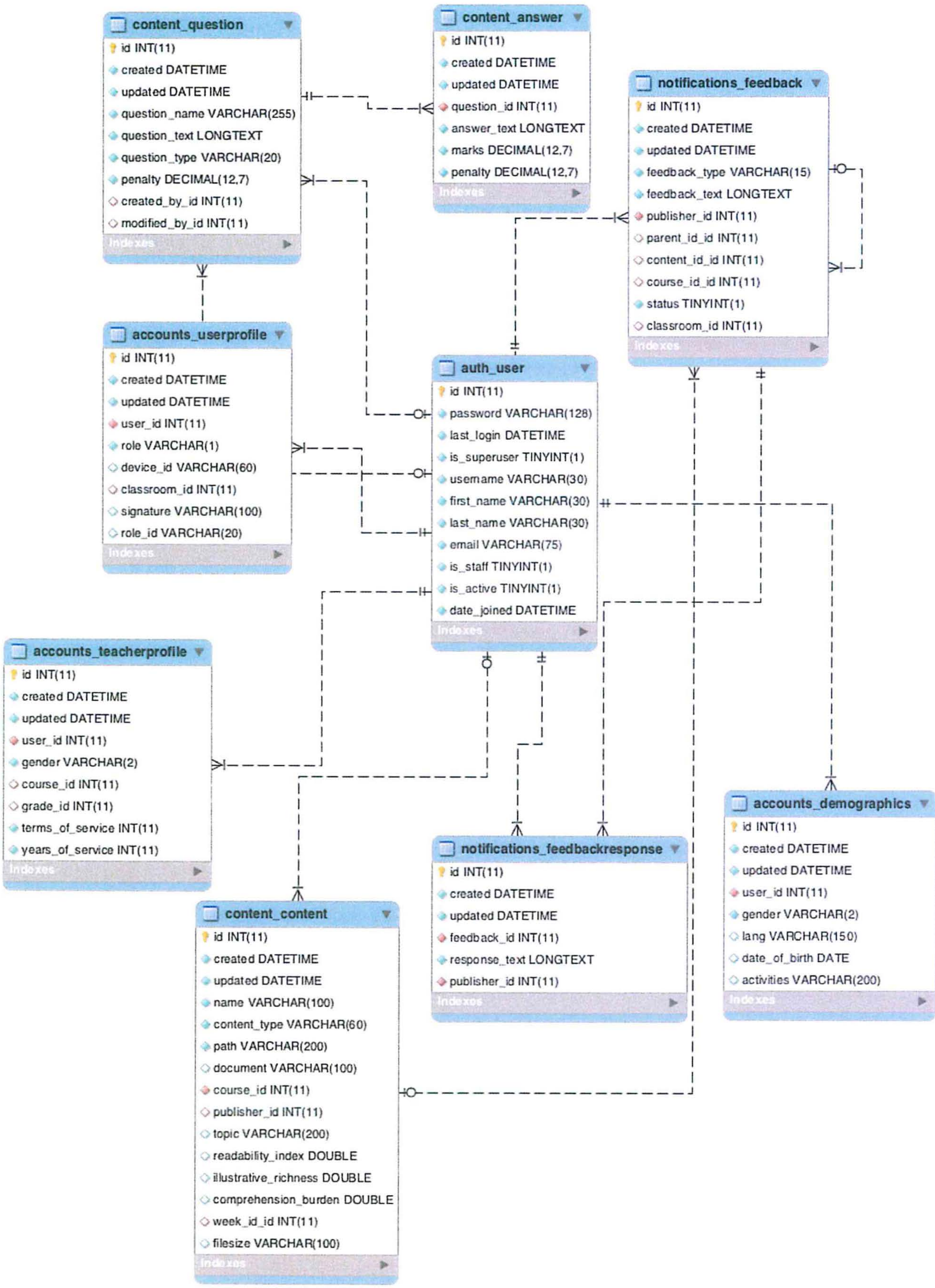

Figure 4.9: Entity Relationship Diagram

4.2.5 System Design Process

For other developers to implement a similar events framework using programming language of their own they should consider the following steps:

i) Referring to the framework architecture described above, the developer should implement each component as a class.

ii) The structure of output JSON document resulting from the framework configuration should use the structure described in Table 2.2.

iii) Based on requirements described in chapter 2 the developer should develop or select a suitable blended learning platform to integrate the events framework into.

iv) System design details should be considered insetting up all the required components that are essential for contextual data collection.

v) Finally, the developer should forward engineer the Entity Relationship Diagram to create the required SQL data schema.

Chapter 5: System Implementation and Testing

This chapter gives a comprehensive explanation of how the event framework was implemented, deployed and tested. The design of this project involved selection of an adaptive blended system to enable collection of events by the event framework. This system was selected and event framework integrated in it as per the design outlined in the previous chapter. This aimed to show how different blended systems can make use of the event framework for data collection. The integration was done in close consultation with the initial developer of the blended learning system.

5.1 System Implementation

From the review done on blended learning systems in section 2.6 of chapter 2, Medupal system was found to be really innovative in the field of blended learning. However, the system could not be termed as a fully blended learning system. To elevate it into an adaptive learning system, the events framework was integrated into it to enable collection of SAI data which is essential for adaptive learning.

Medupal was implemented in java programming language and deployed in android platform. Integrating the events framework to Medupal blended learning system introduced a third mode (interactive mode) into the previous existing modes (school and remote modes) making it an adaptive learning system. The system was improved to make use of data collected by the events framework in order to adopt to individuals' learning model. Figure 5.1 shows an overview of the Medupal system architecture designed using agile and prototype engineering processes. The architecture comprised of three sub-systems: a native mobile client, a backend system and Cloudant system.

The events framework was developed in java and packaged as a library. To integrate it into Medupal system a developer imported the jar file into the system as a library and added the configurations. The event framework can be configured to work with the three sub-system: to collect student activity data it must be configure within the mobile client, to synchronise collected data with Cloudant cloud sub-system it requires the transfer transport protocol and access credentials of account configured in order to dump the SAI data, finally, to connect to the backend for SAI data analyses it must be configure to expose relevant data to the backend sub-system.

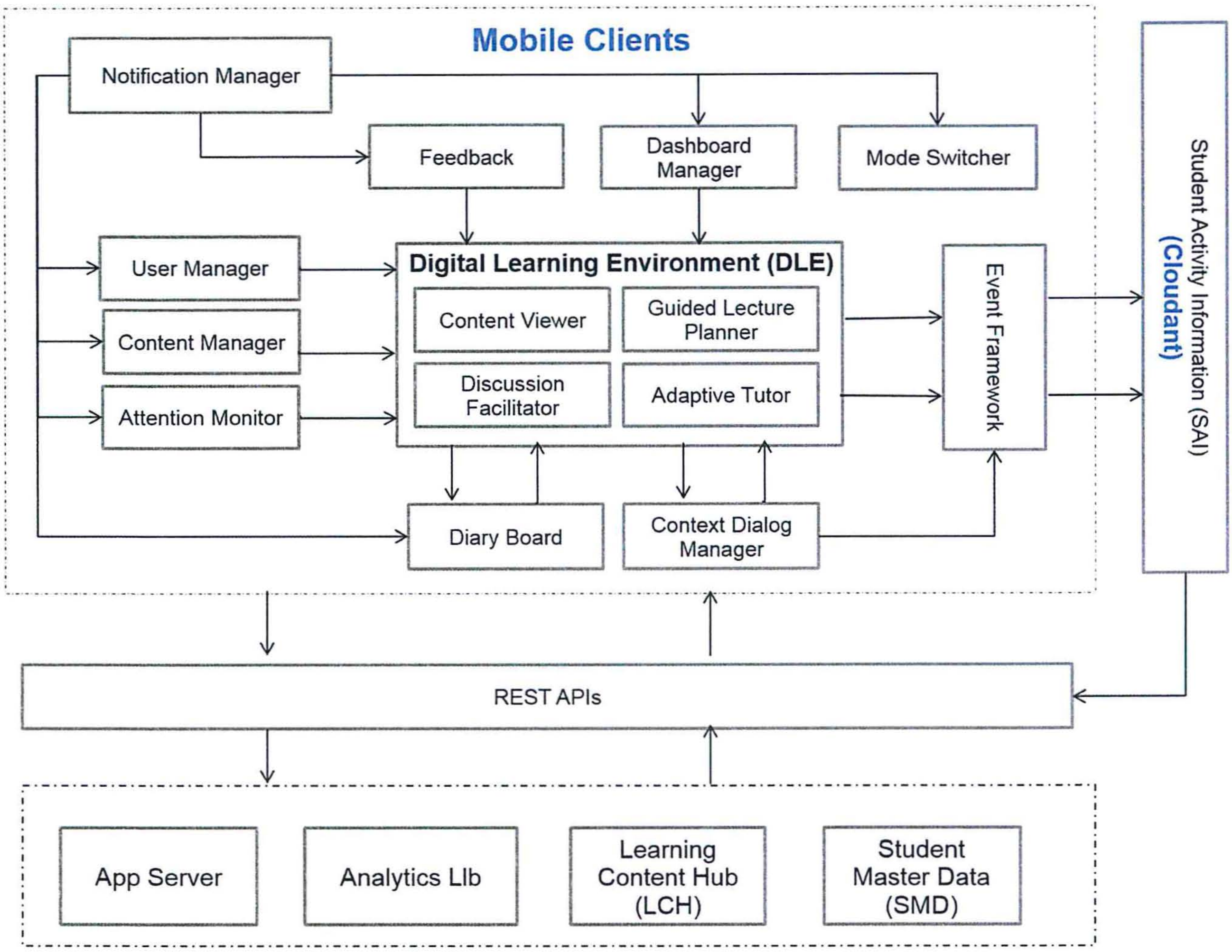

Figure 5.1: Medupal System Architecture

5.1.1 Native Mobile Application

Based on user requirements collected from the workshops, Medupal system's core components were redesigned and built in Android platform. The events framework was integrated and configured into the system for SAI data collection. Since the mobile client was designed to accommodate both the teacher and student, different configurations had to be done on each mobile client (teachers' mobile client and students' mobile client).

a) Digital Learning Environment

Digital Learning Environment (DLE) comprises of content viewer components. Content viewers facilitates capturing of content level interaction data and they are of three kinds: text document (pdf) viewer, video player and quiz viewer. To capture document events (i.e. page numbers visited, time spent per page, zoom, etc.) the events frameworks' JSON text document was configured to open when a text document is opened and closed when the viewer is closed. To capture events from video player (i.e. play, stop, rewind, forward, time, etc.) the multimedia JSON document of events framework is used and was configured to capture these events on open and stops of the video player. Finally, to capture performance events a quiz viewer was configured. The three documents were stored locally and latter synchronised to Cloudant sub-system once an Internet connection was available. Appendix B shows figures of the various document viewers.

b) Manager Components

Application manager components are responsible in managing application data in different levels. The managers comprise of validation, encryption and error handling algorithms, which ensures data consistency. Some of the manager components implemented include: user manager which is responsible user creation as well as deletion and access level restriction, content manager manages storage and retrieval of content, download and deletion of content, notification manager tracks feedback and questions sent via the application.

5.1.2 System Backend

The system backend is comprised of five components: Application Server, Learning Content Hub (LCH), Students Master Data (SMD), Analytic Library and REST APIs. The application server is implemented using Moodle Content Management System. Moodle is a free open-source software learning management system written on PHP and distributed under General Public License (GNU). LCM and SMD are managed using Moodle. The APIs component is developed in java and deployed in Bluemix cloud, its REST endpoints are exposed to be consumed by the mobile clients.

5.2 System Testing

System testing was done extensively in all modules, both at the framework development level and integration into a blended learning platform. The testing lifecycle was useful because it aided the researcher in identifying whether or not the research objectives were met. It was also useful in identifying what other improvements would be necessary for future enhancement of the framework. The following are the three broad areas where testing was carried out: framework functionality, system testing and system usability.

5.2.1 Functionality Testing

Black box testing was used to test if specifications and requirements define earlier were met in system implementation. This was done by providing inputs to test the system, then observing the results to examine if it conforms to the functionality it was intended for. These tests were done when the events framework was integrated into the blende learning system. In this section a detailed description of tests done on the functions of the framework is highlighted. All tests were done using Espresso a UI testing framework suitable for functional UI testing. Table 5.1 and 5.2 shows the various functional test cases carried out.

a) **Test case on user sentiments collection**

On successful login to the system, or at any point of interaction within the system the user would be prompted to answer a personal question to capture their general sentiments (their general mood for the day, course understanding or a general view to a random view). Table 5.1 shows the test that was done to collect user sentiments.

Table 5.1: Sentiments Collection Test Case

Test Case	User sentiment collection test		
Description	Captures students general mood throughout the day based on course understanding or temperament.		
Pre-condition	Student should be registered to use the system.		
Process	Activity	Expected results	Results: Pass/Fail
1	The student login to the system	Navigate to home page and prompt student to answer a personal question	Pass
2	Click on avatar at the top section of drawer menu.	Display an array of sentiment similes for student to pick from	Pass
3	Click on one of the displayed avatars	Prompt probing for more information depending on a selected avatar.	Pass
4	Pick of the provided reasons to finish	Close the sentiment screen and display selected avatar at top section of the drawer.	Pass

b) Test case on visualization generation

One of the major functionality of the system was to generate visualization from collected data in a way that a user could draw insights that are easier to understand and make sense of. An example is how a learners' performance correlates with their engagement. Table 5.2 shows the test case done to generate performance verses engagement relation visualization.

Table 5.2: Generate Visualizations Use Case

Test Case	Visualization/Insight generation		
Description	Generate insights for the teachers that are easier to understand and adopt based on a subject.		
Pre-conditions	Teacher loads collected interaction, performance and contextual student data		
Process	Activity	Expected results	Results: Pass/Fail
1	Teacher login to the system	Display a dashboard showing performance, engagement and understanding based on the subject they teach.	Pass
2	Select between performance, engagement and understanding to generate overall class visualization.	Display generated visualization on the right side.	Pass
3	Click on a visualization item to view students level visualization.	Generate deeper level visualization showing all students in the class.	Pass.

5.2.2 System Integration Testing

White-box testing was done to the system to determine how well the framework as a component works together with the other systems' components. The other system components include: Cloudant remote database where all collected data events are stored, content reader responsible for generation of content-level interaction and finally the content server where content is downloaded from and uploaded to via Moodle. The results of the test are shown in Table 5.3.

Table 5.3: Events Framework Integration Test Case

Test Case	System Integration Test		
Description	Determine how well the events framework fits in the blended learning system.		
Pre-condition	The event framework is integrated into the system and all other components are working well		
Process	Activity	Expected results	Results: Pass/Fail
One	Change user sentiment avatar at the top section of the drawer	Text JSON document is uploaded into Cloudant DBaaS.	Pass
Two	Open a vide content item send fast forward to preview	Multimedia JSON document is uploaded to Cloudant DBaaS	Pass
Three	Attempt a quiz and submit for grading	Performance JSON document is uploaded to Cloudant DBaaS	Pass

5.2.3 Acceptance Testing

A black-box test to determine whether the framework met the intended specification and satisfied the stakeholders (students, educators, etc.) requirements was done. To conduct this test, the researcher created a set of pre-defined scenarios and test cases, which were used to come up with research questions given to the target population. Table 5.4 depicts some the aspects that were considered.

Table 5.4: User Acceptance Test Case

Test Case	User Acceptance Testing
Description	Testing how well the system users perceive the system as a whole
Process	Expected results
Ability to access the application	The should be able to easily locate the application as was placed in the child zone and other device features were locked.
Testing aesthetics of the mobile application	Users should find the interface appealing
Testing ability of users to use the system functionality	User should use the system with ease
Testing response time	The application should be able to load data in less than 30 seconds.

5.2.4 Performance Testing

Tests were done to determine how the system performed in terms of responsiveness and stability before and after integrating the events framework into the system. This was necessary to investigate, measure, validate and verify the quality attributes of the events framework such as scalability, reliability and resource usage (i.e. bandwidth, battery and memory).

a) Load testing

Load testing were done to determine responsiveness of the system for both normal and peak load conditions. Apache JMeter tool was used to test how much the system server could handle. Table 5.5 shows some of the aspects that were considered.

Table 5.5: Medupal Load Test Case

Test Case	Load Testing		
Description	Evaluating performance acceptance criteria and target load levels		
Process	Activity	Expected Results	Results: Pass/Fail
1	Measure response time	Response time should not be more than 30 seconds	Pass
2	Measure throughput by having users perform a number of transactions at the same time	The system performance throughput reduces gradually with increased number n of transaction	Pass
3	Resource utilization	Systems resources should comfortably accommodate users transaction and data generated by the application	Pass

b) Stress Testing

The system was monitored after subjecting it to an overload to ensure that the system can sustain the stress. This was essential to determine how the system recovered from a stress phase as is critical and most likely to happen in production environment. The reason for performing this test were: to monitor system performance during failure, verify that system saves data before crashing and to verify if unexpected failures do not cause security issues. Table 5.6 shows Medupal stress test case.

Table 5.6: Medupal Stress Testing

Test Case	Stress Testing		
Description	Monitor how the system performs when subjected to overload.		
Process	Activity	Expected Results	Results: Pass/Fail
1	How does the system behave when maximum number of users are logged into the system at the same time	System performs well during failures	Pass
2	All user performing the critical operation at the same time (e.g. downloading content)	Does system save downloaded segment and resume download	Pass
3	All user accessing same file at the same time	System prints a meaningful error message and not a random exception	Pass
4	Hardware issue such as database down or an external component crashed	Verify if unexpected failure causes security issues.	Pass

5.2.5 Security Testing

In order to test any flaws and gaps in the framework from security and vulnerability point of view a security test was done. This was important since the framework involved collecting learners' personal data. The most important aspects that were considered included: confidentiality, integrity, authentication, data security and validation. The results of security test were shown in Table 5.7.

Table 5.7: Security Test Case

Test Case	Security Testing		
Description	Testing security of the adaptive learning system as a whole		
Process	Activity	Expected results	Results: Pass/Fail
User authentication	User provides username and password so as to access the system	Unlock the system for use	Pass
Password encryption	Password encrypted using md5 before storing in the database and in local cache	Hashes stored password should match the right user provided password after hashing	Pass
User access level	Separation of user levels.	Only allow access to information the user has right to.	Pass

Chapter 6: Discussion of Research Findings

The first objective which was to investigate the available learning technologies in blended learning environment was extensively covered in chapter two of this study. Analysing of the second objective looking to analyse existing applications for adaptive learning technologies in blended learning environment was also covered in chapter two above. After careful analysis of collected data through the configurable event framework, the insights drawn has proven to be of major importance to the emerging field of adaptive learning. The framework gathered interaction data both explicitly and implicitly. This section sort to show how objective three and four in subsection 1.3 was achieved.

6.1 Discussion of Post Data Analysis and User Test Results

To design a configurable event framework that would enable collection of fine-grained data as highlighted in objective three, the researcher conducted a limited pilot spanning for a period of 4 weeks with a target population of 22 pupils attending standard 5 at a local primary school. Only two subjects were covered for the pilot, Mathematics and Science. Two teachers conducting these subjects were instrumental in ensuring the success of the pilot. The pupils were already familiar with the blended learning technology as they were already using tablets in class for course content delivery. This came in handy since the adoption was seamless and there were minimal user experience issues.

With the help of the researcher the two teachers uploaded the learning materials they had prepared earlier into the system through the backend platform supported by Moodle. Learning materials were in form of lecture slides, short videos and quizzes. The lessons were 35 minutes long and time was organised as follows; 2 minutes to download contents unlocked and pushed to the students' tablets by the teacher, 20 to 30 minutes for content delivery both through the chalkboard and tablet content reference, 10 minutes to complete a short quiz, and finally 3 minutes for question and answer.

While students used the platform during the lesson, the framework collected data around user engagement, tests performance and sentiments. Student used the last three minutes of the lesson to give feedback on the lesson and also post questions using the platform. The teacher would read through the questions and either give an answer in class or respond to the questions later in the day. In section 6.2 the researcher described and discussed results obtained from analysis of captured data and how it fits in adapting learners within a blended learning environment. In section 6.3, the researcher analysed how objectives were met and validated the hypothesis.

6.2 Analysis of Data Results

For ease of understanding, learners' events data collected through the framework would be referred to as Student Activity Information (SAI). This information is representative of external contextual and application content level interaction events collected from content viewing, performance from assessment and environment context collected using the in-built device sensors.

6.2.1 Analysis of Class Alignment

The term "class" here refers to active learning session with a teacher delivering course materials to learners in a blended learning environment. From SAI data collected during a class session, the researcher tried to measure the level of leaners' engagement as the teacher was going through learning materials. In this case we will consider a mathematics lesson where the teacher was teaching a topic on Least Common Multiples (LCM) of numbers. When the researcher analysed the lessons Students Activity Information (SAI) as shown in Figure 6.1, it was found that the teacher's attention was on slide 4 (Figure 6.3, right) of the learning content. However, Figure 6.2 shows that most of the students were concentrated on slide 3 (Figure 6.1, left).

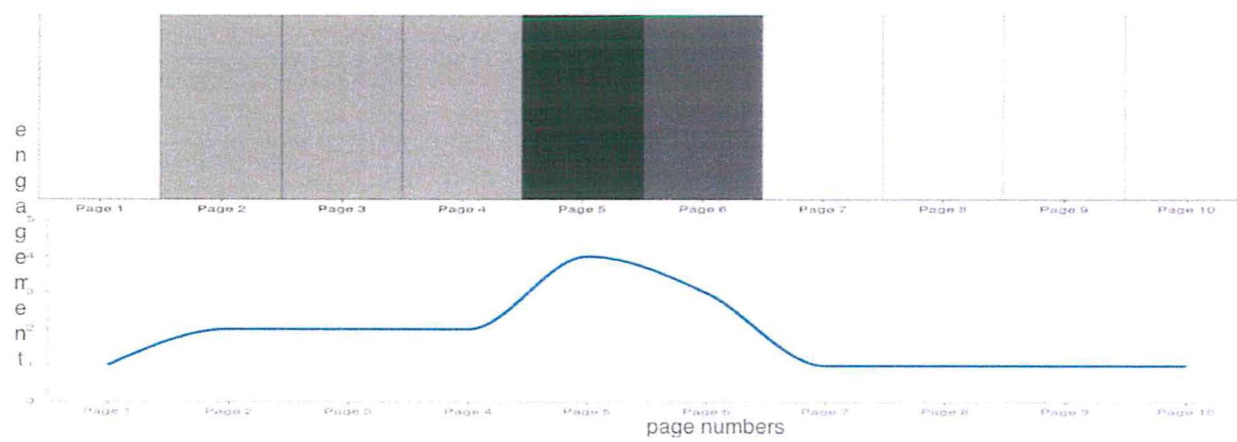

Figure 6.1: Teachers engagement with LCM of numbers presentation content item

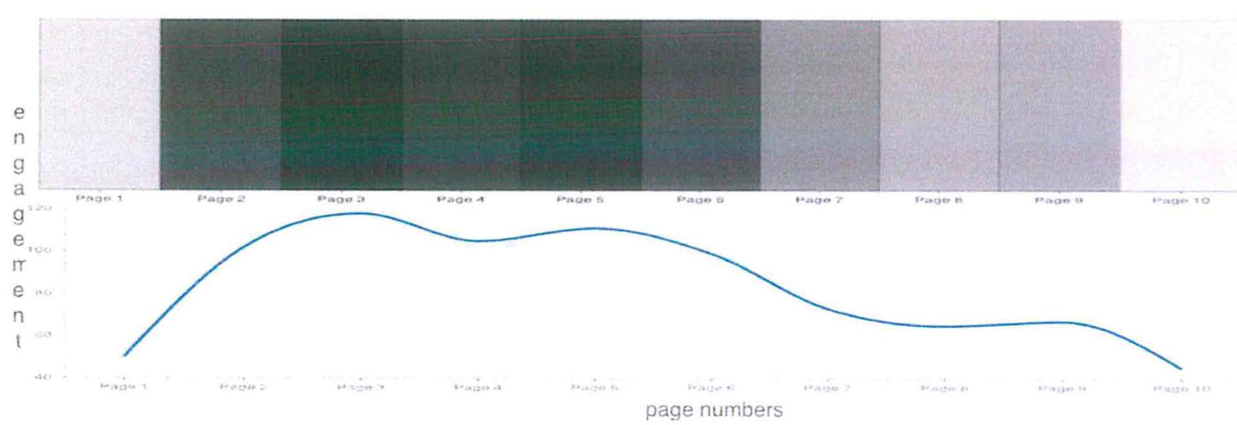

Figure 6.2: Average class engagement with LCM of numbers content item

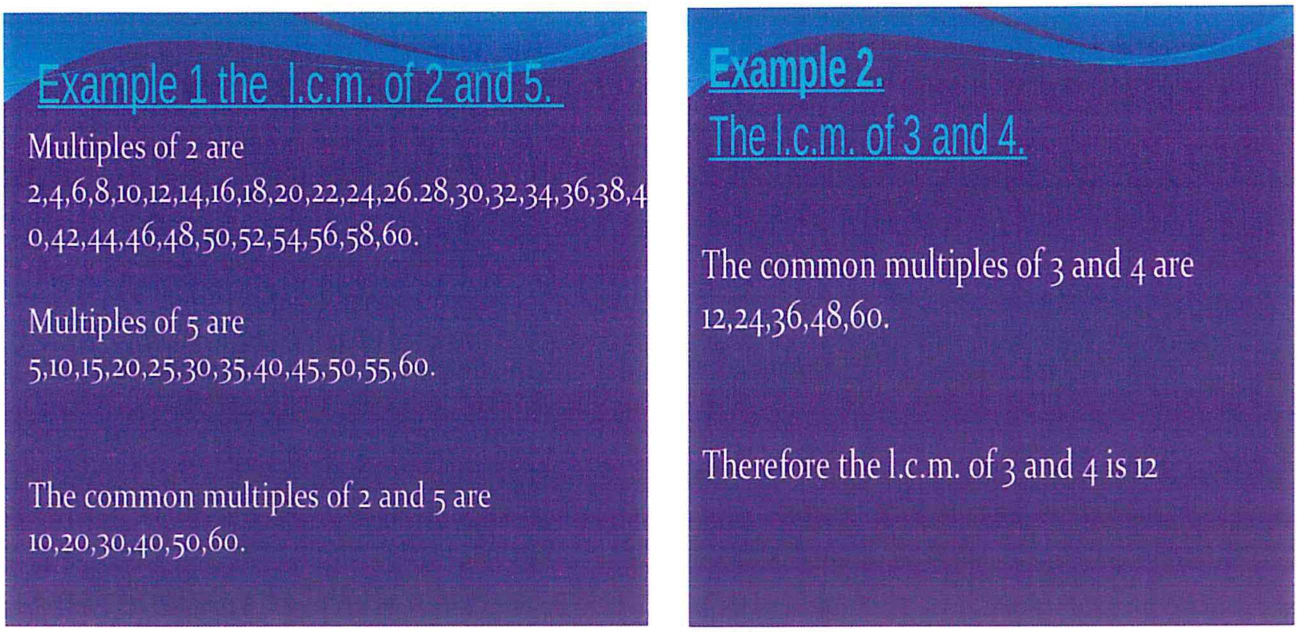

Figure 6.3: Slide 3 (left) and slide 5 (right) of the LCM of numbers content item

From the insights above deeper analysis were done to get an understanding of what could have caused the misalignment. The analysis revealed that slide 3 was heavily packed with examples, which were difficult for students to comprehend in the given short period of time. However, this kind of deep analysis is hard to design and need more specialization in the future. From this analysis there were interesting findings that the teacher could make use of: one is to simplify the examples in slide 3 and secondly to allocate more time for the lesson.

This analysis was also useful in drawing attention to how learning activities and learning contents are prepared and used. Most teachers reuse content from previous years without updating or revising content of the lecture notes. On the other hand, teachers usually don't get feedback on content item they used in class (e.g. on difficulty level, comprehension burden and illustration richness). With the help of SAI analysis, the teachers will be well advised in preparing and revising lecture notes for future lessons.

6.2.2 Analysis of Performance Based on Quiz

From the Student Activity Information (SAI) we also analysed performance data of students based on the assessment/quizzes done for Mathematics and Science. For this analysis the researchers goal was to:

i) Understand the relationship of time-spent on quiz in relation to perforce.
ii) Rank difficulty of quiz based on performance and time spent.
iii) Profile students based on quiz attempts patterns.

It should be noted that the amount of time to attempt a quiz was not pre-assigned. The teachers, based on their experience determined how log a quiz should take. Figure 6.4 shows total time taken to complete 7 quizzes taken for the mathematics subject plotted against the scores.

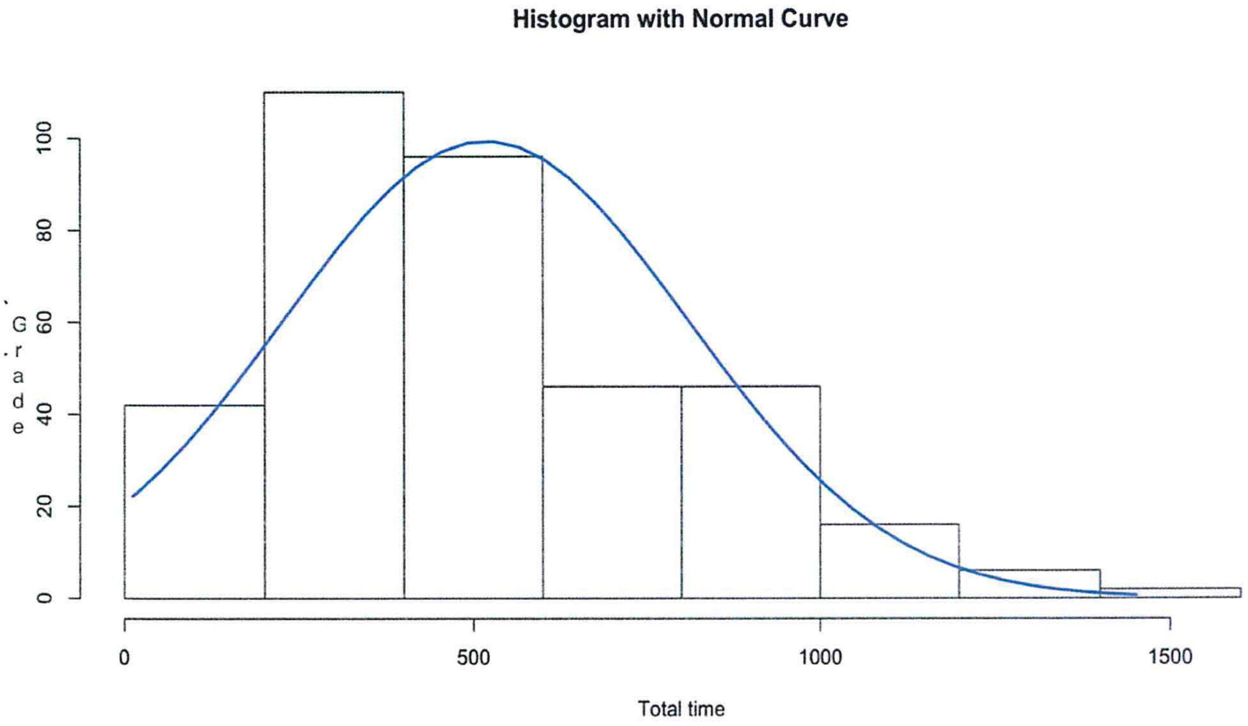

Figure 6.4: Total time taken to complete a quiz against the grade

To achieve the first goal of understanding the relationship of time spent on each quiz with respect to performance, the researcher further plotted a total time distribution. Figure 6.5 shows a linear and local regression for the 7 quizzes.

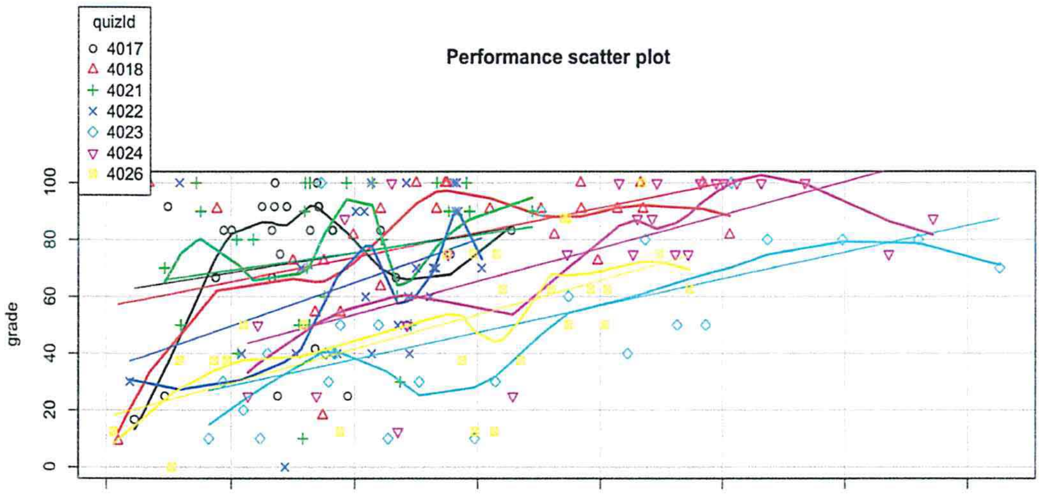

Figure 6.5: Local and linear regression scatter plot for the 7 quizzes

From linear regression, the researcher noted that there is a positive correlation between time-spent and performance on each quiz. The more the time spent the more likely that the performance improved. However, the researcher also noted a drop in performance from the subsequent quizzes. The 7 quizzes were set from the various topics taught in mathematics subject. To understand why class performance dropped the researcher looked at the individual topics and their relationship on concept dependency. Table 6.1 show the class performance in three subsequent topics, which are Least Common Multiples (LCM), Subtraction of Mixed Numbers (SMN) and Addition and Subtraction of Fractions (ASF).

Table 6.1: Comparison of Class Performance for the three sub-sequent Topics

Percentage of class performance per quiz			
Score	LCM	SMN	ASF
>75%	69.23	26.92	26.92
50% to 75%	23.08	34.62	23.08
< 50%	7.69	38.46	50

The topics are arranged in order with preceding topic being a prerequisite to the next in sequence. For LCM, which was a prerequisite topic for the others, the performance was commendable with 69.23% of the class (about 15 students) scored 75% and above, 23.08% of class (5 students) scored 50% and above but below 75%, and only 2 students scored below 50%. However, the class performance dropped in the subsequent topic SMN as shown in Table 6.1 second column. On the other hand, we noted a positive correlation between time-spent on quiz and performance. Shorter time period was allocated to the quizzes covering the subsequent lessons.

In the second goal the researcher looked to rank difficulty of quizzes based on performance and time-spent. While analysing the performance, it was noted that some student attempted the same quiz up to 6 times perhaps trying to achieve a maximum score. Figure 6.6 show unusual continuous data-points from students where multiple attempts were made for the same quiz.

Students with ID 2,9, 16 and 18 showed a pattern of retaking the same quiz multiple of times. In each time we noted a slight increase in their performance. From these analysis the teacher would be able to point out students who guess answers in an attempt to game the system.

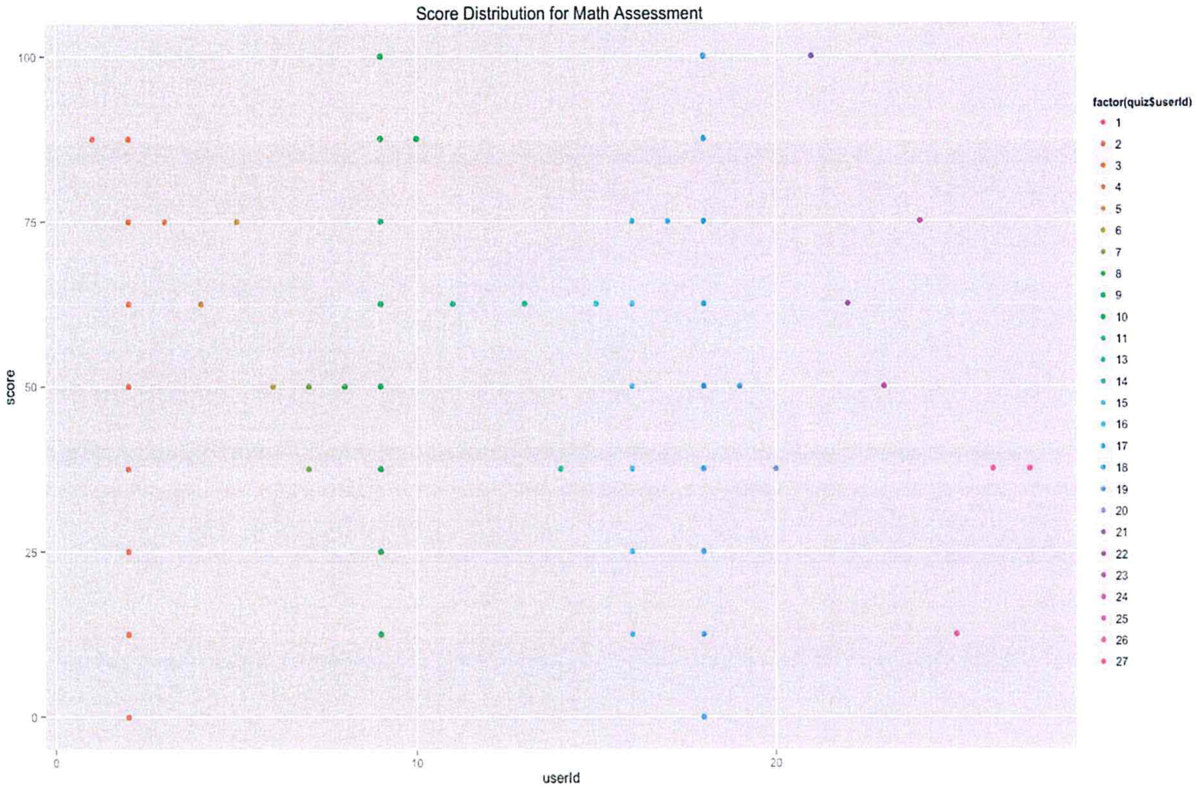

Figure 6.6: Student multiple attempts plot for the same quiz

6.2.3 Analysis of Engagement versus Performance

Based on quiz performance data extracted from the Students Activity Information (SAI), the researcher classified students into three groups; highly performing (score above 75%), average performing (score between 50% to 75%), and low performing (score less that 50%) students. Then a correlation between their performance in relation engagement with learning content was drawn. We discovered that on average high performing students had higher engagement with the content and thus they performed very well in the quizzes. Figure 6.7 shows the correlation of engagement to performance.

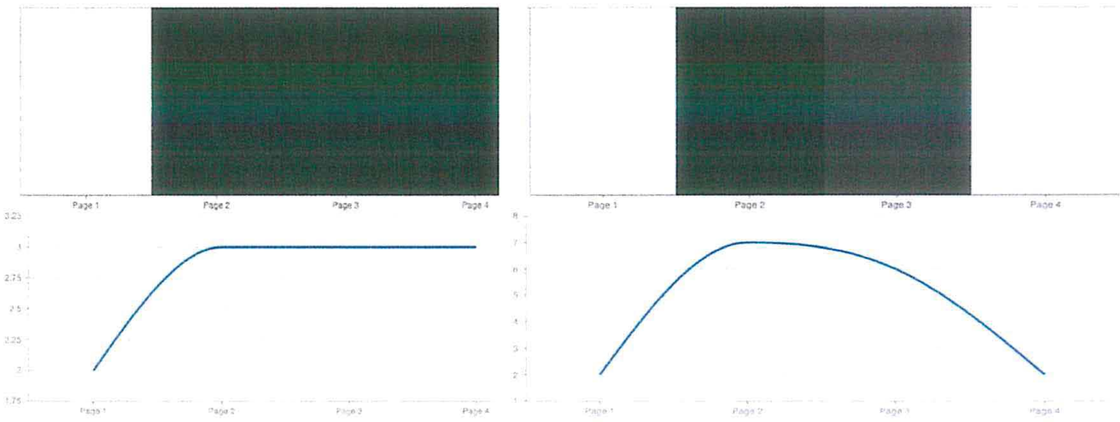

Figure 6.7: Positive relationship between engagement and performance

6.3 Discussion of User Tests Results

After successful completion of the pilot period, a post analysis meeting was held to get feedback from teachers and students who were the initial users of the system, the researcher distributed a review/feedback questionnaire (post-data analysis form) to the users. This was important so as to validate if the tool worked as expected in line to our objective four. The post-data analysis form was developed using google documents. Collected data was later exported and uploaded to the cloud storage for later analysis. The questionnaire used can be found in Appendix B.

6.3.1 Usability testing results

Ease of use of the system was one of the test, the researcher seeked to look at. All functions of the sytem were tested from login, content download and interaction to general navigation. Results for each reseach questionwere independently analysed and the findings are discussed below.

a) Launching application

For the student users, the application was loaded under the kids environment locking other application from access to minimise distruction from the sole objective of the study. This made it easy in locating the application for the students. For the teachers the application was not placed in the kids zone but was easily available from the tablets home page. Here the researcher wanted to know how wasy it was to launch the apllication from their tablets. Figure 6.8 shows the responses provided by the respondents. 18 responses were received for this question. 17 students responded and agreed that launching the application was easy. However, one of the user who was not conversant with the digital devices had difficulties locating and launching the appliaction.

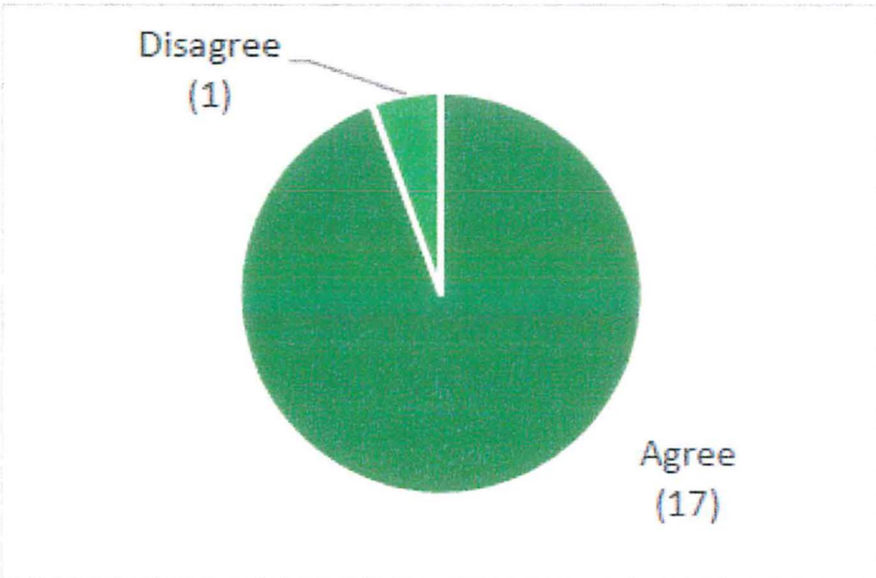

Figure 6.8: Ease of launching the application

b) Aesthetic Value of Application

The post-questionaire asked the user if they felt that the application was generally appealing to the eyes or not. The response received indicated that the user liked the look and feel of the application in general. This was necessary in data collection as would make user remain attracted and engaged to the system. Figure 6.9 shows the ratio of response received. Out of the 18 respondent, 16 of them agreed that the system was aesthetically apealing while 2 of them did not find the apllication appealing.

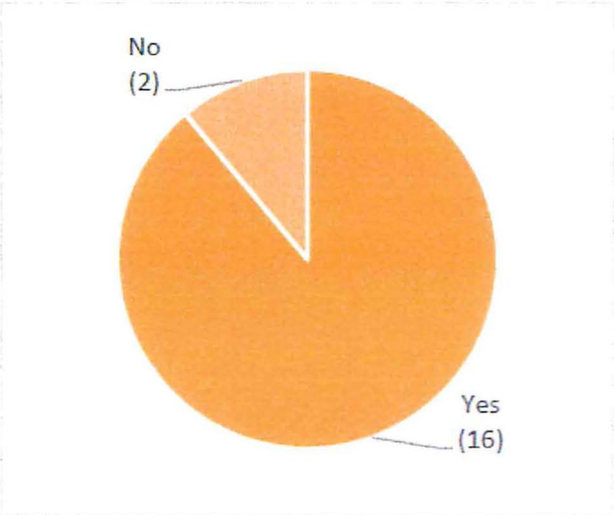

Figure 6.9: Aesthetic Value of the Application

c) Navigability within the Application

The various menu options of the application were strategically located on various panels observing principles of good user interface design. To test this the user were asked if they found it easy locating the menu items. Figure 6.10 shows that 17 of the respondents found it easy to navigate aroung the application.

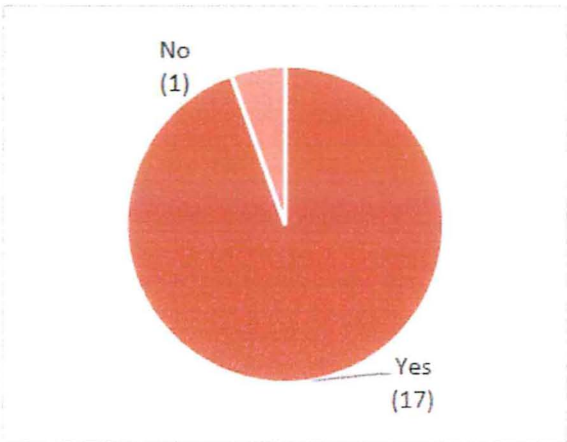

Figure 6.10: Locating Menu Items in the Application

d) Responsiveness of the Application

The researcher also sought to know if adding the event framework affected the responsiveness of the system in any manner when being used. Users were asked if they found it easy to interact with the application from the point of login, content download and interaction, content viewing and taking a quiz. For teachers, they were asked if the visualizations were generated first enough. 12% of the respondents i.e. 3 users found it slow in terms of response time. From their opinion the users thought the system was slagging due to poor Internet connection. In future work (section 7.3) the researcher has suggested application of technologies such as cooperative downloading in sharing of resources such as bandwidth to speedup the download process. Figure 6.11 shows response to the question if the application was responsive enough.

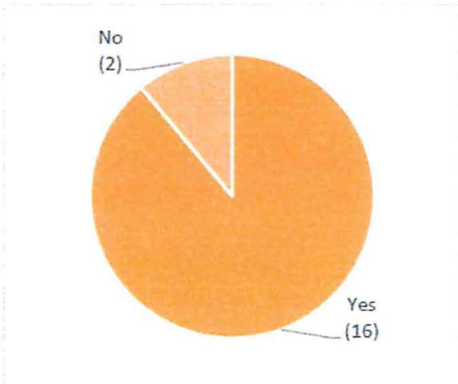

Figure 6.11: Responsiveness of Application

6.3.2 Functionality Testing Results

a) Generating Visualization in the Application

Eight teachers were given the system to use and later asked if they found it easy to generate visualizations necessary in drawing insights for adaptive learning. All of the 8 respondents agreed that it was easy to generate the visualization and were able make sense out of them and use them for better content delivery in the next lesson. Figure 6.12 indicates the unanimous response from the teachers.

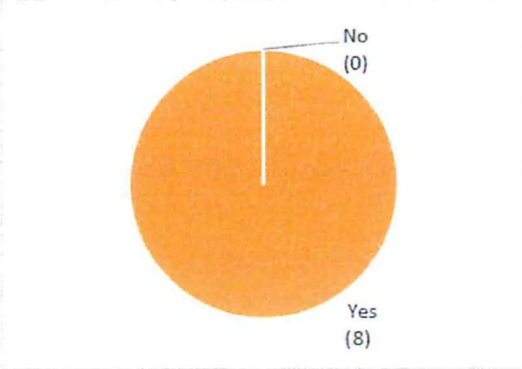

Figure 6.12: Ease of generating visualizations

b) Posting Questions and Feedback via the Mobile Application

One of the major objective for this study was to personalise interaction between teacher and student. By students asking questions directly to the teacher they would get direct answer. Also the teacher would get feedback and be able to assess general engagement of students. The reaseacher sought to know if it was easy to post questions and feedback via the application. Figure 6.13 shows 16 of the 18 respondents responded with a yes.

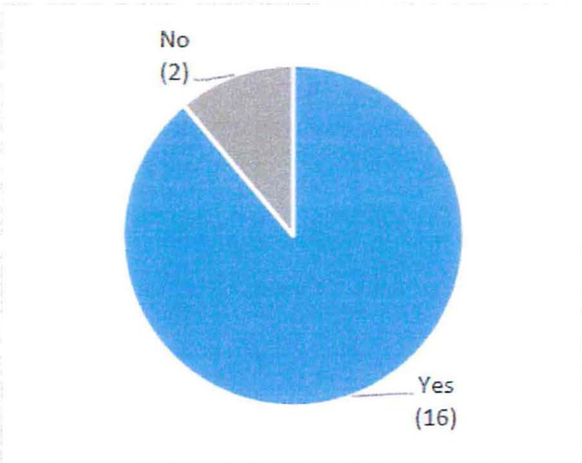

Figure 6.13: Ease of posting Questions/Feedback via the Application

c) Ability to Use Application Functionality

Users were asked to rate their overal experience while using various features within the application. In this question the researcher sought to know if the research met its purpose and if the users were comfortable using it and coming back again to the platform. Figure 6.14 shows how the repondent answered when asked if they had any challenges while using the system. 15 answered no while 3 admitted to encountering some challenges along the way. This was mainly attributed to constrained nature of mobile device resources such as low battery levels and insufficient bandwidth.

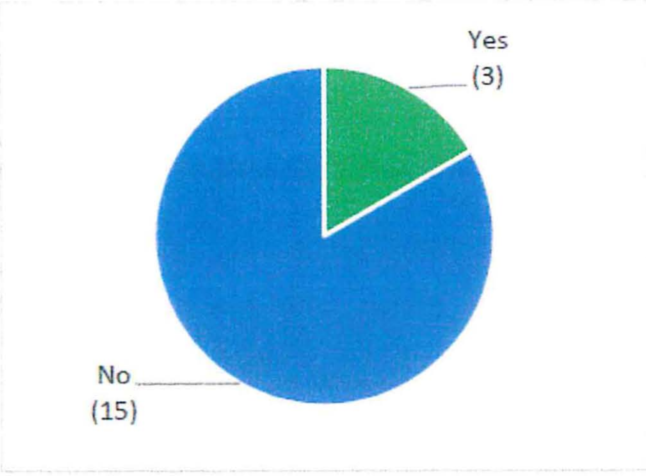

Figure 6.14: Ability to Use Application Functionalities

6.4 Discussion of Reserch Objectives

The research objectives were stated in section 1.3 and their corresponding research questions in section 1.4 in chapter one of this study. Data was colected from both primary and secondary sources, which enabled the researcher to meet the research objectives. To facilitate this a pilot study was carried out to collect data used in achieving some of the objectives. Howerver, other objectives were met at different chapters of this study as outlined below.

The first objective sought to investigate the existing adaptive learning technologies in a blended learning environment. This objective was met in chapter 2 through research from secondary sources and refferences made highlited in the reference section. Here the researcher looked at the existing adaptive learning technologies in a blended environment. The focus was in Kenyan schools where the ratio of teacher to students is very low, since the introduction of free pre-primary education. This has greatly contributed to high students dropout as there lack adaptive ways to offer personalised education. Some deliberate attempts to address this issue have been made, though, not sufficient enough. An approach to design a technological enhanced learning experiences crucial for the success of adaptive blended learning was reviewed. Some framework implementing this design were looked at, these includes: Open Education Resource (OER), and MLearning.

The second objective sought to review existing mobile devices, architectures, design and model of collecting learners' fine-grained contextual and sentiment data in a blended learning environment. Section 2.3, 2.4 and 2.5 helped achieve this objective. Section 2.3 looked at mobile technologies in the Kenyan market. The mobile market was seen to maintain an upward growth trend in terms of subscribers and penetration. The mobile network technologies essential in data transmission were also seen to have greatly evolved with more high speed Internet now available. Mobile application architectures were reviewed in section 2.4 with the researcher looking at mobile web architecture, native application architecture and the consideration for selecting the best mobile application architecture. Finally, in section 2.5 the researcher looked at the various built-in mobile phone sensors, as they are essential in collecting the learners' fine-grained contextual data.

The third objective was to analyse some of the existing applications for adaptive learning technologies in a blended environment, fine-grained data collections and events sources. This was achieved in section 2.6, 2.7 and 2.8. The researcher reviewed some of the research done in application of adaptive learning technologies in blended learning. These approaches were then compared with the proposed solution to outline how this study differs from the existing ones. The researcher reviewed some of the technologies to be used in developing the event framework and the sources of events to be used in instrumenting the event framework for adaptive learning.

Objective four, looked to understand how to design an extensible and configurable adaptive event framework that allows fine-grained sensor and contextual data capture was met partly in chapter 4 and 5. In chapter 4 the researcher came up with the designs flows and structures of the proposed framework. In chapter 5 the researcher developed and implemented the framework to meet the desired requirements of this study. Further, the two workshops held with both the teachers and learners separately helped in meeting this objective, where questions and observations were made to help understand the requirements. The workshops made it evident that there was a gap in personalised learning as both students and teachers were not contempt with the existing learning models. This study, therefore, had a strong justification for designing and developing a framework to collect contextual and sentiment data from learner to draw insights necessary in supporting adaptive learning.

The fifth, and final objective of this study was to integrate the developed framework in a new or existing blended learning system then tests the viability of the system. Tests were done in section 5.3 and the test results extensively analysed in section 6.3 of this study. Functionality, usability and security tests were all done on both the front-end and backend of the system. Test findings revealed that 83% of the users had no issues with the general workability of the system. This and other tests carried out helped the researcher identify some of the future work that could be carried out to improve on the system as outlined in section 7.3 of this study.

6.5 Summary of Research Findings

With increase in technology adoption across sectors, data collection is essential in driving decisions and improving outcomes in general. Adaptive learning has long been in existence, however minimal or no data on students' engagement and sentiments has been considered. With this data collected, deeper instrumentation will be carried out making it possible to detect learners' difficulties such as indecision and confusion.

From the collected Student Activity Information (SAI) data, the researcher was able to point out class misalignments, which the teachers had outlined as the major drawback in content delivery. With this data the instructors will now be able to detect if they are moving very first or too slow, how difficult the content is to understand, who is not understanding and suggestions on how to resolve these anomalies, all in real-time. From back in time teachers are known to reuse learning content from previous year as they ague that the curriculum doesn't change. However, this makes it hard to know which learning activities worked and which ones did not work as there lack feedback mechanism. With SAI data the teacher will be able to detect content that is hard to comprehend so as to simplify it accordingly. Time allocated to a lesson is also a major concern. It is hard to manage 35 minutes allocated to a class lesson without the help of data.

Overall, the objectives were met. The pilot period was instrumental in SAI data collection, which was later analysed to draw the findings. With the teacher looking at class alignment, time management, students' sentiment and how all these affects a learner's performance, engagement and understanding the findings were satisfactory. This will contribute to adaptive learning in leaps and bounds.

Chapter 7: Conclusions, Recommendations and Future Work

7.1 Conclusion

Mobile technology has rapidly grown across the world changing the face of communication in urban and remote areas. These devices are now fitted with numerous sensors, opening up their possibilities of use from only communication gargets to ubiquitous tools. According to Communication Authority of Kenya (2015), the mobile penetration stands at 88.1 per cent with 37.8 million subscribers. In response to this enormous growth in the mobile sector, companies, NGOs and government alike have realised the potential in using this tool to address today's world grand challenges. Education is one of the areas where this tool has been a great success. It has helped teachers and students gain access to meaningful content and tips regardless of their geographical location.

In this study the researcher leverages use of the mobile devices' network technology, sensors and other available resources to revolutionize adaptive learning in blended learning environments. To get started the researcher reviewed various literatures so as to gain understanding of adaptive learning technologies in blended learning environments. It was evident that more data is needed to understand and enhance students learning models.

This study presents a mechanism to collect user interaction data with the learning content, environment contextual data and personal sentiments provided by the student. With this information the researcher designed and implemented algorithms to draw relations and generate actionable insights to improve the students learning outcomes. The solution is packaged into an event framework comprising of four major components namely: sensing and estimation engine to capture the raw data from sensors and user provided data, rave engine to generate visualizations, events summarization comprising of algorithms that filters and map reduce the raw data to meaningful data and finally the event logs which is a data store implemented using Cloudant DBaaS.

The focus on student engagement, sentiment, and context (along with knowledge); mechanisms to infer these implicitly and explicitly; and using rich user models to provide several advanced services for teachers and students across multiple modes in a blended environment help to differentiate our approach from other related work. We reported on a very limited pilot and usability study that preliminarily demonstrated the practicality and benefits of this approach.

The solution was tested and integrated into a blended learning system for evaluation. A short pilot study was carried out and results were discussed in chapter 6 of this study. The findings indicated that adaptive learning technology could benefit greatly from the proposed solution, especially where speedy decisions and data to justify the actions taken is required. Furthermore, students too could make use of these insights to guide their learning in absence of the teacher. Our next step is to launch a larger deployment which will enable us to reach more users and generate more learning models that can be adopted across schools. In this light we can confidently conclude that the problem was solved.

7.2 Recommendations

From the field study conducted and the analysis of research findings, there were lots of discoveries and learning. The researcher proposes some crucial point that would be worth while noting in extending the developed system; they are highlighted below and could go a long way in guiding extensive research in this diverse area.

i) With more sensors being packed into the mobile device more events should be collected around the users' environment thus providing more data to be analysed.

ii) The event framework is a well-packaged library and is not only applicable to the education industry only. It can also be configured to collect data in other fields of study such IOT, medical diagnosis, health and fitness among others.

iii) In our adaptive learning case study, we could extend its capability to include image analysis. Facial expression can tell a lot about a person's emotional state. If this could be leveraged, adaptive decisions could be made more accurately.

iv) This study is not only applicable to pre-primary schools but should also be scaled up to accommodate higher learning institutions like secondary schools and universities.

v) Tablets, which were the preferred mobile device for this study faces various challenge such as insecurity (theft), constrained resources (memory, battery, bandwidth etc.), among others. The various stakeholders could join hand to help resolve these issues with government making such devices affordable through tax reduction.

7.3 Future work

With increasing innovation in technology and mobile devices in particular, many industries operations will be greatly disrupted. Newer ways of doing things will evolve as these devices get packed with newer and more advance sensors. As a result of this more features and component will keep on being added to the event framework. From this study the researcher highlighted some of the future work that could be done towards achieving cognitive adaptive learning. To achieve this more data needs to be collected. For future work the following should be done.

i) When faced with different situations, flickers of emotions pass over people's face before they can even control themselves. Since mobile devices are fitted with frontal facing camera it is easy to collect these micro emotions. Analysis of such data has applications in broad areas such as medical where facets are used to detect children with autism. In education this could be used to detect confused students and also level of engagement.

ii) Due to the mobility nature of mobile devices, various challenges are inevitable such as constrained resources available (battery life, memory and bandwidth intermittency). A lot have been done to try resolve these challenges ranging from having power backup to resolve issue of low battery and provision of affordable bandwidth package from telecom companies. Currently each device has to download content directly from server yet it is the same content needed by other users wasting on bandwidth and battery life. In future the framework will include a mechanism to make all available devices in a class setting to work collaboratively, sharing resources among each other to accomplish a task such as content download.

iii) Currently the event framework has only been tested in adaptive learning under education. The framework has numerous applications and will be tested in other areas going forward. This will add cognitive capabilities to the integrated application improving on decisions making.

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Appendices

Appendix A: Questionnaire

Questionnaire was used to gather post study feedback from the users. The aim was to gather feedback on usability of the blended learning application.

Post Questionaire

1. **Launching the application was easy**
   Mark only one oval.
   - ◯ Agree
   - ◯ Disagree
2. **Is the application generally appealing to the eye?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No
3. **Is the location of the menu items easy to find?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No
4. **Was the application responsive and seamless, especially during navigation?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No

5. **Did you fin it easy to post questions and feedback through the application?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No
6. **Looking at the general workability of the application, do you think your overall experience while using the application was positive?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No

Powered by Google Forms

Appendix B: Events Collection from Content Viewers

a) Sentiments Data Collection

Figure B.1 show the screen for collecting user sentiments. Students can give a general sentiment on how they are feeling which is very important. This would affect the pupil in class if not attended to. Changing the avatar on menu drawer top section sets sentiments. Figure 5.1 shows collection user sentiments.

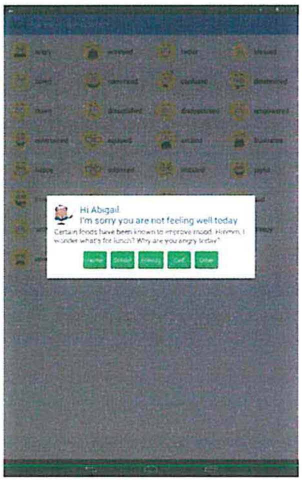
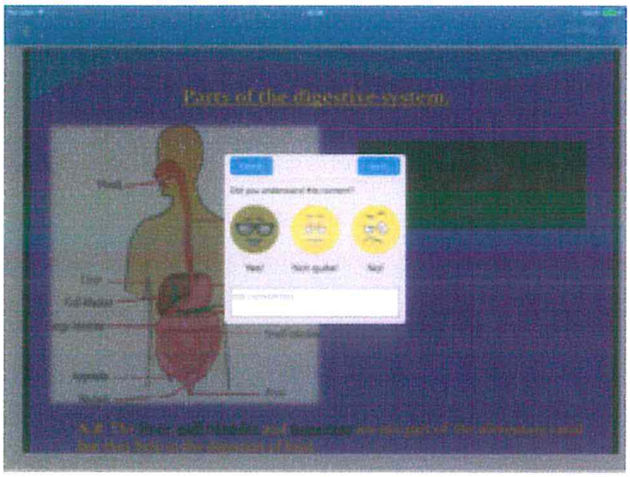


Figure B.1: User Sentiments Data Collection

b) Multimedia Data Collection

The event framework also collects content-based event as the student interacts with the reading material or a video clip. Contents can either be in pdf, ppt or video. Some of the events captured are forwarding, rewinding, pause, start, stop, zoom-in, zoom-out, hover, click, etc. The following figure 5.2 shows interaction with the content to facilitate collection of these events.



c) Performance Data Collection

Traditionally, the score attained in a particular test measures students' performance. To collect data, the event framework tracks all event involving a particular test i.e. number of attempt per question, amount of time spent in answering a question and mark scored. Figure 5.3 shows performance events collection.

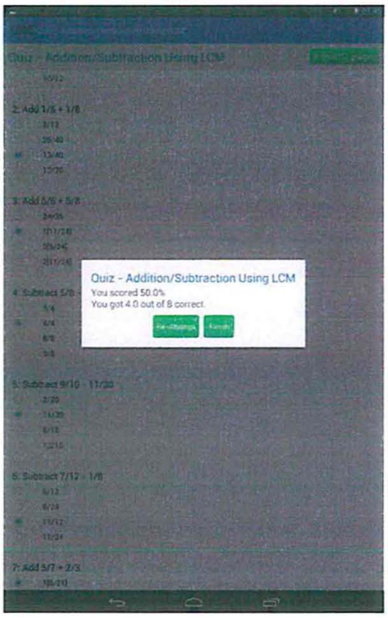


Figure 0.1: Content Interaction Data Collection

Appendix C: JSON Events Documents

a) Device Sensor-Level Events

The following JSON document illustrates an example of the events collected from device sensors in context of a learners' environment.


```
{
 "_id": "000bc98843844c69b2fb2561678d1e5a",
 "_rev": "1-11b11a3fdbb64e0e9ab66c6e2300072a",
 "SentimentEventList": {
  "sentimentType": "GENERAL_SENTIMENT",
  "EVENTLIST": {
   "SENTIMENT_OPENED": [
    {
     "timestamp": 1422688996803,
     "eventID": 1
    }
   ],
   "SENTIMENT_CLOSED": [
    {
     "timestamp": 1422689066075,
     "eventID": 10
```

```
      }
     ],
     "MICROPHONE": [
      {
       "timestamp": 1422688997114,
       "micNoiseLevel": "low",
       "eventID": 2
      },
      {
       "timestamp": 1422689012470,
       "micNoiseLevel": "low",
       "eventID": 4
      },
     ],
     "ACCELEROMETER": [
      {
       "motion": "stationary",
       "timestamp": 1422689011839,
       "eventID": 3
      },
      {
       "motion": "stationary",
       "timestamp": 1422689041849,
       "eventID": 6
      }
     ],
     "TIME_SENTIMENT": [
      {
       "timestamp": 1422689066074,
       "wakeTime": "7:00",
       "sentiment": "sleepy",
       "eventID": 9,
       "sentiment_time": 1422689066049,
       "sentiment_value": -1,
       "sleepTime": "11:00"
      }
     ]
    },
    "userId": 6
  }
}
```

b) Content Interaction Events

The following JSON document illustrates an example of content interaction events collected when a user opens a reading content such as pdf or video.

```
{
 "_id": "002823b4023f45c6b036c275bdd0b08e",
 "_rev": "1-0175b0b9b7ed4d53835aa1e2d09980ae",
 "DocumentEventList": {
```

"contentType": "pdf",
"courseId": 2,
"repositoryId": 2,
"contentId": 8,
"EVENTLIST": {
 "CONTENT_OPEN": [
  {
   "timestamp": 1417680553254,
   "pageNumber": 1,
   "eventID": 1
  }
 ],
 "PREVIOUS": [
  {
   "timestamp": 1417680587175,
   "newPageNumber": 3,
   "oldPageNumber": 4,
   "eventID": 6
  },
  {
   "timestamp": 1417680651389,
   "newPageNumber": 4,
   "oldPageNumber": 5,
   "eventID": 13
  },

 ],
 "SENTIMENT": [
  {
   "timestamp": 1417680903030,
   "pageNumber": 2,
   "eventID": 68,
   "weight": 0,
   "sentiment_value": "FAIR",
   "sentiment_comment": ""
  }
 ],
 "CONTENT_CLOSED": [
  {
   "timestamp": 1417680903507,
   "pageNumber": 2,
   "eventID": 69,
   "total_page": 11
  }
 ],
 "MICROPHONE": [
  {
   "timestamp": 1417680553625,
   "micNoiseLevel": "low",
   "eventID": 2
  },
  {

"timestamp": 1417680584292,
"micNoiseLevel": "medium",
"eventID": 5
},
{
"timestamp": 1417680722309,
"micNoiseLevel": "high",
"eventID": 26
},
],
"ACCELEROMETER": [
{
"motion": "stationary",
"timestamp": 1417680568339,
"eventID": 3
},
{
"motion": "stationary",
"timestamp": 1417680598352,
"eventID": 7
}
]
},
"userId": 19
}
}

c) Performance Events

The following JSON documents show events collected from a test assessment. The document tracks the number of times the student attempted the quiz, number of attempted questions and the grade

{
"_id": "02a28feb814a455e9d9e1c69e4fa4121",
"_rev": "1-8509814b416b431da63bf56a8135ee2e",
"AssessmentEventDocument": {
"contentType": "Assessment",
"courseId": 2,
"repositoryId": 4007,
"contentId": 4007,
"EVENTLIST": {
"SUBMIT_QUIZ": [
{
"timestamp": 1423212227115,
"eventID": 4
}
],
"QUESTIONS_UNATTEMPTED": [
{
"timestamp": 1423212227907,
"eventID": 6,
"questionID": 64

```
      }
    ],
    "GPS": [
      {
        "timestamp": 1423212225773,
        "eventID": 2,
        "longitude": 36.7575858,
        "latitude": -1.3503453
      }
    ],
    "GRADE": [
      {
        "total": 2,
        "grade": 1,
        "eventID": 5
      }
    ],
    "CONTENT_CLOSED": [
      {
        "timestamp": 1423212227910,
        "total_time": 3233,
        "eventID": 7
      }
    ],
    "QUESTIONS_ATTEMPT": [
      {
        "timestamp": 1423212226325,
        "answerID": 232,
        "eventID": 3,
        "correct": true,
        "questionID": 65
      }
    ],
    "MICROPHONE": [
      {
        "timestamp": 1423212225273,
        "micNoiseLevel": "low",
        "eventID": 1
      }
    ]
  },
  "userId": 2
 }
}
```

Appendices D: Map Reduce Function

MapReduce capabilities of Cloudant were used to manage and manipulate views and were stored as secondary indexes. Sample JavaScript map reduce function to describe such a view is shown below.

In this example, the function returns the number of times a particular content item was accessed by the class.

```
"map": "function(doc) {
//MAP DOCUMENTS OF TYPE PDF(DocumentEventList)AND
    VIDEO(VideoEventsDocument)
if (doc.DocumentEventList) {
   emit({
      "courseId": doc.DocumentEventList.courseId,
      "contentId": doc.DocumentEventList.contentId
       //EMIT THE KEYS, courseId AND contentId OF
           THE DOCUMENTS OF MATCHING TYPE
      }
      //EMIT THE VALUE 1 FOR EACH KEY
       , 1);
 }else if (doc.VideoEventsDocument) {
     emit({
        "courseId": doc.VideoEventsDocument.courseId
        ,
        "contentId": doc.VideoEventsDocument.
            contentId
     }, 1);
}
}",
"reduce": "_sum"
```