Vol. 38(1), pp. 116-129, June 2019
ISSN 1821-536X (print)
ISSN 2619-8789 (electronic)

Tanzania Journal of Engineering and Technology

Review Paper

Research Methodology Adopted in Developing TanSSe-L System

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ABSTRACT

Research methodology is among the very important part in a research work. It is the heart which describe the activities necessary for the completion of the research work. Research methodology provides a plan of investigation considered to obtain answers to research problems and it depends on the context of application. This paper presents the research methodology adopted when developing Tanzania Secondary Schools e-Learning (TanSSe-L) system, a learning management system (LMS) which was successfully developed through customization of Moodle open source LMS. TanSSe-L system is a context centered platform for secondary schools in Tanzania. TanSSe-L system was developed using a number of methods and techniques taking into consideration open source/low cost system and the issue of sustainability, where academia, industry and Government were involved in a triple helix model. Focus group discussion in action research methodology, made secondary school stakeholders be involved in the TanSSe-L system development.

Keywords: *Mode 2, Model Driven Architecture (MDA), Object Oriented Approach, Open Source, Research Methodology, TanSSe-L System, Triple Helix Model.*

INTRODUCTION

Research methodology as defined by Kothari (2004) is a process of arriving at dependable solution to problems through the planned and systematic collection, analyzing and interpretation of data. To emphasize more on this, Kothari (2004) stated that research methodology is a systematic effort to gain new knowledge, search for (new) knowledge/facts through objective, systematic and scientific method of finding solution to a problem. Research methodology is aiming to solve a problem, serve society by increasing standard of living. Research methodology is a way to systematically solve the research problem by logically adopting various steps, help to understand not only the products of scientific inquiry but the process itself.

As defined by Kothari (2004) research methods refers to those methods and/or techniques that are used for conduction a research. Research methods or techniques, thus, refer to the methods the researchers use in performing research operations. In contrary to this, research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. In it we study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them. It is necessary for the researcher to know not only the research methods/techniques but also the methodology (Kothari, 2004). Actually, research methodology does not only talk of the research methods but also consider the logic behind the methods used in the context of research study. Research process is different, it refers to the series of actions or

steps necessary to effectively carry out research. This is in accordance with Pandey and Pandey (2015) and the steps starts from the formulation of the research problem, reviewing literature, developing research questions etc. up to when writing a report. With this paper, a research methodology is presented.

Tanzania Secondary Schools e-Learning (TanSSe-L) system is one of the products of the ICT for eLearning research project conceived at the University of Dar es Salaam. The overall main objective of the e-learning project was to improve the quality of science education in secondary school in the rural areas of Tanzania. A project developed a tool to enable ICT support to rural secondary schools, by providing teaching materials, which are user friendly and facilitating self-learning and information sharing, starting with science and mathematics subjects. The project was based on three pillars; establishment of suitable and effective connectivity and configuration, development of a context centered platform which includes an e-learning management system using open source software and development of learning content materials for self-learning and sharing (Kalinga, 2010). This paper presents the research methodology used to develop a context centered platform which was named as Tanzania Secondary School e-Learning System and abbreviated as TanSSe-L System.

The research methodology adopted by Kalinga (2008) and Kalinga (2010) involved development of a concept of research methodology; "Mode 2" and Triple Helix model to portray an application of applied and context-driven research work on a specific problem; Data collection approaches where focus group discussion was emphasized. This part gives an overview of qualitative research and participatory action research methodology; Design approach in which software engineering was employed. In this part, the Object-Oriented System Analysis and Design (OOSA&D) approach with the Unified Modelling Language (UML) were employed and integrated with Model Driven Architecture (MDA) which emphasizes the power of the model in software development; Selection and customization of open source LMS platform gives the TanSSe-L system the functionality as specified by the requirements of Tanzanian secondary schools; Mirroring and replication of the TanSSe-L system was applied to ensure that the system is highly available to end users. Lastly the paper discusses key issues.

DEVELOPMENT OF TanSSe-L SYSTEM

Mode 2 and Triple Helix Model

TanSSe-L system was a context-driven research work on a specific problem. Triple helix processes and Mode 2 methods of knowledge production in the specific context of its application and implication was adopted. Gibbons *et al.* (2015) exploit the major changes in the way knowledge is being produced in science and technology, the social sciences and humanities, but mainly in science and technology. Comparing the traditional way of doing research by academia, which Gibbons *et al.* (2015) call "mode 1" and where knowledge is generated within the context of a discipline and cognition, Mode 2 knowledge is created in a broader, trans-disciplinary social and economic context. That is, it is a form of knowledge production, which is context-driven, problem focused and inter-disciplinary. "Context-driven" means research carried out in the context of application, arising from the very work of problem solving and not governed by the paradigms of traditional disciplines of knowledge.

Lating (2009) states that trans-disciplinary work is a form of learning and problem-solving activity involving co-operation among different parts of society and academia in order to meet the complex challenges of society. In trans-disciplinary research, researchers work jointly to develop a shared conceptual framework and methodological approach that integrates and goes beyond their respective disciplinary perspectives to address a common problem. Therefore, the research cuts across, between and beyond disciplines.

In the product-based economy, development was driven by industry. This is not possible in the current knowledge-based economy. Future development in the knowledge economy is driven by incremental innovation within industry. Innovation can be achieved as a result of an alliance between government, industry and academia. This is a triple helix alliance. The purpose of the triple helix is to stimulate knowledge-based economic development, drawing on the resources of all three members of the helix (Lating, 2009).

Walsh (2001) defines the "triple helix" as a partnership between industrial, academic and governmental communities, which recognizes the differing goals and stakeholder communities of the three groups, but stresses the common interest of those groups to provide value to the communities in which they reside. The triple helix concept realizes that the loose links among these three parties have to be tightened. A more open and intensified communication has to be established between academic and business communities, business and government, and government and educational institutions. In addition to their primary tasks of higher education and academic research, the universities are also expected to provide both highly qualified personnel and results of research for use in economic contexts (Kadiman, 2006).

Mode 1 knowledge is closely related to basic (also called fundamental or pure) research, which is driven by a scientist's curiosity or interest in a scientific question. The main motivation is to expand man's knowledge, not to create or invent something. There is no obvious commercial value to the discovery that results from basic research. Kuhn (2012) states that the term "basic" or "fundamental" research indicates that, through theory generation, basic research provides the foundation for further, often applied research.

On the other hand, mode 2 can be related to applied research. Applied research, is designed to solve specific, practical problems of the modern world, rather than to acquire knowledge for knowledge sake. Kuhn (2012) states that one might say that the goal of the applied scientist is to improve the human condition. Basic research can partly be involved in applied research.

This research methodology for TanSSe-L system developed being presented can be understood as applied research, which is strengthened by using triple helix collaboration networks and acknowledging mode 2 knowledge production. Taking place in the context of application fits nicely with the choice of applied science. With application of "mode 2" and "triple helix", the research was designed with a number of methods and techniques in order to integrate the collaboration of actors through focus group interviews and software development. The different methods are introduced below.

Data Collection

Research methods can be classified in various ways; the main two are quantitative and qualitative. Both have been employed in this research, although qualitative research methodology has been employed to a greater extent as follow.

Qualitative Research Methodology

Development of the TanSSe-L system was mainly based on qualitative research methods where qualitative data were obtained from observation (field-work), in-depth interviews and focus group discussions. There are various qualitative research methods, and the choice of which one to employ is influenced by the way the researcher collects data. In this research, all the above-mentioned qualitative means of data collection were employed to get primary sources of data, but the emphasis was more on focus group discussion. The means of data collection, also presented by Kalinga *et al.* (2007) include:

- Interview

Interviews using open-ended questions were conducted with selected stakeholders of the schools (administrators, students and teachers) and officers in the Ministry of Education and Vocational Training (MoEVT), Tanzania

Telecommunications Company Limited (TTCL) headquarters and at regional level, as well as Regional and District Education Officers.

- Physical Observation

Physical observation of the real status of schools included libraries, laboratories for science subjects, the number of teachers and their qualifications, the presence of computers and/or computer laboratories and their utilization. Others included the availability of electricity, a school Local Area Network (LAN), public connectivity such as telephone lines, and other public services in nearby areas like hospitals and institutions.

- Focus Group Discussion

Focus group discussion was the key means of data collection, guided by open-ended questions. The focus groups were organized to smaller sub-groups as follows: with students alone, with teachers alone, with school administrators, joint discussion with students and teachers, with research members, and with the MoEVT officers.

Ewings *et al.* (2003) explain that focus group discussion is a widely used research method that involves bringing people together for in-depth discussions of issues of interest. The information provided by a group discussion is usually richer, more complete, and more revealing than that which can be obtained through questionnaires. In focus group discussion as elaborated on by Ewings *et al.* (2003), the researcher brings together a small number of subjects to discuss the topic of interest. The group size is kept deliberately small, so that its members do not feel intimidated but can express opinions freely. A topic guide to aid discussion is usually prepared before hand and the researcher usually 'chairs' the group, to ensure that a range of aspects of the topic is explored. The discussion is frequently tape-recorded, then transcribed and analyzed.

Focus group discussion was also inspired by participatory action research methodology. Rowley (2003) says that, in action research, action and research proceed concurrently. Participatory action research depends upon a collaborative problem-solving relationship between the researcher and the clients, which aims to both solve a problem and generate new knowledge. Participatory action research, sometimes known as participatory research, is "learning by doing", that is a group of people identify a problem, do something to resolve it, scrutinize their efforts and, if not satisfied, try again (O'Brien, 2001). In the Nordic countries, the "Scandinavian model" was introduced in the middle of the '80s (Ehn *et al.*, 2000) which introduced a participatory approach involving users for context-sensitive and robust IT systems. Coming closer to the sub-Sahara African context, the participatory action research conducted in the presented project is linked more to participatory rural appraisal introduced by Rydhagen (2002).

Importance of Involving Users in System Development

The knowledge of how ICT and its application can improve the social and economic lives of people generally is very limited in many Tanzanian communities. Although Tanzanian secondary school members may have and be in contact with computers, does not mean that they really understand the impact that ICT if used effectively could have on improving performance. Coming to the issue of developing the TanSSe-L system for their use, if lack of knowledge was not carefully considered, the motivation to use the TanSSe-L system could have been very minimal or completely absent. The emphasis on participatory action research methodology is that the introduction of technology into organizations accompanies learning and generates a specific form of knowledge. Therefore, through focus group discussion, an understanding of the use of the TanSSe-L system was made possible, thereby ensured its utilization in the future.

The prospective users that were mainly students, teachers, school administrators and MoEVT officers were considered to be the

primary source of data. They were involved in the whole process of developing the TanSSe-L system, especially during the requirement gathering, requirement analysis and deployment phases.

Secondary Sources of Information

Data collection did not stop with primary sources of information using qualitative research methodology. Data were collected from secondary sources of information by going through existing relevant documents and texts, which included the National ICT policy, ICT for basic education, Basic Education Statistics (BEST) in Tanzania from MoEVT and other relevant documents from MoEVT, documents searched for on the Internet relating to e-learning in Tanzania, other research reports on e-learning in Tanzania, documents from semi-autonomous agencies of MoEVT like the National Examinations Council of Tanzania and Tanzania Institute of Education.

Design Approach

Software engineering is the design methodology adopted in this research. As defined by Pollice (2005) and the Institute of Electrical and Electronics Engineers (IEEE, 1993) software engineering is the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software, and the study of these approaches. Software engineering addresses the system development life cycle in a systematic way. The followings were used in developing TanSSe-L system:

Object-Oriented System Analysis and Design

There are several software development approaches employed. The two most commonly applied approaches are the structured approach and object-oriented (OO) approach.

OO, the one used in developing TanSSe-L system, decomposes the system into objects that is, it examines the system in terms of the components in the system and how these components act and interrelate. The analyst first identifies the objects that comprise the system, then creates an object model which groups the objects into classes, and describes each class in terms of its attributes (or data), methods (or functions) and relationships with other classes (Schach, 2004).

The key idea in the OO approach is that the real world can be accurately described as a collection of objects that interact. An object model includes four components: objects (that is abstract data structures), classes (i.e. abstract data types), inheritance (hierarchical relationships among abstract data types) and polymorphism.

In software development, a successful information system is subject to frequent evaluation and revision within the SDLC. Pressman (2010) adds to this by pointing out that a system's life cycle consists of four principal phases:

- Requirements Phase

This is the process whereby the users' needs in a software project are identified, modelled and validated. This phase is regarded as one of the most important aspects of building an information system because it is during this process that what is to be built is decided on. It is an iterative process by which the needs and requirements of individuals and groups significant to the development are researched and identified. Requirements phase defines the customer, user and market requirements, design requirements and technical requirements (Arayici and Aouad, 2005).

- Analysis Phase

This is when the main information for designing the new system is obtained. It specifies the system objectives and describes the work and its constraints with which designers have to comply.

- Design Phase

This is when the architecture is established. The phase starts with the documentation delivered by the requirement and analysis phases and incorporates the requirements into the architecture.

- Testing/Implementation Phase:

This is when the system is built. The implementation phase deals with issues of quality, performance, baselines, libraries, and debugging. The end deliverable is the product itself.

These phases address what is to be built, how it will be built, building it and ensuring the quality to highest possible standard. This research adopted the OO software development approach with UML. Using this approach Booch *et al.* (2005), and Booch *et al.* (2001) argue that the process of object-oriented analysis (OOA) from SDLC is composed of the following activities: requirement capturing, specification component identification, and specification representation. During requirement capturing, several function-viewed notations are used, including the context diagram of the structured analysis technique, use case diagrams and activity diagrams of the UML. During specification component identification; a systematic procedure is provided to identify classes and their attributes from the data, to identify class operations from class, responsibility and collaborator cards, and during specification representation most notations used are from UML.

An OOA technique is generally composed of an OOA process to analyze requirements and identify specification components (e.g., classes and class relationships), and an OOA model to represent specifications. UML can be used for OO models in all phases of software development, including OOA. In this connection, Chen *et al.* (2000) say that OOA provides rich notations for representing OO components, such as classes, objects, object behaviors of classes, object interactions and even functions (use cases and activity diagrams).

UML is the standard language for specifying, visualizing, constructing, and documenting all the components of a software system (OMG, 2003b). With UML, a software system can be described at various levels of granularity (for example, the system, the subsystem, and the class levels) and from various viewpoints (for example, the logical view and the use-case view). UML helps to simplify the process of software design, making a model for construction with a number of different views. UML can help in the following ways: aiding understanding of complex systems, exploring and comparing design alternatives at low cost, forming a foundation for implementation, capturing requirements precisely, communicating decisions unambiguously and simplifying reality. UML is also the one adopted by MDA, which is also used in this research.

TanSSe-L was a system to be developed and so it abided by the SDLC, which includes:

- System Requirement Specification and Analysis phase where use-case diagrams, a conceptual model, system sequence diagrams and system operation contracts were used;
- System Design phase where collaboration and design class diagrams were used; and
- System Implementation, testing and deployment phase where an open source LMS was customized, tested and deployed for usage at pilot schools;

However, there was an intermediate step between the TanSSe-L system design phase and the TanSSe-L system implementation phase which involved transformation as applied in the Model Driven Architecture (MDA) approach.

Model Driven Architecture

Design through modelling, which is a norm in the engineering domain, enforces a careful investigation of the structure, behaviour and architecture of a system in the early stages of development and promotes documentation and reuse. Czarnecki *et al.* (2005) mention that, the Object Management Group (OMG) initiative concerning MDA attempts to separate the application functionality specification from the implementation of that functionality on specific technology platforms. This approach is designed to play a key role in the fields of

information systems and software engineering. MDA is supposed to provide a basic technical framework for information integration and tool interoperability based on the separation of the Platform Specific Model (PSM) and from the Platform Independent Model (PIM).

The MDA guide indicates that the PIM represents the functionality and behavior of a system and captures only the application logic. The PIM is then converted into the PSM, which captures the technology-specific details of system implementation. The separation of concerns between the application and technical aspects of a system promotes separate, yet controlled, evolution of both aspects of the system based on different needs. The primary goals of MDA are portability, interoperability and reusability through architecture separation of concerns (OMG, 2003a). A key standard in the MDA is that it is based on UML as recommended by OMG.

Brown *et al.* (2005) insist that models provide abstractions of a physical system that allow engineers to reason about that system by ignoring extraneous details while focusing on relevant ones. All forms of engineering rely on models to understand complex, real-world systems. Models are used in many ways, which are to predict system quality, reason about specific properties when aspects of the system are changed, and communicate key system characteristics to various stakeholders. The models may be developed as an originator to implement the physical system, or they may be derived from an existing system or a system in development as an aid to understanding its behaviour.

UML is one of the technologies specified by OMG to enable a model-driven approach. OMG in its UML specification version 1.5 OMG (2003b) mentions that UML offers a standard way to write a system's blueprint, including conceptual things. Development of the TanSSe-L system was also based on MDA using UML as the modelling language. Several diagrams were used to visualize the system for ease of understanding and discussion with end-users and research group. Diagrams that were involved were 'use case' diagrams in the requirements specification phase, 'conceptual', 'sequence', 'collaboration', 'design class' and 'component' diagrams in system requirements analysis and system design phases.

As stated earlier, MDA is supposed to provide a basic technical framework for information integration and tool interoperability based on the separation of the PSM from the PIM. To support these principles, the OMG has defined a specific set of layers and transformations that provide the conceptual framework and vocabulary of MDA as summarized in Figure 1.

The set of layers defined includes the computation independent model (CIM), the PIM and the PSM. Along with the conceptual framework, OMG through MDA has also provided a set of standards to express models, model relationships and model-to-model transformations (OMG, 2003a). The MDA guide explains each of these layers as follows:

- A *computation independent model* is the view of the system from the computation independent viewpoint, which focuses on the environment of the system, and the requirements of the system, while the details of the structure and processing of the system are hidden or are as yet undetermined.
- A *platform independent model* is the view of the system from the platform independent viewpoint, which focuses on the operation of a system while hiding the details necessary for a particular platform. A platform independent view shows that part of the complete specification that does not change from one platform to another.
- A *platform specific model* is the view of the system from the platform specific viewpoint. A PSM combines the specifications in the PIM with the details that specify how that system uses a particular type of platform. The platform specific viewpoint combines the platform independent viewpoint with an additional focus on the detail of the use of a specific platform by the system.

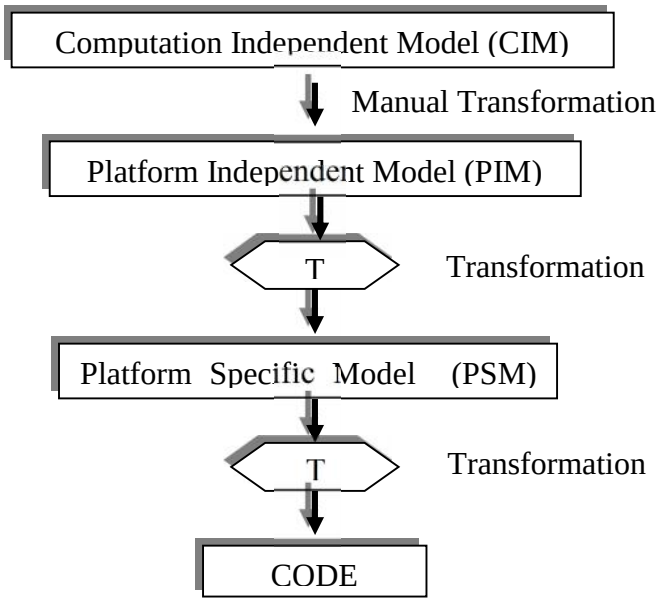

Figure 1: MDA Conceptual Framework (Source: OMG, 2003a)

OOSA&D and MDA Integration for TanSSe-L System Development

TanSSe-L system development integrates the OOSA&D approach with MDA. When relating OOSA&D to the MDA conceptual framework, as shown in Figure 2, the CIM for TanSSe-L system is a modelling system showing specifications requirements. UML's use case diagrams were used to model the users' requirements and their boundaries. The CIM also showed the TanSSe-L system's architecture and standard specifications.

OMG (2003a) in its MDA guide explains clearly that a common technique for achieving platform independence is to target a system model for a technology-neutral virtual machine. A virtual machine is defined as a set of parts and services (communications, scheduling, naming, etc.), which are defined independently of any specific platform and which are realized in platform-specific ways on different platforms. A virtual machine is a platform, and such a model is specific to that platform. However, that model is platform independent with respect to the class of different platforms on which that virtual machine has been implemented. This is because such models are unaffected by the underlying platform and, hence, fully conform to the criterion of platform independence.

In view of the TanSSe-L system, the development of PIM targeted and focused on a global way of developing LMSs, specifically viewing the presence of open source LMS for customization, as one methodology in the research. Three main functional areas realized include: -

- Management of TanSSe-L system users
- Management of learning materials with learning activities
- How to track users' interaction with learning materials and learning activities, and generation of tracking reports

PIM as indicated in Figure 2 is related to the design class diagram (DCD) of the TanSSe-L system design phase in accordance with the OOSA&D approach. System analysis and part of the system design phases is the transformation approach from CIM to the TanSSe-L system PIM (hereby a DCD). UML was used to model the TanSSe-L system at different levels of abstraction from the platform independent viewpoint. These models give what was expected to be provided by the

TanSSe-L system for Tanzanian secondary schools. At this stage, the structure of the TanSSe-L system database through DCD was used to select the open source LMS platform. The selected open source LMS is a virtual machine specific to the TanSSe-L system PIM. Again, to include the TanSSe-L system context, merging the model of the TanSSe-L system PIM with the TanSSe-L system-specific PIM was employed to get the actual TanSSe-L system-specific PIM.

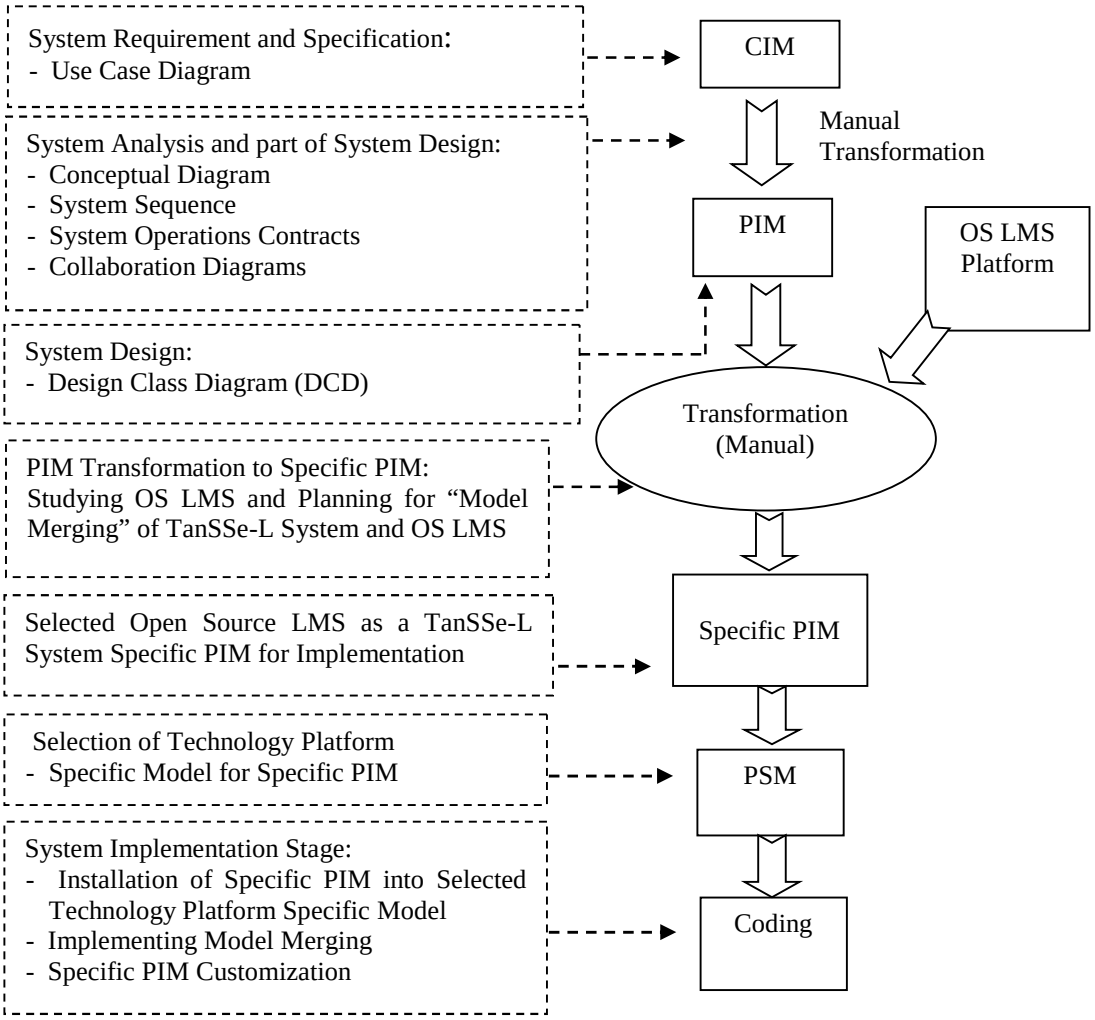

Figure 2: TanSSe-L System OOSA&D Integration with MDA

OMG (2003a) emphasizes that when PIMs are based on virtual machines, transformation is not necessary. Instead, it is the PIM of the virtual machine itself that needs to be transformed into a PSM for a particular platform. The selection of the TanSSe-L system-specific PIM also considered the PSM which the research used, that is a Linux, Apache, MySQL and PHP (LAMP).

A summary of the PIM transformation into PSM is as follows: -

- DCD was used to study the functionalities, similarities and differences in the number of possible open source LMS to be customized;
- One open source LMS was selected which would suit the TanSSe-L system's requirements, including the technology available and already prepared for the TanSSe-L system. The open source LMS selected was the TanSSe-L system-specific PIM;
- Needed major modifications to the specific PIM when related to DCD (TanSSe-L system PIM) were planned and documented; and

- The technological PSM for the specific PIM selected was understood in relation to the PSM for the TanSSe-L system.

During TanSSe-L system implementation, the following were done with reference to the transformation of the PIM into the PSM:

- The TanSSe-L system PSM was in place,
- The TanSSe-L system-specific PIM was installed,
- Models were merged to incorporate all missing information in the TanSSe-L system-specific PIM (selected open source LMS), and
- Continued customizing of the TanSSe-L system-specific PIM with the help of the documented plan.

An overview is that, the TanSSe-L system PSM depended on the platform implementation specification for the TanSSe-L system-specific PIM (selected and merged open source LMS). The implementation stage involved modifying the database, language terminologies, customizing codes, page interfaces and Structured Query Language (SQL) of the TanSSe-L system-specific PIM.

Customization of open source LMS platform

Learning Management Systems (LMSs) are specialized learning technology systems based on state-of-the-art Internet and WWW technologies in order to provide education and training following the open and distance learning paradigm (IEEE LTSC, 2001a; IEEE LTSC, 2001b).

LMSs in use today are either commercial products (e.g. WebCT, Blackboard), or free open source products (e.g. Moodle, Claroline), or customized software systems that serve the instructional purposes of particular organizations. LMSs that belong to the third category are exponentially increasing, as most education and training institutions are building or planning to build their own LMSs. This is due to the fact that a customized LMS will fit better their specific learning purposes, and will prove to give a good return on investment over the years (Collier, 2002),

It is obvious that Tanzanian secondary schools cannot afford the cost of commercial LMS, nor getting hold of a system optimally suited to the specific context. The alternative means is to customize open source LMSs. To ease the TanSSe-L system development process and to help generate a timely solution, existing open source LMS platforms were used. Most open source LMSs could support the basic functions needed for developing the TanSSe-L system, but there was an obvious need for detailed customization.

TanSSe-L System database mirroring and replication

The TanSSe-L system is for Tanzanian secondary school members (students, teachers, school administrators and MoEVT officers) who are geographically dispersed in different regions. The TanSSe-L system server is centrally placed at the University Computing Center (UCC), UDSM and its url is http://tanssel.ecse.udsm.ac.tz/moodlecvs/.
Access to data in the centrally placed database is by the means of network connectivity (Internet) which is not very reliable for several reasons, such as limited bandwidth and/or electrical breakdowns. Amir *et al*. (2002) reveal that the centralized approach suffers from two major drawbacks:

- Performance problems due to high server load or high communication latency for remote clients
- Availability problems caused by server downtime or lack of connectivity. Clients in parts of the network who are temporarily disconnected from the server cannot be serviced

Lack of connectivity due to several reasons, like electrical power failure, is common and a major problem in Tanzania. To increase the availability and accessibility of the database, replication of database is possible, and it implemented one of the specific objectives of the research, that is to enable publication of learning materials. As shown in Figure 3 replication creates copies of the database,

which can be then placed on an individual school's server or cluster of schools for the purpose of easy sharing of data from the database, across multiple sites. The main reason for replicating in the first place as stated by Zhao (2015) is to enable remote users to continue working even if the connection to the central site is down.

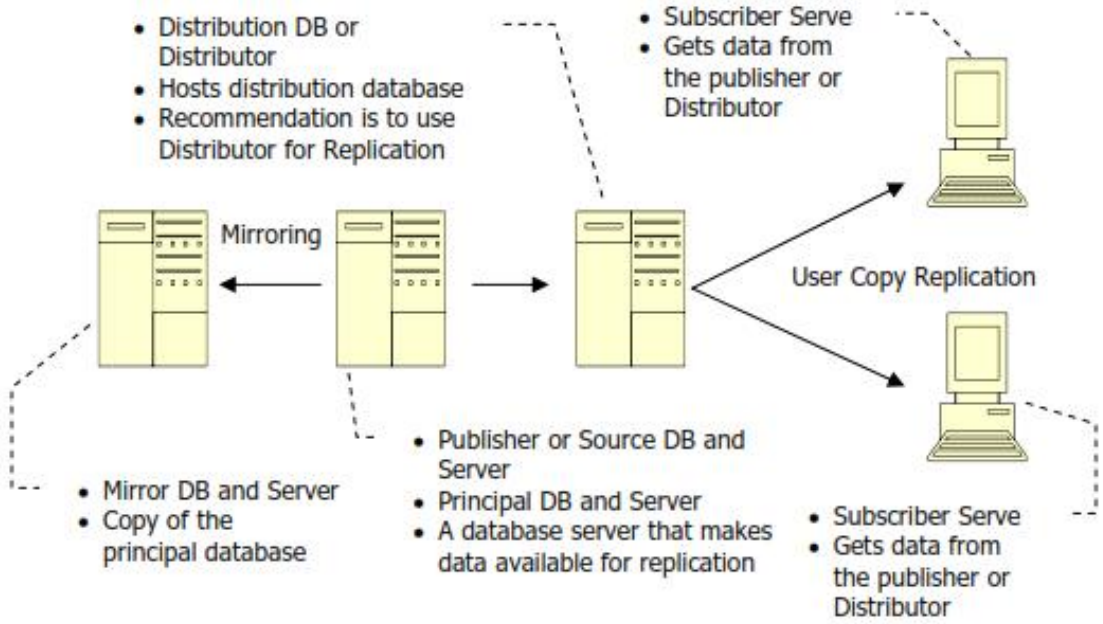

Figure 3: Architecture for Database Mirroring and Replication

To ensure high availability of learning content from the database, replication was also supported by mirroring of the database so as to overcome the planned and unplanned downtime. Mishra (2006) observed that unplanned downtime is primarily caused by hardware failure (computer failure and storage failure), disk corruption, power outages, communication failure, natural disasters, terrorism, human error, and other factors that cause the primary production database, the production server, and/or the production data Centre to be unavailable. Planned downtime is primarily due to changes that are applied to the production system. These might be hardware upgrades, software upgrades, and database storage and configuration changes, which cause the primary database or server to be unavailable for a short period of time.

Zhao (2015) found that many of the open source database management systems (DBMS) by default provide only the limited master-to-slave (publisher to subscriber) replication capabilities and setups. Mirroring and replication involve much more than setups. Apart from a thorough understanding of the replication mechanism employed by the DBMS to be used by the TanSSe-L system, that is MySQL, it also required careful analysis and planning before the implementation of replication. Zhao (2015) emphasizes that all database administrators must make sure that the design takes the distributed database into account.

DISCUSSION

Research methodology plays an important role when doing a research. It gives a systematic strategy to solve a research problem. This paper presented a detailed research methodology applied to develop a Tanzania Secondary Schools e-Learning (TanSSe-L) system. Systematically, research methodology with their importance have been explained.

The software design approach was applied simply to produce a software solution to a problem. Producing quality software needs, a thorough understanding of the requirements of users. Visualization in the course of continuous improvement is necessary for the participation of the personnel, and allows end-users to grasp the concept of the system and how it operates

without having to understand software terminologies.

Focus group discussion as inspired by participatory action research methodology is fundamental to a context-driven research work on specific problems in the real word. The emphasis of participatory action research is that it is a methodology which accompanies the introduction of technology into organizations and learning. Through discussion and demonstrations, a common understanding of how TanSSe-L could complement traditional teaching was arrived at. Focus group discussion is a way of exchanging knowledge, that is, users giving their experience of using the system they are in and researchers giving new suggestions and techniques to improve that system.
A model is used for a proper understanding of a system before its actual implementation. Integration of the power of models made software development life cycle stages be done more systematically and helped in describing the system from different viewpoints, each focusing on a particular concern.

Problems facing mainly developing countries need to be addressed by making use of applied research, which is designed to solve specific practical problems and meet a specific need within the community. The world should now call for implementing more applied research in addition to basic or traditional research that is mode 1. Taking advantage of software produced by the open source community, customization of open source LMS platforms can be used to develop a system which is optimally suited to the specific context.

Access to the centrally placed servers is a challenge to many of the developing countries like Tanzania in-terms of bandwidth limitation and electrical power breakdowns. If central servers get damaged, then all the users will be affected. Mirroring of data is important and it may save as a backup of the system. Replication as well will bring the TanSSe-L system near to users, hence make it available even with low bandwidth.

REFERENCES

Amir Y., Danilov C., Miskin-Amir M., Stanton J. and Tutu C. (2002). Practical Wide-Area Database Replication, Technical Report CNDS-2002-1, Johns Hopkins University.

Arayici Y. and Aouad G. (2005). Computer Integrated Construction: an Approach to Requirements Engineering, 12(2): 194-215, Emerald Group Publishing Limited.

Booch G., Rumbaugh J. and Jacobson I. (2001). The Unified Modelling Language User Guide, Addison-Wesley Edition.

Booch G., Rumbaugh J. and Jacobson I. (2005). The Unified Modelling Language User Guide, Object Technology Series, Addison Wesley, 2nd edition, 2005.

Brown A. and Conallen J. (2005). An Introduction to Model-Driven Architecture, Part I, Part II and Part III, Addison Wesley.

Chen J.Y. and Chou S.C. (2000). An Object-Oriented Analysis Technique Based on the Unified Modelling Language, NSC88-2213-E-009-012.

Collier G. (2002). e-Learning Application Infrastructure, Sun Microsystems White Paper. Available online at http://www.sun.com/products-n-solutions/edu/whitepapers/index.html, Retrieved in March 2006.

Czarnecki K.K., Favre J., Gogolla M. and Mens T.T. (2005). Essentials of the 4th UML/MoDELS Workshop in Software Model Engineering (WiSME'2005).

Ehn P., Sjögren D. and Sundblad Y. (2000). Co-operative Design — Perspectives on 20 Years with the Scandinavian IT Design Model, NordiCHI 2000, Stockholm Report Number: CID-104, ISSN Number: ISSN 1403-073X, Publication Date: October.

Ewings P., Powell R., Barton A. and Pritchard C. (2003). Qualitative Research Methods, Helpsheet 9, RDSU, Peninsula Research & Development Support Unit, May.

Gibbons M., Limoges C., Nowotny H., Schwartzman S., Scott P. and Trow M. (2015). The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies, 1st Edition, Kindle Edition, SAGE Publications Ltd.

IEEE (1993). IEEE Standards Collection: Software Engineering, IEEE Standard 610.12-1990, IEEE 1993.

IEEE LTSC (2001a). Draft Standard for Learning Technology Systems Architecture (LTSA), Learning Technology Standards Committee (LTSC), Draft 9, http://ltsc.ieee.org/.

IEEE LTSC (2001b). Draft Standard for Learning Object Metadata (LOM), Learning Technology Standards Committee (LTSC), Draft 6.4,http://ltsc.ieee.org/.

Kadiman K. (2006). The Triple Helix and the Public, Paper Presented at Seminar on Balanced Perspective in Business Practices, Governance, and Personal Life, Mercantile Club, Wisma BCA, Jakarta. 7 December 2006.

Kalinga E.A., Bagile B.B.R. and Trojer L. (2007). An Interactive e-Learning Management System (e-LMS): A Solution to Tanzanian Secondary Schools' Education, XXI. International Conference on Computer, Electrical, and Systems Science, and Engineering (CESSE), 2007 WASET.ORG, ISBN 978-975-01752-0-6, V-21, 19.

Kalinga E.A. (2008). Development of an Interactive e-Learning Management System (e-LMS) for Tanzanian Secondary Schools, Blekinge Institute of Technology, School of Technoculture, Humanities and Planning, Licentiate Dissertation Series No. 2008:03, ISSN 1650-2140, ISBN 978-91-7295-134-1.

Kalinga E.A. (2010). Development of an Interactive e-Learning Management System (e-LMS) for Tanzanian Secondary Schools, Blekinge Institute of Technology Doctoral Dissertation Series No 2010:10, Publisher: Blekinge Institute of Technology, ISBN: 978-91-7295-191-4, ISSN 1653-2090

Kothari C.R. (2004). Research Methodology; Methods and Techniques, 2nd Edition, New Delhi, Vishwaprakashan.

Kuhn T.S. (2012). The Structure of Scientific Revolutions: 50th Anniversary Edition Fourth Edition, The University of Chicago Press.

Lating P.O. (2009). Hybrid E-learning for Rural Secondary Schools in Uganda Co-evolution in Triple Helix Processes, Blekinge Institute of Technology Doctoral Dissertation, Series No 2009:01, ISSN 1653-2090, Printfabriken, Karlskrona, Sweden, ISBN 978-91-7295-158-7.

Mishra S. (2006). Database Mirroring Best Practices and Performance Considerations, SQL Server Technical Article, Microsoft Corp., February 2006, Applies To: SQL Server 2005.

O'Brien R. (2001). An Overview of the Methodological Approach of Action Research, In Roberto Richardson (Ed.). Theory and Practice of Action Research, Available online at http://www.web.ca/~robrien/papers/arfinal.html.

OMG (2003a). MDA Guide Version 1.0.1, Document Number: omg/2003-06-01, 12th June.

OMG (2003b). Unified Modelling Language Specification, March 2003, Version 1.5, formal/03-03-01.

Pandey P. and Pandey M.M. (2015). Research Methodology: Tools and Techniques, Bridge Center. ISBN 978-606-93502-7-0.

Pollice G. (2005). Teaching software development vs software engineering, Worcester Polytech-nic Institute, IBM, 15th December.

Pressman R.S. (2010). Software Engineering: A Practitioner's Approach, Seventh Edition, McGraw-Hill Companies.

Rowley J. (2003). Action Research: an Approach to Student Work Based Learning, Emerald Education + Training, Volume 45, Number 3.2003, pp 131-138, MCB UP Limited, ISSN 0040-0912.

Rydhagen B. (2002). Feminist Sanitary Engineering as a Participatory Alternative in South Africa and Sweden, BTH, Dissertation Series Number: 2002:06, ISBN: 91-7295-017-X.

Schach S.R. (2004). An Introduction to Object-Oriented Systems Analysis and Design with UML and the Unified Process, McGraw-Hill/Irwin, ISBN 0071215107.

Zhao W. (2015). Database Replication and Clustering for High Availability, Encyclopedia of Information Science and Technology, Third Edition.

Walsh S. (2001). The Use of the Triple Helix Concept in Accelerating the Pace of Commercialization of Micro and Nano Technology Based Products.