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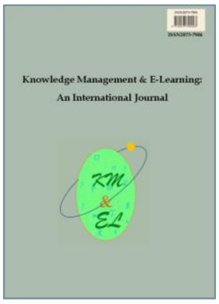

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Mobile-based system for cost-effective e-learning contents delivery in resource and bandwidth constrained learning environments

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Mobile-based system for cost-effective e-learning contents delivery in resource and bandwidth constrained learning environments

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Abstract: The advancement in Information and Communication Technologies (ICTs) has brought opportunities for the development of Smart Cities. The Smart City uses ICT to enhance performance and wellbeing, to reduce costs and resource consumption, and to engage more effectively and actively with its citizens. In particular, the education sector is adopting new ways of learning in Higher Education Institutions (HEIs) through e-learning systems. While these opportunities exist, e-learning content delivery and accessibility in third world countries like Tanzania is still a challenge due to resource and network constrained environments. The challenges include: high cost of bandwidth connection and usage; high dependency on the Internet; limited mobility and portability features; inaccessibility during the offline period and shortage of ICT facilities. In this paper, we investigate the use of mobile technology to sustainably support education and skills development particularly in developing countries. Specifically, we propose a Cost-effective Mobile Based Learning Content Delivery system for resource and network constrained environments. This system can be applied to cost-effectively broaden and support education in many cities around the world, which are approaching the 'Smart City' concept in their own way, even with less available technology infrastructure. Therefore, the proposed solution has the potential to reduce the cost of the bandwidth usage, and cut down the server workload and the Internet usage overhead by synchronizing learning contents from some remote server to a local database in the user's device for offline use. It will also improve the quality of experience and participation of learners as well as facilitate mobility and portability in learning activities, which also supports the all-compassing learning experience in a Smart City.

Keywords: Mobile; Smart city; e-Learning; Synchronization and cache; Offline

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1. Introduction

Higher Education Institutions (HEIs) require a cost-effective and efficient system for the delivery and accessibility of learning contents which favours personalized and innovative learning while minimizing the development and operation cost. However, it has been reported by Bakari, Mbwette, and Salaam (2010) that persistent internet connectivity in third world countries is still a major challenge for both public and private HEIs.

There are existing Learning Management Systems (LMS), such as Moodle, which are adopted by the majority of HEIs in developing countries. Moodle is a web-based LMS which highly depends on the Internet for high performance and reliability. Despite the great opportunity brought about by Moodle and other LMSs; learning content delivery and accessibility is still a challenge in developing countries due to the constrain in resources and bandwidth (Mtega, Bernard, & Dettu, 2013; Milovanović, 2010; Trifonova, Knapp, Ronchetti, & Gamper, 2004; Trifonova, 2006; Jayakumar, Manimaran, & Gopianand, 2013; Swarts & Wachira, 2010). These challenges include the high cost of the band width usage; the limited mobility and portability features; the un-accessibility of e-learning contents during the offline period; the server workloads and the Internet usage overhead. Therefore, there is a need for a technology to bridge these gaps. The adaptation of mobile technologies is growing at a rapid pace, bringing along a lot of opportunities that can enhance the learning contents delivery and accessibility for HEIs within resource and network constrained environments. The survey conducted in this study, found that the majority of HEIs in Tanzania own basic ICT infrastructures such as Local Area Network (LAN), Internet, computers, and mobile technology that form the basis for the establishment of e-learning. Furthermore, it was found that the majority of students owns more than one mobile device which can be used as a vehicle to facilitate the access to learning contents (Mahenge, Mwangoka, & Simba, 2014).

Previous studies (Momo, 2008; MLE, 2009) proposed Mobile Moodle (Momo) and Mobile Learning Engine (MLE). Both applications are based on J2ME, while the MLE project developed a client application and an additional web version to access Moodle courses from mobile browsers. However, the structure of the XML schema used in MLE caused problems, such as high memory requirement and delay in response time. Piguillem et al. (2012) proposed Moodbile; the android application that supports both online and offline accessibility by storing offline contents in the memory cache. However, synchronization functionality was not implemented. The proposed systems require continuous and reliable Internet connection during downloading contents to the memory cache as a result, they favour learning environments with sufficient resources and reliable Internet connectivity. Lujara (2008) proposed Compact Disk Read Only Memory (CD-

ROM) for offline delivery; however this solution cannot accommodate the needs due to the rapid growth of the amount of information and the increased number of e-learning users. Furthermore, a client-side proxy architecture for supporting the offline use of learning contents and bracing approach for increasing the web server performance was suggested (Trifonova, 2006; Makker & Rathy, 2011). However, pre-fetching and caching contents to the local memory were done automatically by the system owing to filling the cache with documents without any prior knowledge of the user. For third world countries, taking Tanzania as an example; the extension of the learning content delivery to mobile computing devices and the implementation of cost-effective solutions for HEIs within resource and bandwidth constrained environments is still an open research topic (Tlhapane & Simelane, 2010).

In this paper, we explore opportunities brought by mobile technologies to find out a cost-effective solution for e-learning content delivery and accessibility for HEIs in resource constrained environments, which will serve as a basis for implementing the 'Smart City' concept in a developing country. Nam and Pardo (2011) argued that a Smart City is supported by strategic principles aligning to three main dimensions including technology, people, and institutions. Further key characteristics of the Smart City point to the integration of infrastructures and technology-mediated services, social learning for strengthening human infrastructure, and governance for institutional improvement and citizen engagement (Andone, Holotescus, & Grosseck, 2014).

We demonstrate a Cost-effective Mobile Based Learning Content Delivery system for HEIs referring to the constraints in resource and network bandwidth. The developed system is a significant contribution toward enhancing the availability and accessibility of learning resources in a reliable, cost-effective and timely manner. In the end, the proposed system is expected to improve the quality and participation of the learners as well as facilitate mobility and portability in learning activities.

2. Methodology

This development was conducted at HEIs in Tanzania. The system design requirements were gathered in three HEIs where different techniques and methods for requirement gathering were employed, including interview, rapid prototyping and review of empirical literatures were used.

2.1. Software development life cycle (SDLC)

A software development process is often described in terms of a set of activities needed to transform user requirements into a software system. At the highest level of abstraction, a development process is sometimes called development life cycle, one of the model used is an evolutionary development model which includes exploratory development and rapid prototyping. It has been reported by Pratikshya (2013) that, the major advantage of the evolutionary development model is its flexibility that is; the ability to accommodate changes. This is due to facts that customer needs are dynamic, they keep changing, thus evolutionary development model can accommodate changes by adding features to the system as proposed by users as the needs arises. Furthermore, due to time limitation, this study will develop the initial version of software which can later be evolved to higher versions by other researchers through adding new features. The evolutionary development model will best support evolvement of higher versions as shown in Fig.1.

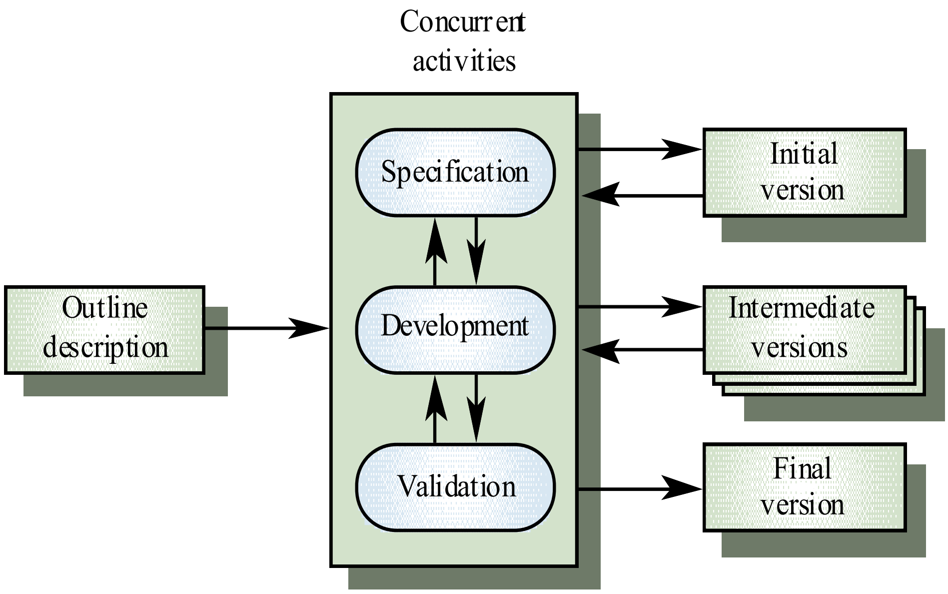


Fig. 1. Evolutionary development model.
SOURCE: Pratikshya (2013)

2.2. Tools and technologies used

The proposed system consists of two main parts; the backend and the front-end. The backend consists of a database management system and a web server. This part of the system enables system administrators and other users to get access to the collected learning contents. The implementation of the backend uses open source relational database management system (MySQL) for main storage of the learning contents and server side-scripting language (PHP). The front-end part is the mobile application running on android mobile operating systems deployed in user's mobile computing devices (smartphone, PDA). This part of the system is used for accessing the learning contents. SQLite database is used for the persistent temporary storage of the learning contents that can be accessed during the offline period. The HTTP Protocol is used to manage the communication between client and server. The applications for Android are developed in the Java Programming Language and executed in a Virtual Machine (VM) called Dalvik VM. The Android Software Development Kit (SDK) was used to provide the Application Programming Interface (API) libraries and developer tools necessary to build, test, and debug the Android Apps. Android is a Linux-based, open-source operating system designed for use on smart phones, e-readers, tablet personal computers, and other mobile computing devices (Rogers, Lombardo, Mednieks, & Meike, 2009). The choice of these technologies was based on fact that, the system developed using this technology is easy to use (with a user-friendly interface), easy to manage and maintain as well as widely used and available.

3. Design requirements

Portable computing/communication devices are essential for mobile based e-learning content delivery and accessibility in HEIs. The most significant feature in the mobile environment is the mobility itself. It assists users to be in connection while being outside the reach of conventional communication spaces. In the context of learning environments, mobility can be conceptualized in terms of ability to access the learning contents anytime, anywhere without the restriction of time and space. The significant design requirement for the proposed system is the synchronization of the learning content from some remote server to a local database (mobile database) to fulfil the following purposes:

i. Extend the learning content delivery and accessibility to mobile computing devices;
ii. Synchronize the learning contents to the mobile devices;
iii. Reduce the cost of the bandwidth usage;
iv. Enable the offline access to learning content;
v. Enable the ubiquitous access to learning content anywhere, anytime without the restriction of time and space;
vi. Reduce the internet usage overhead and the server workload;
vii. Improve the quality and participation of the learners in learning activities.

4. System architecture

The proposed system architecture consists of two main parts; the backend and the frontend. The backend consists of the data access layer and data storage layer, and the frontend consists of the presentation layer as shown in Fig. 2.

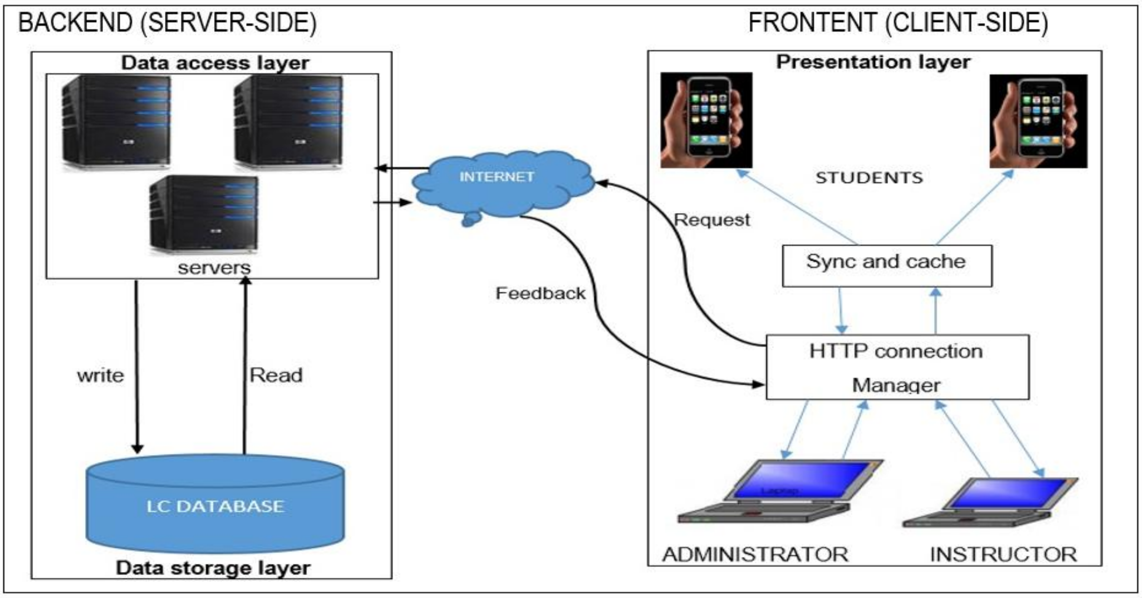


Fig. 2. Mobile-LCDS system architecture

a) Presentation layer: This is the topmost layer of the application that provides the interface between the user and the system. It consists of the following building blocks:

i. *Mobile application interface*: The front-end part is the mobile application running on Android mobile operating systems deployed on the user's mobile computing device. The mobile application interface is used for accessing the learning contents;

ii. *Persistent temporary storage*: SQLite database is used for storing the synchronized learning contents for offline use;

iii. *HTTP connection Manager*: The purpose of a HTTP connection manager is to serve as a factory for new HTTP connections, to manage the life cycle of persistent connections and to synchronize the access to persistent connections making sure that only one thread can have access to a connection at a time;

iv. *Synchronize and cache*: It synchronizes the learning content from some remote servers and stores locally on mobile devices for offline use;

v. *Web interface*: It serves the user management, uploading and updating the learning contents;

b) Data access layer: The purpose of the data access layer is to control the application's functionality by performing detailed processing. This layer coordinates the application processes, commands and makes logical decisions. It moves and processes the data between the presentation layer and the data layer. Thus, the data access layer is the implementation of a web server, which can be done by the apache server to serve the purpose of content management.

c) Data storage layer: This layer consists of database servers that form the main storage. This layer keeps the data neutral and independent from the application servers or the business logic.

When the proposed system; that is Mobile Based Learning Content Delivery System (Mobile-LCDS) is installed in users' access devices; it will provide the mobile user with a user interface to interact with the system, and a persistent storage for the temporary storage of synchronized contents. When a user makes a request; the Application Programming Interface (API) accepts the request by GET or POST methods; then it interacts with PHP classes to get data from a database or store data into the database; and finally it returns the output to the requesting user/device in a JSON/XML format, which is human-readable. The user can synchronize contents from the remote database when the Internet is available; the persistent storage stores synchronized content locally in a mobile device for offline use.

4.1. Synchronization and caching

This part discusses an alternative approach (synchronize and cache) for learning content delivery and accessibility without highly depending on the Internet. The advancement in mobile applications provides an opportunity of being able to work offline. Synchronization for data-driven applications means that a subset of the application data can be stored locally in the access device and the data synchronization mechanism is implemented to keep the local database and the server data (main storage) in a synchronized state. Cache means temporary storage of synchronized data. The goal is to find an efficient and cost-effective approach for learning content delivery in HEIs with resource and network constrained environments.

Without the synchronization and caching policy the user accesses content from the main storage and will need a continuous Internet connection, which is costly in terms of bandwidth connection and usage. Also, it takes long time to access the content from the main storage due to fact that it highly depends on the Internet; as a result it is affected by the following factors:

i. *Web server performance*: Different web servers types used for hosting content, depending on its technical specifications, could have different processing power. For example, web servers configured with high-powered central processing units and huge amounts of memory would have superior processing capability, compared to those that are insignificantly configured. Also servers could still be overloaded when the number of concurrent accesses exceeds the webserver capability;
ii. *Location of web servers*: Typically, web servers are hosted on the backbone of networks to facilitate the delivery of content. On the occasion where the web server is hosted on a remote site (for security/management purposes), a leased line connection is required for a network service provider. In this case, the provided bandwidth of the leased line becomes the bottleneck if users are demanding more bandwidth than available capacity;
iii. *Firewalls and security*: Where security features are installed in a network, the investigation and filtering of packets with every additional layer of firewall may decrease the effective throughput of the system;
iv. *Internet speed*: The Internet speed can vary depending on the differing expectations of speed of download and access of various end-users hence causing some delay in contents delivery;

The majority of HEIs in third world countries like Tanzania face the challenge of resource and network bandwidth constraints. As a result the delivery and accessibility of the learning contents using Internet based learning systems become a challenge. Contents synchronization and caching is an alternative approach for content delivery and accessibility without heavily depending on the Internet connection. For the contents that have been synchronized and stored locally in an access device for future use, every time a user needs such contents, is able to access it offline from the temporary storage. The storage capacity of the most mobile computing devices is large enough to store huge amount of data. It has been reported by Randell (2013) that, Apple's reasonably priced iPhone, the 5c, is the most generous of the 16GB phones recently tested, giving the user 12.6GB of memory (79% of the total space) unused space. Also, Google's new Nexus 5, which runs on the Android operating system like the S4, offers relatively free 12.28GB (77%) of the usable space, the iPhone 5s provides 12.2GB (76%) of the usable storage, The Samsung Galaxy S4 has just 8.56 GB, and others have reasonable memory space that can allow storage large amount of data. This is a promising indicative possibility for storing huge amount of data locally in mobile computing devices. This study employs the opportunity brought by the Android built-in SQLite database for temporary storage of synchronized contents. However, the memory size of the phone will limit how much data can be retrieved from a query.

With synchronization and caching policy the proposed system Mobile-LCDS would support the offline accessibility of learning content. When the Internet is available; the system will synchronize the subset of contents stored in the permanent storage or the remote server to a local database where they can be used offline as illustrated in Fig.3. Therefore the proposed system reduces the access time since there is no delay due to the independence of the Internet connection; cuts down the cost of bandwidth connection and usage: alleviates the server workload and the Internet usage overhead; and improves the quality of experience and participation of the learners in learning activities.

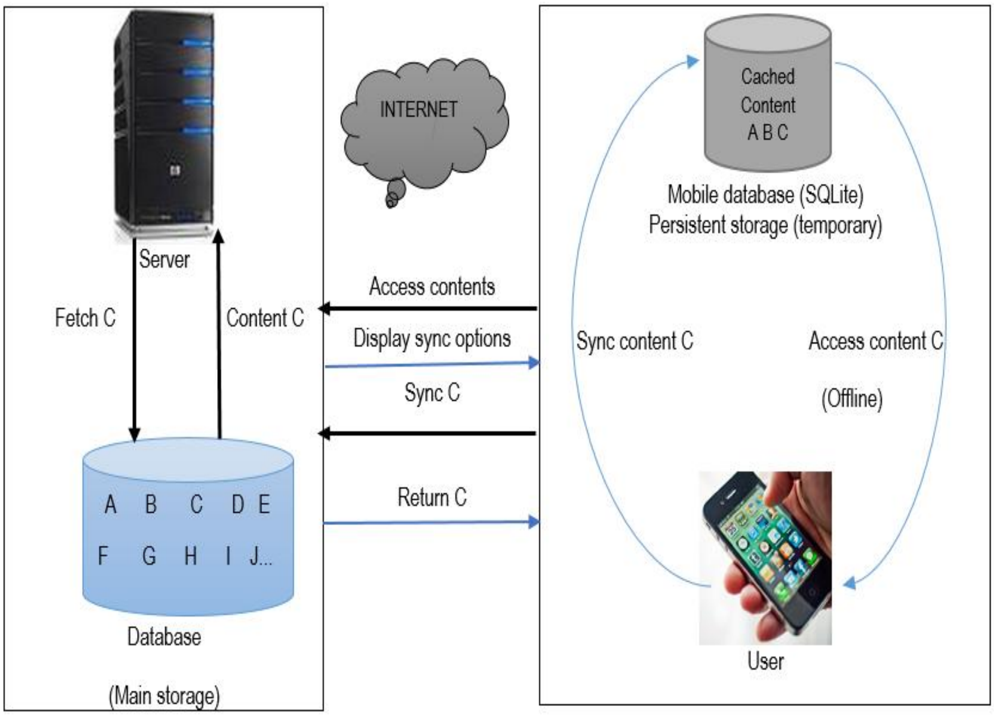


Fig. 3. Contents sync and caching

4.2. Use case modelling

A use case model shows a view of the system from the user perspective, thus describing what a system does without describing how the system does it. A use case provides developers with a view of what the users want (Kendall & Kendall, 2011). It describes a function provided by the system that yields a visible result to the actors. An actor describes an entity that interacts with the system. The actor can be either a human or a computer interaction. The use case diagram model was preferred in this study because it demonstrates the user‘s view of the system. The model gathers design requirements of the system and shows the interaction between the actors (users of the system) and the system itself. The system consists of three actors; Student, Instructor and the System administrator with the role of each actor shown in Fig. 4.

4.3. Mobile-LCDS data flow sequence

A data flow diagram (DFDs) is a structured analysis technique used to put together a graphical representation of the data processes that a Mobile-LCDS comprises. The DFD level-0 represents the system's major processes within the context process, the data flows and the data stores at a high level of detail as explained in Fig.5. It is the decomposition of the context diagram. The major processes in the DFD level-0 represent the major functions of the Mobile-LCDS.

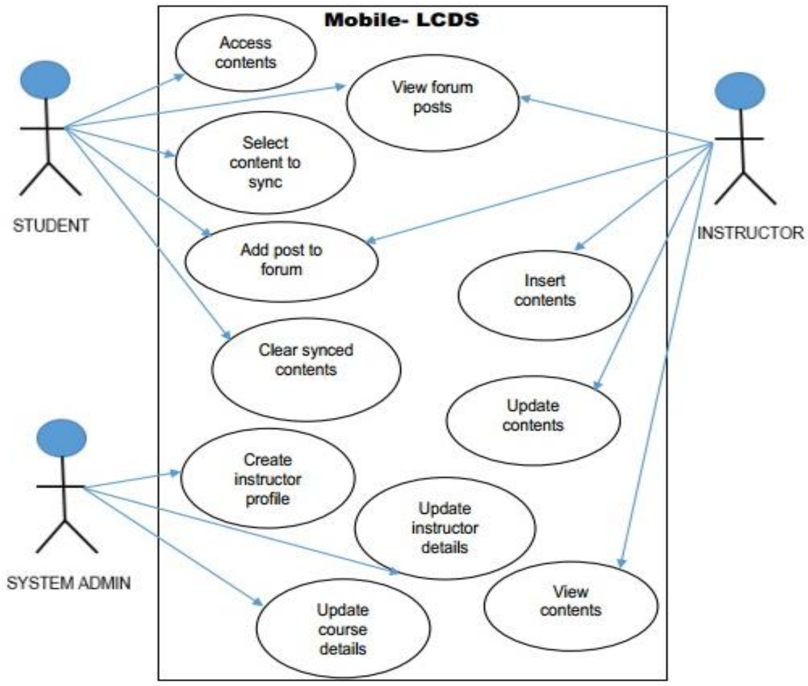


Fig. 4. Mobile-LCDS use case diagram

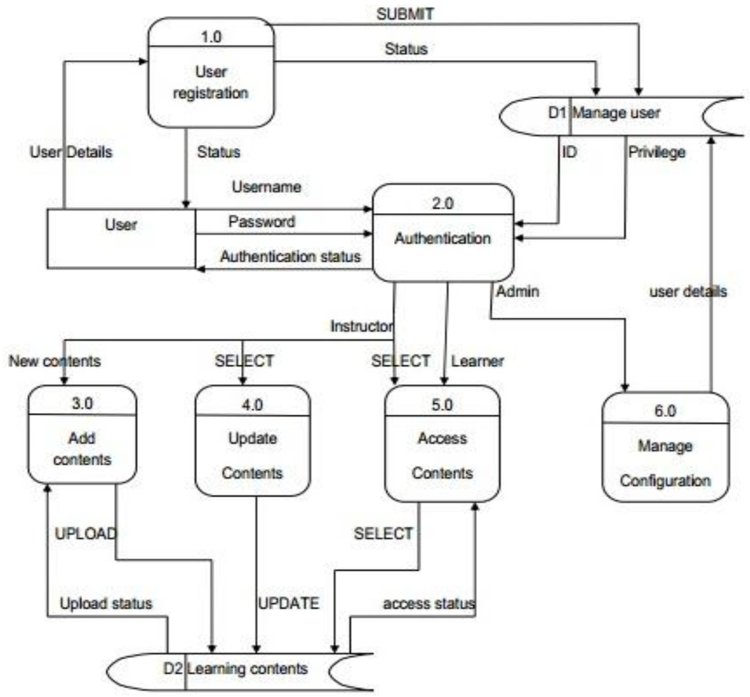


Fig. 5. Mobile-LCDS data flow diagram level 0

The details of Mobile-LCDS DFD-level 0 descriptions are shown in Table 1.

Table 1
Mobile-LCDS DFD-level 0 description

PNO	PROCESS	FUNCTIONAL REQUIREMENTS	TASKS	EXTERNAL ENTITIES
1.	User Registration	Register user	Accept user details, process captured data and send to manage the user data store for storage	Every user
2.	Authentication	Authenticate user	Verify username and password	Every user
3.	Add contents	Insert new contents	Verify the format of the uploaded file and send it to the learning contents data store for storage	Instructor
4.	Update contents	Delete/edit contents	Modify the contents stored in the system	Instructor
5.	View contents	View contents	View the learning contents	Learner
6.	Manage configuration	Configure user settings	Manage user settings and system configurations	System administrator

5. Interface and different components of the system

Fig. 6 presents interface and system components for the mobile client application for users with preferences and intentions of synchronizing the required contents for working offline in the future. The application offers sync options to the user based on user needs and preferences. The system allows a user to synchronize learning content on a semester basis, yearly basis or synchronize all the contents – depending on the device's storage capacity. The sync options are significant for allowing the user to synchronize only the required contents; as a result this avoids filling the local database (cache) with unnecessary contents. Synchronizing the learning contents locally in mobile devices has various advantages, including: reducing the cost of the bandwidth connection and usage; ability to access the learning contents anywhere, anytime without the restriction of time and space; reduction of the Internet usage overhead and the server workload; and speedy and smooth access to the learning content due to the fact that all the required contents will be available in the mobile device –thus the user does not need to re-connect to the Internet.

A student forum is an important feature to improve the collaboration between students and the students' participation in learning activities. A student forum is implemented in order to improve the quality of experience and participation of the learners in learning activities; encourage collaboration among students and instructors using messages and discussion forum regardless of their physical location. It helps the students interact and share information like assignments resources, problems faced in the field, tutorials and innovation ideas.

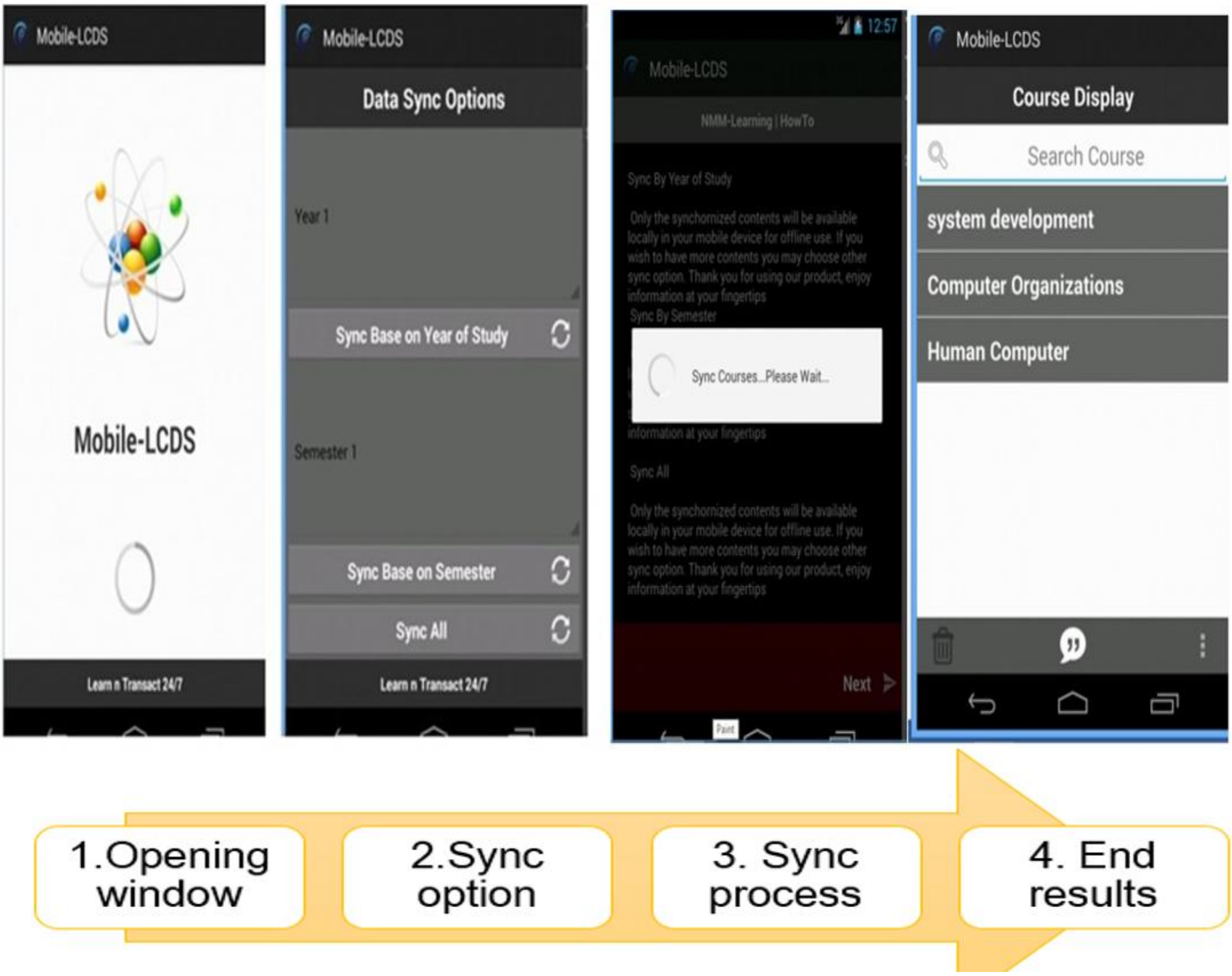


Fig. 6. Interface and system components

A student forum allows the user to:

i. View other students posts to the forum;
ii. Add his/her own post to the forum;
iii. Refresh to get recently added posts to the forum.

The contents synchronized can be cleared out to free memory space in order to accommodate more data. The proposed system also includes web-interface components to be used by system administrators for managing the users of the system and the instructors for uploading and updating the learning contents.

The system admin can perform the following actions after login into the system:

i. Create a new instructor profile;
ii. View, edit and delete instructors;
iii. Edit course details;
iv. Change password;
v. Logout.

The instructor can perform the following actions after login into the system:

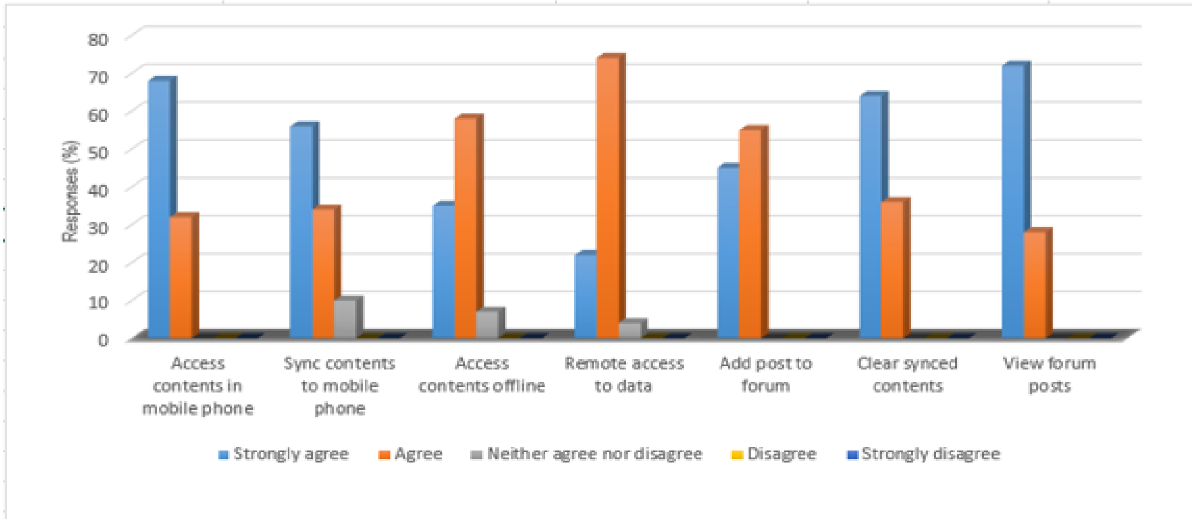
i. Insert course details;
ii. View students' feedback;
iii. Edit course details;
iv. Change password;
v. Logout.

6. Results and discussions

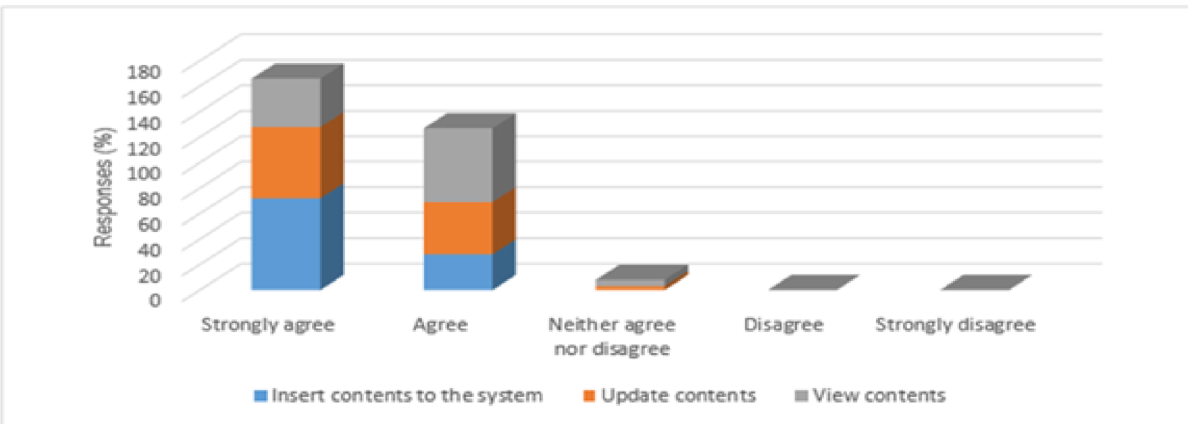
This section presents the results from the user acceptance functional requirements testing. Testing and validation of the proposed system was conducted in order to evaluate the system against the system design requirements specified and the results were summarized in Fig. 7. System testing is the process of evaluating a system or system component in order to verify that it satisfies requirements or to identify differences between expected and actual results (Glenford, Badgett, Todd, & Corey, 2004). System validation is the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled (Torp, 2004).

The results indicate that the system developed satisfies the system design requirements specified as revealed in the results presented in Fig. 7(a) and 7(b). The majority of the user responses ranged from strongly agree to agree as evidenced by the results obtained. This study explored the opportunities brought by mobile technologies in order to improve learning content delivery and accessibility, especially in resource and bandwidth constrained environments. We propose a mobile based system for cost-effective learning content delivery that bridges the gaps in existing e-learning systems by allowing significant bandwidth savings through the offline use of learning contents. The developed system can synchronize learning contents locally in mobile devices when the Internet connection is available. The synchronized contents can then be used offline; this reduces the cost of the bandwidth connection and usage, reduces the Internet usage overhead and the server workload, improves the e-learning system performance, the Internet access as well as the quality of experience and participation of the learners in learning activities.

Compared to existing Internet based learning system like Moodle, the presented system does not highly depend on the Internet connectivity. As a result it can benefit HEIs within resource and network constrained environments, which is the main problem the majority of HEIs in third world countries, particularly Tanzania, are facing. In the Mobile-LCDS, the learning experience is considered in terms of offline accessibility; mobility and portability; increased motivation in learning activities; enlarged collaboration through the integration of social networking tools; social interaction (for example discussion forum) as well as cost-effectiveness and ability to learn anytime, anywhere. It is expected that the learning outcome can improve individual skills, social skills as well as the acquisition of new skills, and the quality and participation of learners in learning activities will be enhanced. The proposed system is underpinned by the traditional learning environment and also supported by effective learning policies, rules and regulations, human resources, the Internet and technologies to facilitate the access to learning materials. On the other hand, the successful implementation of a blended mobile learning requires a strategic approach which should be owned by the university management, the academic staff and the students as well as other stakeholders.



(a) Learners



(b) Instructors

Fig. 7. User acceptance functional requirements testing results

7. Conclusion and future works

In this paper, we present a Cost-effective Mobile Based Learning Content Delivery solution for resource and network constrained learning environments. While owning and maintaining an ICT infrastructure for HEIs has many challenges including the cost of the hardware, software and human-ware; the growth of the mobile technology has brought a new opportunity toward its use for education purposes. The presented system can be applied to cost-effectively broaden and support education in many cities around the world, which are approaching the 'Smart City' concept in their own way, even with less available technology infrastructure. Therefore, the presented system has the potential to enhance the performance of existing e-learning systems, to reduce costs and the resource consumption, and to engage the learners more effectively and actively in learning activities. It will also cut down the server workload and the Internet usage overhead by synchronizing the learning contents from some remote server to a local database in the user's device for offline use. Eventually, the proposed system is significant for the enhancement of the wellbeing, the quality of experience and participation of the learners as well as for facilitating mobility and portability in learning activities.

The future work will address the implementation and the test of the system in real working environments. The system will be tested using a black box testing technique to deduce errors. From the mobile side, the usability evaluation will be conducted using different mobile computing devices. The System Usability Scale questionnaire, a recognized usability instrument, will be applied to measure the usability and the user satisfaction of the system. Additionally, future studies should consider measuring the extent level of performance improvements, conducting rigorous impact assessments and implementing further system enhancements in real scenarios.

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