

# A Mobile Science Laboratory: Architectural Design For Secondary Schools In Uganda

**Conrad M. Mubaraka (PhD)**  
Sen. Lecturer, Department of Computer  
Education,  
Kabale University,  
Kabale, Uganda  
\*Email: kmikemubeee@yahoo.com

**Eunice Ndyareeba**  
Ass. Lecturer, Department of Foundations of  
Education,  
Kabale University,  
Kabale, Uganda

**Abstract**—The teaching-learning process has remarkable effect on the entire education system in Uganda. Science subject have been peculiar in numerous forums hence a desire to change the modus operandi to demystify the illusion of difficult in students' minds. The study was partially experimented at Hilltop S.S.S \_Sheema in Western Uganda to assess the role the ICTs can make in the teaching and learning of science subjects (i.e. Biology, Chemistry and Physics). The 16 participating schools alluded to effective use of ICT when practical sessions were recorded and replayed before some students. An architectural design of a mobile science laboratory was developed which registered significant effect among students in Sheema and Uganda as a whole. The study thus recommended that schools can adopt this architecture to not only cut costs but also allow self-directed learning of the students.

**Keywords**—Security, Mobile, Learning

## 1. Introduction

The African continent embraced formal education since the coming of missionaries in the 18<sup>th</sup> century and till now the same doctrine holds and has contributed much in transforming the mindsets of the population and societies and general development, both positively and negatively, of the continent. In E. Africa and Uganda particularly, education has been given a certain level of preferential treatment to the effect that no parent can complain of lack of access to educational services. For example, the establishment of universal primary education (UPE) and universal secondary education (USE) aim at contributing to the literacy levels of citizens. Although the government has facilitated establishment and running of education institutions, there still exist some flaws that need attention. One peculiar area of exploration is use of technology in the learning process.

Technology in education is becoming vital for transforming society to the effect that technology not only improves productivity but also makes work efficient and officers' effectiveness in delivering education services. It should be noted that over the last decade, the incorporation of service-learning into education has grown at an astounding rate (Lee, 2013). Despite the increase, service-learning remains

an underexplored pedagogical innovation in technology and education. These have had the impacts of service-learning on student learning and development outcome. The results confirmed that service-learning had a positive impact on student learning and development along three dimensions: academic learning, interpersonal development, and personal development. This can be improved if university entrants are groomed at early ages-secondary school.

Additionally, the sophistication of the integrated world of work and increased recognition of learning processes as critical corporate assets require graduates to develop 'process orientation' and an 'integrated view' of learning (Seethamraju, 2013). Responding to these dynamic changes in learning, schools are also continuing to modify their curriculum and introducing innovative teaching and learning strategies. Such innovations register impact as a teaching and learning tool on the students' ability to develop an integrated view and their generic attitudes towards learning. They contribute to deep learning in addition to resulting in significant improvement in their process orientation and integrative skills.

## 2. Background

Despite the existence of numerous contributing factors by the education, there are those whose effect has remained, adversely and directly concerning national development. Such factors include environmental management for climate changes control, exposure and use of technology as one of the MDGs for better learning and living, harnessing girl child wellbeing, taming corruption, nurturing critical and innovative minded citizens, entrepreneurial skills, modern agricultural techniques, integrating indigenous and international cultures in an agile environment, life skills, lack of manpower and reading material and conducting teaching-learning activities in a friendly, conducive and ambient setting. Some of the identified dimensions of life need to be taught at early stages (12-20 years) because once one is accustomed to them at advanced age, it may be difficult to tame them. The environment should not be crowded; the teacher-student ratio should be manageable, employ simplified and modern means of delivery such as video tutorials among others.

Foreseeing such impediments, the government opened room for private institutions to supplement its effort. Many private institutions opened majorly aiming at making profit and fell short sight of the community needs. Furthermore, there are schools that have established centres of excellence and can be instrumental in helping other schools cope with technological changes.

### **Mobile Learning**

Mobile learning (m-learning) is an avenue designed based on electronic and mobile technologies. However, conventional m-learning applications have posed hurdles in terms of high cost of devices and network, low network transmission rate, and limited educational resources (Chen, Liu, Han & Xu, 2010; Gao & Zhai, 2010; Li, 2010). To solve such an impediment, cloud-based m-learning applications have been introduced. For example, due to large storage capacity and powerful processing ability of clouds, the applications provide learners with extra ordinary services such as data (information) size, faster processing speed, and longer battery life. The combination of combining M-learning and cloud computing enhances the communication quality between students and teachers (Zhao, *et al*, 2010). They used an open source JavaME UI framework and Jaber for clients on smartphones. A web site was built on Google Apps Engine which enables students communicate with their teachers at any time. Also, the teachers could obtain the information about student's knowledge level of the course and could answer students' questions in a timely manner.

In addition, Yin, David & Chalon (2009) considered a cloud-based m-learning system based on Mobile Interaction in Augmented Reality Environment platform where it was discovered to have helped learners access learning resources remotely. Another example of mobile cloud computing (MCC) applications in learning was 'Cornucopia' implemented for researches of undergraduate genetics students and 'plantations pathfinder' designed to supply information and provide a collaboration space for visitors when they visited the gardens (Rieger & Gay, 1997). The purpose of the deployment of these applications was to help the students enhance their understanding about the appropriate design of MCC in supporting field experiences. According to Ferzli & Khalife, (2011), an education tool was developed based on cloud computing (CC) to create a course about image/video processing. Through mobile phones, learners could understand and compare different algorithms used in mobile applications (e.g. deblurring, denoising, face detection, and image enhancement).

This study considered pertinent technological factors to enhance teaching-learning process by employing a pragmatic approach spearheaded by Hilltop S.S.S\_Sheema, Western Uganda, E. Africa. Hilltop in her vision wishes to extend such services across board and become the benchmark for

innovative and technological teaching-learning paradigms. Hilltop S.S.S started on 2<sup>nd</sup> February, 2015 with S.1 (36 students) and S.2 (5 students) with vocational skills taught alongside government stipulated subjects. On 6<sup>th</sup> February 2016 we started S.5 with five students; and the pioneer S.2 composed S.3. Therefore by 6<sup>th</sup> February 2017, Hilltop S.S.S shall be fully fledged with S.1-S.6. Two kilometers off Mbarara-Kasese highway, Hilltop S.S.S is located in rural place neighboring five UPE primaries and four USE secondary schools which include: Kagongi P/S 500m; Mukinga P/S 900m; Rwamujojo P/S 1km; Mushanga P/S 2km; and Busesire P/S 2km. The secondary schools include: McAllister College-Kyogera 1km; Sacred Heart\_Mushanga 2km; Gonzaga H/S 2km; and Great Valley 2km. Hilltop S.S.S is strategically located in the centre of the mentioned schools and is currently boosting of a population of 112 students and 12 staff members today. Like any other secondary school in Uganda, we teach eight mandatory subjects and four optional subjects including: ICT, entrepreneurship, Kiswahili and vocational skills. The following extrapolate what we are:

*Philosophy:* Hilltop S.S believes that each student is unique and his/her uniqueness is shaped by the environment in which one has grown. Society being a totality of different personalities; blending them together can shape a student's future despite the diverse socio-economic backgrounds. This thus enhances innovations and creativity among students who then can impact on the national development of Uganda. *Vision:* To become a model of quality technological and innovative education services in Uganda. *Motto:* 'We strive to become the instrument for change'

### **3. Problem Area**

Currently there are many primary schools than secondary schools which escalates discriminate admissions - taking the cream with first grades; hence dropouts and unpolarised training. More so the available secondary schools are quite in a distance and sometimes ill-equipped with science laboratory, inadequate science teaching material and lack competitive pedagogy. Other indicators of the problems include: moral decay among teachers/parents and officers (corruption), inadequate teacher training approaches, cultural erosion, low numeracy and literacy levels, socio-cultural tendencies (genital mutilation), low income levels/livelihood and discrimination of the girl child among others.

The government of Uganda recently directed to have in selected sub-counties secondary schools. This is a positive move provided teachers and laboratories are up to date. Despite the availability of such government support in education sector, factors such as socio-cultural practices (e.g. a girl child should be married off as a boy child assists the parents in markets and shops); corruption tendencies,

lack of competitive pedagogical skills among science teachers and low parental involvement in the teaching-learning process have crippled the initial government plans of providing basic education to all citizens by 2015. The affirmative action (2.0 points added to every female university entrant) at university level has tried to control some of such practices but there still exists pockets of dire need which government together with private sector partnership can combiningly tame the situation.

Furthermore, due to paradigm shift in Ugandan education system: accelerated learning versus Uganda National Examination Board (UNEB) directives, some students have withdrawn from school citing inconveniences and disturbances. The UNEB parameter of mathematics and English affecting grade classification; the fallacy that sciences are hard and female students perform poorly, some practical examinations carrying 60%, inadequate practical requirements and the disparity between UNEB and national curriculum development centre (NCDC) syllabi have adversely affected the teaching of sciences. More so, to be admitted for tertiary institution every candidate ought to have passed at least one science subject (i.e. physics, chemistry or biology). Such situations have contributed to unbecoming behavior (e.g. examination malpractices), school dropout rates which have escalated into drug abuse, robbery, unwanted pregnancies and other vices causing a drawback on the national development. To get this dilemma alienated pertinent stakeholders: ministry of education, parents, teachers, learners and school administration ought to engage in the best learning practices as much as possible.

The use of technology has emerged one of the driving forces to such circumstance and enhanced livelihood. Of late brainshare a platform for hosting various past paper examinations was created. Different schools, especially secondary schools, want to post their exam sets for fame and gaining more popularity-competition. This has escalated the tendency of looking for grades rather than mastery and demonstration of syllabus content. In addition, sciences have been at their poorest level of performance partly due to inadequate teaching time and creative pedagogy among teachers. Some students have consistently demonstrated their ability to do better in rural schools compared to urban school; and yet given rigorous exposure to practicals they can do much better. For example, posting recorded practical sessions can significantly improve a student's practical skills for he/she can follow the steps and perform the same practical without the teacher appearing physically.

The general objective of the learning platform was to enhance awareness and the active involvement of the teachers and learners in the teaching-learning process of sciences in secondary schools in Uganda. Specifically, the study sought to assess the clarity of explanation during practical sessions; ii) examine the visibility of the experiment results; (iii) demonstrate

handling/manipulative skills with apparatus; (iv) assess the cognition of the learners in practical exercises; (v) assess the cost implication and content authenticity on the school administration side; and (vi) examine the implication on intellectual property rights for teachers.

#### 4. Literature Review

Information Communication Technology (ICT) has become essential in almost every educational, employment community and recreational environment. Access to electronic and Information communication Technology (ICT) can help students with a wide range of abilities and disabilities prepare for and succeed in adult life. Specifically for disadvantaged students, such access has the potential to maximize independence, productivity and participation in academic programs, employment, recreation and other adult activities (Lawal, Loyinmi & Abolarinwa, 2013). In addition, for those who have the interest and aptitude advanced Information Communication Technology skills can open doors to high-tech career fields that were once unavailable to disadvantaged people. However, most people would agree that a major goal of schooling should be the development of students' understanding of basic mathematical concepts and procedures. All students including those disadvantaged and those at risk of school failure need to acquire the knowledge and skills that will enable them to "figure out" math-related problems that they encounter daily at home and in figure work situations. Unfortunately, there is considerable evidence to indicate that this objective is not being met, especially for children exhibiting difficulties, like lack of access and fees. Since the first discouraging result of mathematics achievement reported by the National Assessment of Educational Progress (NAEP) in 1973, there has been little evidence to suggest that science subjects' achievement has improved significantly. Higher expectations, change in life style, compounded with more boring curricula, add to the challenge (Perie et.al, 2005).

Although users and application developers benefit from storing a large amount of data/applications, they should be careful of dealing with the data/applications in terms of their integrity, authentication, and digital rights. The data related issues in MSL are as follows:

*Integrity:* It has been of much concern by many system users about the consistence and reliability of their data on the storage infrastructure and a number of solutions have been proposed to address this issue (Wang, et al, 2009; Tanenbaum & Van Steen, 2007). There are quite a number of consideration to make peculiar of which is energy consumption. Itani *et al* (2011) tackled energy consumption in regard to: a system user, a storage infrastructure service, and a trusted third party as the main system components and this had three phases: In the first phase, files A that needed to be sent to the storage infrastructure would be assigned with a message authentication code .MACA. These MACA would be stored locally,



while the files were sent and stored on the storage infrastructure. In the second (update) phase, a case when a user wanted to insert the data into file A was considered. The storage infrastructure then sent file A to this user. At the same time, the storage infrastructure also sent a requirement to the trusted crypto coprocessor (TCC) to generate MAC0A. TCC then sent MAC0A to the client to verify A by comparing it with MACA. If everything was properly authenticated, the user could insert/delete data. Finally, the system client could request the integrity verification of a file, collection of files, or the whole file system stored in the storage infrastructure. This phase started when the user sent a requirement to verify integrity of files to TCC. TCC then retrieved files that needed to be checked from the storage infrastructure and generated MAC0A to send to the client. The client only compared the received MAC0A and MACA that were stored on its device to verify the integrity of such files. This approach not only verified the integrity of data but also saved energy for the device and bandwidth for the communication network. The reason was that checking and verification were processed on TCC and the client just ran a simple code for comparison. The result showed that this solution could save 90% processing requirements, thus saving significant energy for mobile device.

*Authentication:* Chow et.al, (2010) presented an authentication method using cloud computing (CC) to secure the data access suitable for mobile environments. This scheme combined TrustCube (Song et al, 2009) and implicit authentication (Shi, Niu, Jakobsson & Chow, 2010; Jakobsson, Shi, Golle & Chow, 2009) to authenticate the mobile clients. TrustCube is a policy-based cloud authentication platform using the open standards, and it supported the integration of various authentication methods. The authors built an implicit authentication system using mobile data (e.g. calling logs, SMS messages, website accesses, and location) for existing mobile environment. The system required input constraints that made it difficult for mobile users to use complex passwords. As a result, this often led to the use of simple and short passwords or personal identification numbers (PINs). When a web server received a request from a mobile client, the web server redirected the request to the integrated authenticated (IA) service along with the details of the request. The IA service retrieved the policy for the access request, extracted the information that needed to be collected, and sent an inquiry to the IA server through the trusted network connect protocol. The IA server received the inquiry, generated a report, and sent it back to the IA service. After that, the IA service applied the authentication rule in the policy and determined the authentication result (whether or not the mobile client is authenticated successfully for the access request) and sent the authentication result back to the web server. Based on the authentication result, the web server either provided the service or denied the request.

*Digital rights management:* The unstructured digital contents (e.g., video, image, audio, and e-book) have often been pirated and illegally distributed. Protecting these contents from illegal access is of crucial importance to the content providers. Zou *et al*, (2010) proposes Phosphor, a cloud-based mobile digital rights management (DRM) scheme with a subscriber identity module (SIM) card in mobile phone to improve the flexibility and reduce the vulnerability of its security at a low cost. The authors designed a license state word (LSW) located in a SIM card and the LSW protocol based on the application protocol data unit (APDU) command. In addition, the cloud-based DRM with an efficient unstructured data management service could meet the performance requirements with high elasticity. Thus, when a mobile user received the encrypted data (e.g., video stream) from the content server via real-time transport protocol, he/she used the decryption key from a SIM card via APDU command to decode. If the decoding is successful, the mobile user could watch this video on his/her phone. The drawback of this solution was that it was still based on the SIM card of the mobile phone; so, it could not be applied for other kinds of access; that is, a laptop using Wi-Fi to access these contents.

*Enhancing the efficiency of data access:* With an increasing number of cloud services, the demand of accessing data resources (e.g., image, files, and documents) on the cloud increases. As a result, a method to deal with (i.e., store, manage, and access) data resources on clouds became a significant challenge. However, handling the data resources on clouds was not an easy problem because of the low bandwidth, mobility, and the limitation of resource capacity of mobile devices. For commercial cloud storage providers (e.g. Amazon S3), every I/O operations (e.g., put, copy, cut, and list) were taken by the cloud provider. The I/O operations were executed at a file-level in general, so this increased the cost of network communication and service for mobile users. Nam *et al*, (2011) proposed an algorithm in which I/O operations were executed at a block-level. The algorithm used log structured I/O transaction (Rosenblum & Ousterhout, 1992) to minimize the number of the block-level I/O operations. The main idea here was to allow the cloud storage log-structure perform write operation with the optimal number of data blocks that adaptively changed with I/O and cloud storage pricing policy. The authors demonstrated that, through experimentation, the proposed solution reduced the total I/O costs considerably up to 54% compared with the data management at a file level in Amazon Simple Storage Service. However, this solution did not consider about access methods to adapt for this new data management. Shen *et al*, (2010) presented a cloud-based framework, named E-Recall to address the data access issue. This approach builds a novel infrastructure in managing, searching, sharing, and archiving the rich media resources based on the coordination of mobile search, CC, and multimodality integration. There were three main functional blocks

as follow: query formulation, cloud-based indexing structure, and user-centric media sharing and publishing. Query formulation block was designed based on the principle of query dependent fusion (Kennedy, Chang & Natsev, 2008) to optimize the representation for describing user information and search detail. Meanwhile, the aim of a cloud-based indexing structure block was to provide a database access method and that of user-centric media was to help mobile clients share and publish media resources in a friendly way.

### Network Access Management

An efficient network access management not only improves link performance for mobile users but also optimizes bandwidth usage. Cognitive radio can be expected as a solution to achieve the wireless access management in mobile communication environment (Yucek & Arslan, 2009). Cognitive radio increases the efficiency of the spectrum utilization significantly, by allowing unlicensed users to access the spectrum allocated to the licensed users. When this technique is integrated into MSL, the spectrum can be utilized more efficiently. The spectrum scarcity can be solved and thus millions of dollars for network providers can be saved (Ge, Lin & Khajeh, 2011). However, cognitive radio is defined as wireless communication technology in which each node communicates via an optimal wireless system based on recognition of radio resource availability in heterogeneous wireless communication environment. Therefore, mobile users in MSL must be able to detect this radio resource availability (through spectrum sensing) while ensuring that the traditional services will not be interfered.

### Advantages of mobile cloud computing

Cloud computing is known to be a promising solution for MSL because of many reasons (e.g., mobility, communication, and portability [Forman & Zahorjan, 1994]). Cloud computing can be used to overcome obstacles in MSL, thereby pointing out the advantages of MSL. (1) *Extending battery lifetime*. Battery is one of the main concerns for mobile devices. Several solutions have been proposed to enhance the CPU performance [Kakerow, 2003; Paulson, 2003] and to manage the disk and screen in an intelligent manner [Mayo & Ranganathan, 2003] to reduce power consumption. However, these solutions require changes in the structure of mobile devices, or they require a new hardware that results in an increase of cost and may not be feasible for all mobile devices. Computation offloading technique is proposed with the objective to migrate the large computations and complex processing from resource-limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds). This avoids taking a long application execution time on mobile devices which results in large amount of power consumption. Rudenko *et al.* (1998) and Smailagic and Ettus (2002) evaluated the effectiveness of offloading techniques through several experiments. The results demonstrated that the remote application execution

could save energy significantly. Especially, Rudenko *et al.* (1998) evaluated large-scale numerical computations and showed that up to 45% of energy consumption could be reduced for large matrix calculation. In addition, many mobile applications took advantages from task migration and remote processing. For example, offloading a compiler optimization for image processing [Kremer, Hicks & Rehg, 2001] could reduce 41% for energy consumption of a mobile device. Also, using memory arithmetic unit and interface (MAUI) to migrate mobile game components [Cuervo, Balasubramanian, Dae-ki, *et al.*, 2010] to servers in the cloud could save 27% of energy consumption for computer games and 45% for the chess game.

*Improving data storage capacity and processing power*. Storage capacity is also a constraint for mobile devices. MCC was developed to enable mobile users to store/access the large data on the cloud through wireless networks. First example is the Amazon Simple Storage Service which supports file storage service. Another example was Image Exchange which utilized the large storage space in clouds for mobile users [Vartiainen, Mattila, 2010]. This mobile photo sharing service enabled mobile users to upload images to the clouds immediately after capturing. Users may access all images from any devices. With the cloud, the users could save considerable amount of energy and storage space on their mobile devices because all images were sent and processed on the clouds. Flickr [<http://www.flickr.com/Retrieved on 12/6/2018>] and ShoZu [<http://www.shozu.com/portal/index/Retrieved on 14/6/2018>] were also the successful mobile photo sharing applications based on MCC. Facebook [<http://www.facebook.com/Retrieved on 23/>] is the most successful social network application today, and it is also a typical example of using cloud in sharing images.

Finally, the use of instructional, technology tools like Video and Audio-visual material to enhance science instruction can greatly improve the learning process. For example, technology represents chemical reaction concepts in different ways that can be meaningful to chemistry class. It can provide support for students who have trouble remembering mathematical facts and procedure or whose fine motor skills make writing problem and drawing diagrams (for fine art classes) difficult (Cawley *et al.*, 1996, Hasselbring *et al.*, 2005). The flexibility and interactivity that are inherent in Information Communication Technology can help students who otherwise avoid sciences, especially mathematics become engaged in the subject better. Although, the teachers are aware of the improvement which Information and Communication Technology has brought into the teaching of sciences like mathematics several studies have found out that daily studies and practices can help student increase both their speed in calculation and their accuracy in recalling basic facts (Miller, Butter & Lee, 1998).

In a nutshell, technology and education are indispensable in as far as creating an environment for improved livelihood, corruption free, gender equality, entrepreneurial skills and inter cultural mingle. The project philosophy builds on this proposition and wishes to train youths who can be propelled to extend frontiers of thinking and become responsible citizens by equipping them with necessary and updated technological skills.

## 5. Methodology

Given that schools incur high cost to equip and maintain science teaching, parents end up giving up on educating children or schools resort to cheating examinations to pass. The study took place at Hilltop S.S.S\_Sheema by employing a quasi-experimental design with post-test only strategy. The participating schools (16) were purposively selected; those with computers and have demonstrated relatively good performance in sciences for the last three years (Uwezo Assessment Report, 2016). The selected schools were convened for a science symposium at Hilltop S.S.S\_Sheema for five days and on the fifth day this experiment was conducted. The practical sessions runs as: morning, mid\_morning and afternoon for chemistry, biology and physics respectively. After which interview sessions ensued. Participating teachers and students were trained how to access the network and post, retrieve or respond online. A teacher was able to upload content of interest instantly while around school premises or even far away. A teacher or student in participating schools could post as well as see what others have posted; and each user had an ID to distinguish him/her from others. A third party also sufficed to authenticate and protect all the legitimate users, especially teachers' copyrights.

Selected ordinary level (O' Level) students and teachers in the experiment were earlier trained and rehearsed pertinent steps. Three practical exercises were recorded with three teachers of chemistry, biology and physics. Volumetric analysis, food tests and magnetism and electricity were the pertinent topics respectively. Each teacher used three students each with his/her own apparatus set for each of the identified topical areas. One of the students was intended to make common mistakes in the respective practicals so that whoever watches the clip can also learn them and how to correct them. Given that different teachers have different pedagogical skills, all the three practicals were recorded and uploaded so that a student chooses what was clearer for him/her or even enhance his practice after going through all the

sessions. After all those recordings other students formerly not participating, watched them as they performed the same practical exercises. At the end of the three exercises (volumetric analysis, food tests and magnetism and electricity), students, teachers and administration were observed and asked questions pertaining to: (i) the clarity of the explanation; (ii) visibility of the experiment results; (iii) handling/manipulative skills with apparatus; (iv) cognitive enrichment; (v) cost implication and content authenticity on school administration side; and (vi) intellectual property rights for teachers.

## 6. Findings of the Study

The study was guided by the following roadmap: (i) the clarity of the explanation; (ii) visibility of the experiment results; (iii) handling/manipulative skills with apparatus; (iv) cognitive enrichment; (v) cost implication and content authenticity on school administration side; and (vi) intellectual property rights for teachers. It was found that explanation was quite sufficient but the use of technical terms like ionisation could somehow put some students off guard hence losing track. However, they could eventually catch up in the subsequent phases of the experiment. The visibility of the results and pertinent steps was very adequate provided the visual display unit of the viewer has suitable resolution. Also, the manipulative skills were evident enough but more practice would have far reaching effect. With this objective it was difficult to ascertain the amount of force suitable while turning the tap of the burette; otherwise excessive force would get some taps breaking. The same applied to use of stop clock. It was found that with the recorded exercises and regular rehearsals a student gets significant cognitive nourishment. The administration acknowledged a relatively low cost in teaching sciences to the effect that by adopting ubiquitous computing, significant funds can be allotted to other functional units of the school. However, they commended the result of such an investment especially now that schools work hard to obtain good grades. The study leveraged authenticity of subject content by participating teachers and students who had not paid school fees were equally reprimanded. The study thus found it worthy implementing such an innovation for enhanced science teaching in secondary schools in Uganda. Below is the architectural design of the mobile science laboratory (MSL). A reliable information system should have a deplorability that considers user identification, authorization and authentication; system connectivity and communication, storage and fault tolerance.

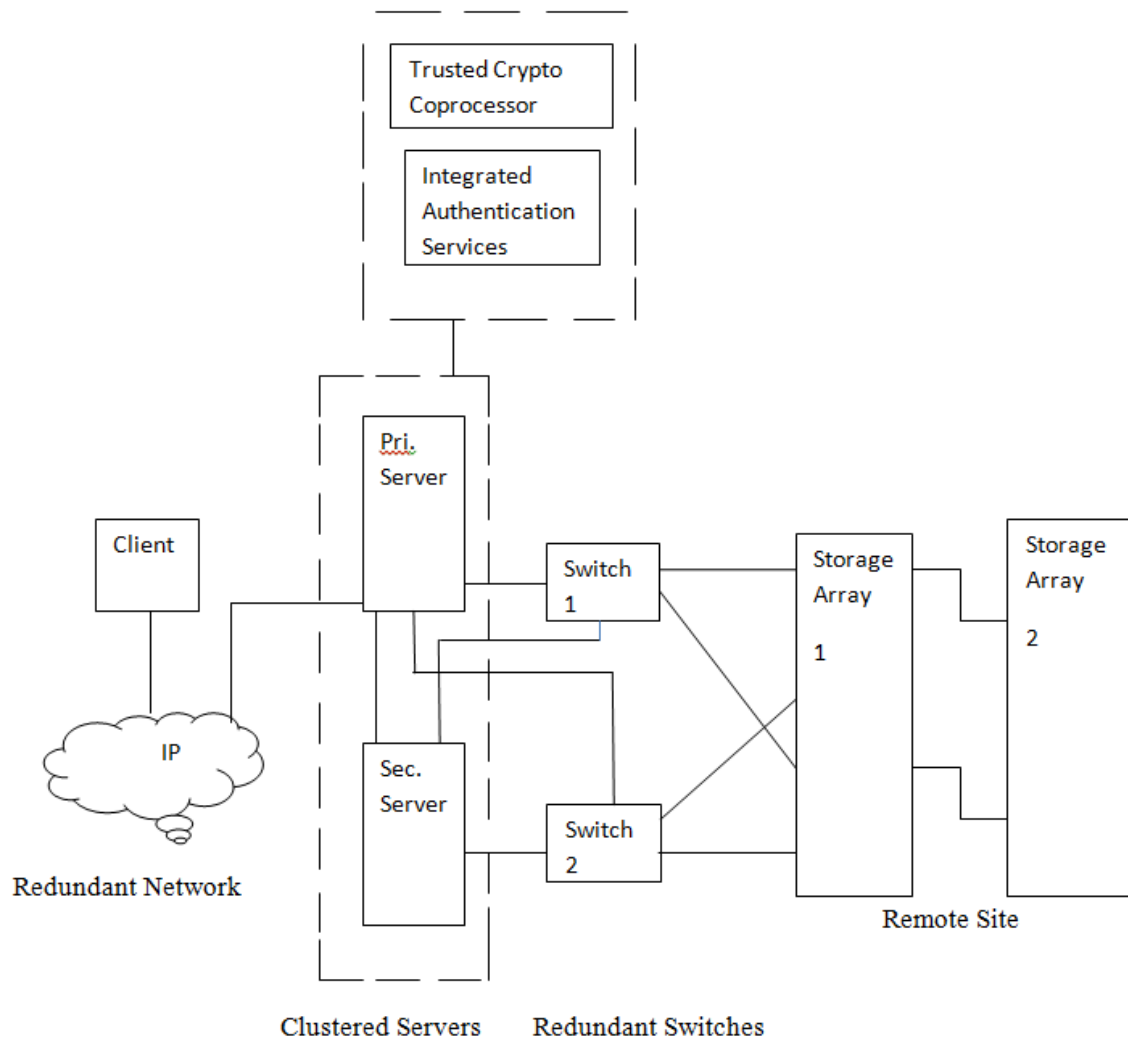


Figure 1: Architectural Design for Mobile Science Laboratory

The study findings showed that school structures, literally referred to the formal setting of supervision and management commitment was vital in the whole process of the teaching-learning management in secondary schools in Sheema. School management ought to commit adequate resources to purchase and sustain technological innovations in teaching sciences. Good security, robust and affective the Mobile Science Laboratory (MSL) calls for total commitment of school management to support: morally and financially. To mitigate a single point of failure, MSL should be designed with redundancy, such that it will fail only if all the components in the redundancy group fail. This ensures that the failure of a single component does not affect practical exercises' availability: bearing in mind that students are free to access them anytime of their convenience; the IT department of the school can incorporate stringent guidelines to implement fault tolerance. Such guidelines may include: careful analysis to eliminate every single point of failure by: i) Configuration of multiple host bus adapters (HBAs) to mitigate single HBA failure; ii) Configuration of multiple fabrics to account for a switch failure; iii) Configuration of multiple storage array ports to enhance the storage

array's availability; iv) RAID configuration to ensure continuous operation in the event of disk failure; v) Implementing a storage array at a remote site to mitigate local site failure; and vi) Implementing server (host) clustering, a fault-tolerance mechanism whereby two or more servers in a cluster access the same set of volumes.

Clustered servers exchange heartbeats intended to inform each server about each one's health. If one of the servers fails, the other server takes over the workload. Furthermore, single point of failure can be alienated by replicating data using either storage array based replication or host-based replication. In storage array-based replication (remote), data can be replicated to another storage array located at a remote site. If the storage array is lost due to a disaster, business continuity (BC) operations start from the remote storage array; while in host-based replication, the application software or the logical volume management (LVM) ensures that a copy of practical exercises managed by them is maintained locally in the data/video bank for recovery purposes. Generally, there should be care in dealing with the



data/applications in terms of their integrity, authentication, and digital rights.

## 7. Conclusion and Recommendations

The experiment allowed the participating teachers to supplement, object or complement each other. This permitted the study to enhance content authenticity and improve on the cognition of learners. The administration could significantly reduce operational cost; and generally bring a paradigm shift in the teaching of sciences in secondary schools. The study thus recommends that schools fasten the teaching of computers as a baseline for effective practical manipulation with computers; improve on the science laboratory and allow room for self-directed study of students to practise the proposed skills. Future research can consider teaching art subjects to ascertain the impact. Also a study to involve Advanced Level students may as well be handy.

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