

DEVELOPMENT OF AN INTERACTIVE E-LEARNING MANAGEMENT SYSTEM (e-LMS) FOR TANZANIAN SECONDARY SCHOOLS

Ellen Kalinga

Blekinge Institute of Technology
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School of Planning and Media Design



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Department of Technology and Aesthetics
School of Planning and Media Design
Blekinge Institute of Technology
SWEDEN

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ABSTRACT

e-Learning, defined as the use of information and communications technology (ICT) for supporting the educational process, has motivated Tanzania to apply ICT in its education systems. Tanzanian secondary schools which are geographically and socially isolated face a number of problems, including a way to get learning materials. The impact of these problems is poor performance in National Examinations. This poor performance however is most noted in science and mathematics. The problem in getting learning materials can be reduced by employing ICT.

This research developed an interactive e-learning management system (e-LMS) to be used by Tanzanian secondary schools. Tanzania Secondary Schools e-Learning (TanSSe-L) system is the name adopted for an interactive e-LMS developed. The research is aimed at supporting teaching and learning functions by allowing for the creation and storage of learning materials, making them available, easily accessed and sharable by students from different secondary schools in Tanzania. It is a context-driven research work of knowledge production in a specific context for application. Initially, the research work focused on two selected pilot schools; Kibaha Secondary School and Wali-ul-Asr Girls' Seminary in Kibaha town, Pwani region. Features of the TanSSe-L system represent the standard form of any secondary school registered by the Ministry of Education and Vocational Training.

The development of the TanSSe-L system made use of software engineering discipline. The research used Unified Modelling Language (UML) and integrated Object-Oriented System Analysis and Design (OOSA&D) and Model Driven Architecture (MDA) to address the System Development Life Cycle (SLDC) in a systemic way. UML design class diagram (DCD) is a Platform Independent Model (PIM) that was transformed into a Platform Specific Model (PSM) in MDA for implementation. Implementation made use of open source LMS to help generate a timely solution to TanSSe-L system development. In this specific context, focus group discussion as inspired by action research methodology was used. The research evolved into a triple helix process in close cooperation with other stakeholders. Finally, it is considered that replication and mirroring will make learning materials highly available to end-users

Keywords: ICT, Tanzania, Secondary Schools, e-Learning, Software Engineering, UML, OOSA&D, MDA, PIM, PSM, LMS, Open Source, Customization, Replication, Mirroring, Focus Group Discussion, mode 2, Triple Helix Processes.

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*To my late father Mr. Ambakisye Mwalukasa Kalinga,
my loving mother Bertha Ulisubisya Kibona,
my loving husband Simon Nicodem Chale,
and our dearest daughter Joan Simon Chale.*

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LIST OF ACRONYMS AND ABBREVIATIONS

ACSEE	:	Advance Certificate of Secondary Education Examination
A-Level	:	Advanced level
ANSI	:	American National Standards Institute
BEST	:	Basic Education Statistics in Tanzania
BTH	:	Blekinge Institute of Technology (Blekinge Tekniska Högskola)
CD-ROM	:	Compact Disk - Read Only Memory
CIM	:	Computation Independent Model
CoET	:	College of Engineering and Technology
CPU	:	Central Processing Unit
CSEE	:	Certificate of Secondary Education Examination
CSS	:	Cascading Style Sheets
CVS	:	Concurrent Versioning System
DBMS	:	Database Management System
DCD	:	Design Class Diagram
ECSE	:	Electrical and Computer Systems Engineering
e-LMS	:	electronic Learning Management System
GB	:	Gigabytes
GRASP	:	General Responsibility Assignment Software Patterns
HTML	:	Hypertext Markup Language
HTTP	:	HyperText Transfer Protocol
ICT	:	Information and Communication Technology
ID	:	Identifiers
IEEE	:	Institute of Electrical and Electronic Engineers
IICD	:	International Institute for Communication and Development
IMS	:	Instructional Management Systems
IP	:	Internet Protocol
Kbps	:	Kilobits per Second
KSS	:	Kibaha Secondary School
LAMP	:	Linux, Apache, MySQL and PHP
LAN	:	Local Area Network
LMS	:	Learning Management System
MB	:	Megabytes
Mbps	:	Megabits per Second
MDA	:	Model Driven Architecture
MoEC	:	Ministry of Education and Culture
MoEVT	:	Ministry of Education and Vocational Training

MySQL	:	My Standard Query Language
NECTA	:	National Examinations Council of Tanzania
O-Level	:	Ordinary level
OECD	:	Organization for Economic Co-operation and Development
OMG	:	Object Management Group
OO	:	Object Oriented
OOA	:	Object Oriented Analysis
OOSA&D	:	Object Oriented System Analysis and Design
OSS	:	Open Source Software
PHP	:	PHP: Hypertext Preprocessor
PIM	:	Platform Independent Model
PoP	:	Point of Presence
PSM	:	Platform Specific Model
RAM	:	Random Access Memory
SAREC	:	Sida/SAREC, the department for Research Co-operation
SCORM	:	Sharable Content Object Reference Model
SDLC	:	System Development Life Cycle
SEDP	:	Secondary Education Development Plan
Sida	:	Swedish International Development Agency
SPARC	:	Standard Planning and Requirements Committee
SQL	:	Structured Query Language
TANESCO	:	Tanzania national Electrical Services Company
TanSSe-L	:	Tanzania Secondary School e-Learning
TCP/IP	:	Transfer Common Protocol/Internet Protocol
TTCL	:	Tanzania Telecommunications Company Limited
UDSM	:	University of Dar es Salaam
UML	:	Unified Modelling Language
UNU/IIST	:	United Nations University/International Institute for Software Technology
WAN	:	Wide Area Network
WWW	:	World Wide Web
XHTML	:	Extensible Hypertext Markup Language
XML	:	Extensible Markup Language

CHAPTER ONE: INTRODUCTION

1.1 General Introduction

Information and Communications Technology (ICT) has been integrated in education in many developing and developed countries, but the use of ICT in Tanzanian secondary schools is still lagging behind. Many Tanzanian secondary schools have no computers, although many are making an effort to acquire them. The few schools with computers use them primarily for secretarial services and computer literacy training. Very few secondary schools have Internet services, which are mainly accessible to the heads of the computer unit, headmasters/headmistresses of the schools and staff. Few schools have ICT infrastructure; that is, a Local Area Network (LAN).

This research comes at a time when many initiatives have already undertaken to address the ICT issue in Tanzania. However, many of them concentrated on big cities and towns, especially in higher learning institutions. Sida/SAREC, the department for Research Co-operation (SAREC), within the Swedish International Development Agency (Sida) has taken the initiative to carry out countrywide ICT surveys to collect information regarding key ratios, connectivity, access, the human resource situation, key institutions, and the policy and regulatory framework (Research proposal, 2001). The ICT surveys have been undertaken in Tanzania, Rwanda, Uganda and Mozambique (Miller et al., 2001). In Tanzania this research was conducted at the Department of Electrical and Computer Systems (ECSE), College of Engineering and Technology (CoET) of the University of Dar-es-Salaam (UDSM).

Looking at the magnitude of different activities that can be improved on by the use of ICT in rural areas, e-learning for secondary schools in Tanzania was given a high priority in the ongoing ICT research project under the above-mentioned programme. It is envisaged that once network connectivity is established in secondary schools, the other services such as e-governance, e-health and e-business can be extended to the surrounding areas (Research proposal, 2001).

The ICT for e-learning project officially started in 2004, and so it is hereby noted that many of the statistical data which are included in this research were obtained in 2004 and 2006. However, this research also tries whenever possible to provide the statistical change of data in each related area. Many of the latest statistical data are of 2008 and have been obtained from the Ministry of Education and Vocational training (MoEVT).

1.2 Statement of the Problem

Tanzanian secondary schools that are predominantly located in rural areas are geographically and socially isolated. These schools face a number of problems in ensuring quality delivery of learning materials. Such schools face three critical issues that are global in perspective, but remain focused on learners' needs, which are the shortage of teachers, the quality of teaching and the capacity of schools in terms of incentives/motivation. Schools located in remote areas are a disincentive to excellent teachers to work there compared to working in urban areas.

The Government is working hard not only to raise the quality of education but also to expand access. The Government's efforts include programmes to raise the standard of teachers, by providing additional funding for high level training up to degree level and in-service training. But the Government's efforts cannot have the desired impact if even motivated teachers cannot have access to basic academic resource materials for themselves and their students.

Together with the efforts taken by the Tanzanian Government towards improving the education system, the rate of increase in the number of newly opened secondary schools and students is still high compared with the rate of increase in the number of teachers, textbooks and learning materials.

National Data (2004) shows that the total number of secondary schools (Government and non-Government) almost doubled between 1995 and 2004 as shown in Table 1.1, that is, from 595 schools in 1995 to 1,291 schools in 2004, an increase of 117%. As a result, student enrolment also increased by 120%, from 196,375 students in 1995 to 432,599 students in 2004.

Table 1.1: Number of Secondary Schools 1995 – 2004										
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Govt. Schools	259	303	350	406	444	527	528	599	649	828
Non-Govt. School	339	353	371	375	382	400	409	425	434	463
Total Schools	595	656	721	781	826	927	937	1024	1083	1291
% Increase	-	10	10	8	6	12	1	9	6	19
Source: Basic Education Statistics in Tanzania 1MoEC, 1995 - 2004										

In contrast the total number of teachers increased by only 68%, from 11,158 teachers in 1995 to 18,754 teachers in 2004. Due to this increased enrollment rate, the teacher-to-student ratio increased from 1:17 in 1995 to 1:23 in 2004. Table 1.2 shows the Enrolment of Students and Teachers, and Teacher-to-Student ratio 1995 – 2004.

Table 1.2: Enrolment of Students, number of Teachers, and Teacher to Students Ratio 1995 - 2004										
Total Enrolment	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Form I-IV	183659	185119	207560	208738	225866	238194	264892	296529	319487	401598
% Increase	-	1	12	1	8	6	11	12	8	26
Form V-VI	12716	13974	18047	18165	21713	23702	24807	26789	25954	31001
% Increase	-	10	29	1	20	9	5	8	-3	19
Teaching Staff	11158	11689	11434	11691	12783	13470	14352	15837	16399	18754
% Increase	-	5	-2	2	9	5	7	10	4	14
Teacher/Student ratio	1:17	1:17	1:20	1:19	1:19	1:20	1:20	1:20	1:21	1:23
Source: Basic Education Statistics in Tanzania from ¹ MoEC, 1995 - 2004										

Statistics shows that, the number of secondary schools keeps on increasing year after year. Further, in 2006, the statistics show that there were a total of 2,292 secondary schools, an increase of almost 78% of 1,291 secondary schools in 2004. The Basic Statistics for education of 2008 (MoEVT, 2008) show a big change regarding registered Tanzanian secondary schools. Table 1.3 summarizes the difference in the statistical data of 2004 and those of 2008. The information included in these differences includes enrolment of students, the number of teachers, teacher-to-student ratio and the number of registered secondary schools.

¹ Ministry of Education and Culture is currently known as Ministry of Education and Vocational Training (MoEVT)

Table 1.3: Difference in Tanzania Secondary Schools' Statistical Data from 2004 to 2008					
Description		2004	2008	Difference	%Increase
Enrolment (Form I – IV)		401,598	1,164,250	762,652	190
Enrolment Form (V – VI)		31,001	58,153	27,152	88
Total Enrolment (Form I – VI)		432,599	1,222,403	789,804	183
Enrolment (Teaching Staff)		18,754	32,835	14,081	75
Number of Registered Secondary Schools		1,291	3,798	2,507	194
Teacher-to-Student Ratio	Govt.	1:23	1:37	14 students more	
	Non-Govt.	1:23	1:41	18 students more	
Source: Basic Education Statistics in Tanzania (BEST) of 2008 from MoEVT					

It can be observed that the rate of increase in the number of newly opened secondary schools and students is still growing up compared with the rate of increase in the number of teachers. Consequently, the teacher-to-student ratio in 2008 was 1:37, compared with 1:23 in 2004 for Government schools.

Many schools lack basic information resources such as well-stocked libraries. Textbooks and other reference materials are not usually available in libraries and if available they are outdated. Purchasing textbooks is considerably expensive. Another problem is the inadequacy of laboratory facilities, especially for science subjects, which leads to newly established schools following the arts curriculum. The result of this is a relatively declining number of students taking science subjects, and of those who do, the majorities perform poorly. Some regional schools do not attract good teachers because of their location, pay scale, competition from private schools, or sometimes because the teachers they need are not available.

These problems have been causing inequality in performance levels between rural and urban schools, as analyzed in sub-item 1.2.1, resulting in poor performance academically in rural secondary schools. The poor performance is more critical in science and mathematics. In turn, many students do not meet the entry requirements for science and engineering courses at higher learning institutions.

1.2.1 Students' Performance Analysis, 1995-2003 and 2008

The Tanzanian secondary education system, which is the level just after primary school, is divided into two main parts. The first is Ordinary level (O-Level) secondary school which goes from form I to form IV. In form IV, students take the National Examination known as the Certificate of Secondary Education Examination (CSEE). After that students can be selected to join the advanced level of secondary school or certificate courses depending on their performance. The second is the Advanced Level (A-Level) secondary school which goes from form V to form VI. In form VI, students take the National Examination known as the Advance Certificate of Secondary Education Ex-

amination (ACSEE), after which students can be selected to join ordinary diploma courses, advanced diploma courses or first degree university programmes, depending on the their performance.

Table 1.4 and Figure 1.1 show the performance of form IV students in the O-Level National Examination as per Basic Education Statistics in Tanzania (2004) of the Mo-EVT between 1995 and 2003. The statistics show that students who obtained divisions I – III range from 23% to 38% only, while those who obtained division IV and division 0 range from 62% to 77%. Students with divisions I – III in this research are considered to have passed the examination and are possible candidates for joining either form V (i.e. A-Level) or certificate courses.

Table 1.4: Form IV National Examination O-Level Performance in Percentage 1995– 2003									
Division Ob- tained	Year								
	1995	1996	1997	1998	1999	2000	2001	2002	2003
I – III in %	25	23	30	29	29	26	28	36	38
IV and 0 in (%)	75	77	70	71	71	74	72	64	62
Total Number of Students Examined	37,850	40,479	41,867	42,887	44,172	47389	50,820	49,512	62,359
Source: Basic Education Statistics in Tanzania of 2004 from MoEC									

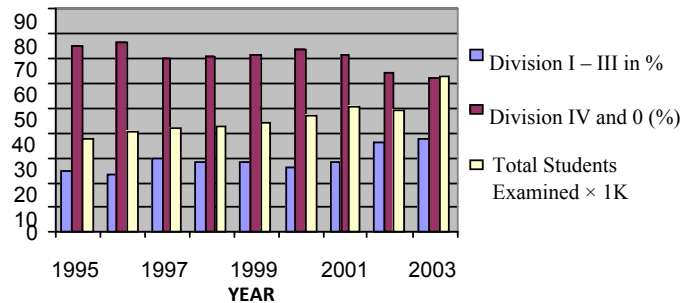


Fig. 1.1: CSEE Student Performance, 1995-2003

The revised statistical data obtained from BEST of 2008 (MoEVT, 2008) shows almost the same status. More students obtained division IV and division 0 than those with Divisions I, II and III. Table 1.5 shows form IV O-Level performance from 2003 to 2007.

Table 1.5: Situation of Form IV O-Level Performance from 2003 to 2007					
Division Obtained	Year				
	2003	2004	2005	2006	2007
I - III in %	38	38	34	36	36
IV and 0 in %	62	62	66	64	64
Total Number of Students Examined	62,359	63,487	85,292	85,865	125,288
Source: Basic Education Statistics in Tanzania of 2008 from MoEVT					

When we consider the subjects of science (Physics, Chemistry and Biology) and Mathematics (Advanced Mathematics) being taken by A-level secondary school students between 1999 and 2004, we can see that the percentage of students who obtained A, B and C grades ranges from 14% to 30% for Physics, 13% to 23% for Chemistry, 10% to 30% for Biology and 19% to 39% for Advanced Mathematics. Evaluation of performance using the grading system ranks 'A' to be an excellent pass while the value respectively drops to 'B', 'C', 'D', 'E' and 'F', with 'F' being ranked as a complete failure. It is realistic to group students with 'A', 'B' and 'C' as the ones who have a greater chance of being selected to join university degree courses or any other higher learning institutional courses. So far, the percentage of the best performance is not satisfactory. Table 1.6 shows the ACSEE students' performance from 1999 to 2004.

In relation to the poor performance observed in Tables 1.4, 1.5 and 1.6, it can be argued that poor performance is main coming from rural secondary schools. This is due to the fact that secondary schools in urban areas seem to have higher ranking than to those in rural areas as shown in Table 1.7. Taking one urban area Dar es Salaam, and two semi-urban areas, Mbeya and Iringa, as samples, we can see that in Dar es Salaam city many of its O-Level secondary schools ranked up to 100th schools out of 1080, in the 2004 CSEE examination, while Mbeya and Iringa region schools were below those in Dar es Salaam, except for few privately owned schools.

Table 1.6: Form VI National Examination (ACSEE) Performance Using Grading System							
Subject	Pass Grade	Year					
		1999	2000	2001	2002	2003	2004
Physics	Grades A, B, and C in %	30	14	14	19	17	19
	Grades D, E and F in %	70	86	86	81	83	81
	Total Number of Students Examined	2,480	2,580	2,947	3,154	3,300	3,534
Chemistry	Grades A, B, and C in %	14	16	13	23	23	20
	Grades D, E and F in %	86	84	87	77	77	80
	Total Number of Students Examined	2,219	2,882	3,107	3,481	3,636	4,121
Biology	Grades A, B, and C in %	10	23	27	21	18	30
	Grades D, E and F in %	90	77	73	79	82	70
	Total Number of Students Examined	1,628	1,901	2,194	2,309	2,313	2,843
Advanced Mathematics	Grades A, B, and C in %	24	21	22	19	23	39
	Grades D, E and F in %	76	79	78	81	77	61
	Total Number of Students Examined	1,547	2,065	2,102	2,288	2,499	
Source: Basic Education Statistics in Tanzania from MoEC, 1995 - 2004							

There are several reasons why a semi-urban or rural school is highly ranked, including:-

1. Seminary (mission-run) Secondary Schools, which normally get assistance from missionaries. St. Francis Girls' Secondary School in Mbeya region is a mission owned school.
2. Government special schools, where top ranked students are being grouped together and provided with special facilities. Ifunda Technical Secondary School in Iringa region and Iyunga Secondary School in Mbeya region are special schools under this Government programme.
3. Deliberate selection of highly ranked students (cream among students) in some schools that do not tolerate failures. This is mainly done by private secondary schools. St. Francis Girls' Secondary School in Mbeya region is one of these schools.

Table 1.7: Ranking of Urban and Rural Areas' Secondary Schools in 2004's CSEE Examinations									
Region	Owner	Name of Secondary School	Division					Total Students Examined	Rank (out of 1080 schools)
			I	II	III	IV	0		
Dar es Salaam (Urban Area)	Private	Mzizima	57	16	52	8	0	133	16
		Loyola	47	29	50	4	0	130	18
		St. Antony	65	66	90	24	0	245	28
	Government	Azania	86	102	130	120	7	445	59
		Jangwani	29	61	96	78	1	265	82
		Kibasila	30	37	80	75	1	223	92
Iringa Region (semi rural Area)	Private	Ruaha	5	17	50	23	0	95	103
		Highlands	9	9	68	23	0	109	98
	Government	Ifunda Technical	51	28	31	36	1	147	35
		Lugalo	28	37	72	65	1	194	106
		Iringa girls'	1	11	39	20	0	71	124
		Tosamaganga	11	21	44	57	4	137	132
Mbeya Region (semi rural Area)	Private	Sangu	4	20	60	65	0	149	155
		St. Francis Girls'	72	9	3	0	0	84	3
		Meta	3	6	53	64	1	127	205
	Government	Loleza Girls'	7	6	34	39	0	86	145
		Iyunga	65	43	43	51	4	206	40
		Mbeya	46	84	80	82	5	297	68
Source: Examination Results Statistics from NECTA, 1995 - 2004									

The problems of Tanzanian secondary schools mentioned were revealed by the second survey done in 2006/2007. The survey is explained in part B of Chapter 4: ICT Surveys.

1.2.2 The Need for ICT Use in Tanzanian Secondary Schools

Recesso (2001) pointed out that each problem in an education system has a direct impact on student learning, but it provides a broader lens for considering the potential use of ICT in education. Like any other developing country, the Tanzanian education system had to undergo a substantial transformation, underscored by the growing application of new ICT. The use of ICT in e-learning and related services has gained

commercial significance. Behling et al (1996) conclude that, generally, the benefits that can be derived from effective utilization of ICT include cost reduction, performance improvement, quality enhancement and the creation of new products and services.

Some rural secondary schools have acquired computers but they are not being used for teaching normal subjects. The ICT for e-learning project intends to make use of the few available ICT resources to improve teaching and learning functions, while taking advantage of using open source software (OSS). “*Tanzania Secondary Schools e-Learning (TanSSe-L) system*” is the name given to the ICT for e-learning project for Tanzanian secondary schools. The name reflects the ownership by all Tanzanian secondary schools, whether Government and/or Non-Government owned. TanSSe-L has three components, to be briefly discussed in Chapter 4 “ICT surveys”. One component is the “Development of an Interactive e-Learning Management System (e-LMS) for Tanzanian Secondary Schools”, which has adapted to the name TanSSe-L, which is used throughout this dissertation. The developed TanSSe-L system allows for the creation, storage, re-use, sharing and delivery of digital learning material, and manages these resources and users from a central object repository.

1.2.3 Definition of Tanzanian Rural Secondary School

There is no single and simple definition of a rural area. However, many definitions tend to identify rural areas as having low population densities and unique economic and social conditions. With regard to rural schools, Sandra et al. (2007) and Sher (1983) state that rural schools have recognizable tendencies, such as less specialization, less equipment and less bureaucracy than schools in non-rural sites. The distinction between rural and urban has been based on the availability and impact of science and technology. On the negative side, it is imagined that rural schools offer students a diminished education due to the lack of science activities (Stine, 1997) and the lack of a consistent curriculum (Amaral et al., 2001). For the teachers, this negative picture of rural-ness includes geographical isolation (Amaral et al., 2001).

As stated earlier, Tanzanian rural secondary schools are generally those schools located in rural areas and are geographically and socially isolated. But in reality, in Tanzania as a developing country, many of its secondary schools whether located in urban, semi-urban or rural areas are subject to similar basic problems mentioned in 1.2. Tanzania has many schools located in urban or semi-urban areas that equally face the same problems as those in rural areas. In this case the definition of rural secondary school with respect to this research is hereby defined as:-

“Tanzanian secondary school, whether located in urban area (a big city), semi-urban area (regional or district city) or real rural area with reference to geographical isolation, as long as it is lacking necessary resources such as books, qualified teachers and laboratories that could enable them achieve good performance, the school will be referred to as a rural secondary school.”

1.3 Research Objectives

1.3.1 Main Objective

The main objective of this research was to develop an interactive e-learning management system (e-LMS) (hereby referred as TanSSe-L system) to be used by Tanzania secondary schools to support teaching and learning processes.

1.3.2 Specific Objectives

The following are the specific objectives (SO) based on the services to be offered by the TanSSe-L system:

- ²*SO1*: To develop a module to enable the creation, storing, publication and sharing of learning materials.
- SO2*: To develop mechanisms for protecting the database and the information stored, as well as for managing users of the system and the work-flow of the learning materials.
- SO3*: To develop ways of evaluating students' learning progress through the TanSSe-L system, including means of assessment.

1.4 Research Questions

The above specific objectives were implemented based on the following research questions (RQ):-

- ³*RQ1*: How can the content of learning materials be made available and sharable among students and teachers, taking into consideration open source/low cost system, the issue of sustainability and the context of the application?
- RQ2*: Why is security an important dimension and what kinds of functionality are adequately efficient?
- RQ3*: How can the TanSSe-L system monitor the learning progress of students, as well as their understanding of the visited learning materials?

1.5 Research Programme

This research involved two higher learning institutions for academic support, UDSM in Tanzania and the Blekinge Institute of Technology (BTH) in Sweden, UDSM be-

² SO - Specific Objectives

³ RQ - Reserach Questions

ing where this empirical research work took place as well as supervision offered. The Division of Technoscience Studies at BTH offered relevant courses and the supervision needed for the research during the licentiate and PhD programme. This has been a sandwich programme, in which eight months have been spent at UDSM and four months at BTH each year for the whole research period.

1.6 Limitation of the Study and the Research Focus

The TanSSe-L system was aimed at supporting the teaching and learning processes of the Tanzanian secondary education system, consequently to improve the performance of students. Measuring the extent of support and the improvement in performance is not a one-day job. It requires ample time for users to adopt and use the TanSSe-L system effectively; starting from the time it was installed. This would go beyond the time limit for the research, resulting in the following limitation:

- The developed TanSSe-L system was prototyped to function in a small LAN having a few computers in a lab, an Apache application server and a MySQL database server. During the development stage it is difficult to involve all Tanzanian secondary schools. The focus was on involving only a few schools, in which case two secondary schools from Kibaha region were selected.
- The TanSSe-L system was installed at UDSM and configured to be used by the selected pilot schools in Kibaha, which were Kibaha Secondary School and Wali-ul-Asr Girls' Seminary. The TanSSe-L system was made fully applicable to these schools.

It was possible to use a few selected schools because Tanzania has only one curriculum for all secondary schools registered under the MoEVT. Features of the TanSSe-L system represent the standard form of any other secondary schools registered by the MoEVT. The TanSSe-L system implemented in these selected schools may later on be extended to other secondary schools in Tanzania in phases. Kibaha as a pilot site is elaborated on Chapter four.

1.7 Thesis Organization

This thesis consists of 9 chapters. *Chapter One* gives the general introduction of the research study. It shows the research problem area, the research objectives, research questions, limitation of the study and the research focus. *Chapter Two* shows the theoretical framework of the research methodologies applied. This research work emphasizes using focus group discussion as inspired by participatory action research, as a key way to successfully develop the TanSSe-L system. *Chapter Three* covers the theoretical background of relevant areas used in this research. In some cases, the learning-by-doing technique is employed, especially when studying web-based technologies. *Chapter Four* gives an overview of the ICT surveys conducted. It also shows how the pilot site Kibaha was selected. System requirements specifications and analysis for the TanSSe-L system are explicitly shown in *Chapter Five*.

TanSSe-L system design as part of SDLC is in *Chapter Six*. *Chapter Seven* presents the TanSSe-L system Platform Independent Model (PIM) transformation to the TanSSe-L system Platform Specific Model (PSM) as applied by MDA. *Chapter Eight* implements and deploys the TanSSe-L system where an open source learning management system (LMS) is customized. *Chapter Nine* gives the concluding remarks of the research work, where its main contribution is discussed and recommendations for future work are made. At the end, after the references, more of the TanSSe-L system operations contracts are shown in *Appendix "A"*, *Appendix "B"* presents some more collaboration diagrams and *Appendix "C"* gives a summary of published conference and journal papers.

CHAPTER TWO: RESEARCH METHODOLOGY

2.1 Introduction

There are a lot of results in the field of software engineering concerning how to represent systems and how to build a base for communication between the developer and the user of a software system (Walker et al., 1998). In order to manage the return on investment in ICT for education, here referred as a LMS, that is a TanSSe-L system, it is essential that the benefits, risks and cost effectiveness of using a new technology and new media are well understood in the context of application. An effective approach is to involve users in establishing the expected use of ICT for the benefit of education as well as in the development process.

The TanSSe-L system that was developed is for Tanzanian secondary school teachers and students, many of whom are not aware of the use of ICT in education. Modelling methodology is the best way to visualize the system to be designed. With modelling, complex and real-world systems are easily understood, qualities of the system are predicted and communication with stakeholders concerning the key characteristics is promoted (Brown, 2004). Models are developed as a way of creating a base for implementing and testing the physical system. Integration of focus group discussion as inspired by participatory action research methodology with MDA is of significance. Focus group discussion can easily be supported by modelling, when it comes to developing software for users.

Methodologies adopted in this research are presented as follows:

- “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, with an emphasis on focus group discussion, and briefly explains the development of the students’ registration database system as the starting point for creating a good relationship and sense of trust between the UDSM, secondary schools and MoEVT, as well as fostering sustainability.
- Design approach in which software engineering was employed. In this part the OOSA&D approach with the Unified Modelling Language (UML) were employed and integrated with 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 of the TanSSe-L system and replication of the database to ensure that is readily available to end users.

Integration of OOSA&D and MDA methodologies with the help of UML in the TanSSe-L system development creates a well organized flow of the SDLC. Lastly, this chapter discusses related works for this research.

2.2 Mode 2 and Triple Helix Model

This is 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 has been adopted.

Gibbons et al. (1994) 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. (1994) 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 knowledge⁴.

⁴The reader is referred to Gibbons et al (1994) and Nowotny, Schott and Gibbons (2001 and 2003) for more insights about mode 2 and trans-disciplinary research.

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 (1996) 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 (1996) 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 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 in order to integrate the collaboration of actors through focus group interviews and software development. The different methods are introduced below.

2.3 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.

2.3.1 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 are also presented by Kalinga et al. (2007).

- *Interview*

Interviews using open-ended questions were conducted with selected stakeholders of the schools (administrators, students and teachers) and officers in the 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 LAN, public connectivity such as telephone lines, and other public services in the area 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 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 com-

plete, 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 beforehand 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.

The importance of considering users in developing computer systems has been recognized since the 1970s (Abels et al., 1998). Systems development encompasses the complete range of activities involved in the process of analyzing, designing, implementing and maintaining an information system (Hirschheim et al., 1995; Jeremy, 2000). It is here taken as obvious that analysis and design cannot be separated from the users' social context and the purpose of the study, and that all social factors that impinge on development are worthy of study, using appropriate research methods. Systems development should be taken to be 'multidimensional social change' (Jeremy, 2000; Lyytinen, 1987). An analytical model for work-oriented information system research and practice is needed so that people doing their everyday tasks and duties should be given the opportunity to make a contribution to the prospective information system. Information systems should be developed in their organizational context.

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-Saharan African context, the participatory action research conducted in the presented project is linked more to participatory rural appraisal introduced by Chambers (1997) and Rydham (2002).

2.3.1.1 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 is not carefully considered, the motivation to use the TanSSe-L system may be 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 ensuring its utilization in the future.

The prospective users that are 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, analysis and deployment phases.

2.3.1.2 Development of Students' Registration Database System

There are many ICT application activities needed by Tanzanian secondary schools to ensure easy and comfortable daily administrative operations apart from ICT use academically. One area which is being implemented almost manually by many secondary schools is the keeping of records of registered students. To enable the schools to start utilizing ICT facilities effectively, the project also decided to develop a student registration database system. To start with, only pilot schools were considered, and a student registration database was designed for Wali-ul-Asr Girls' Seminary. The database could suit any secondary school, subject to slight modifications as per individual school requirements. The Students' registration database, as illustrated in detail by Kalinga (2008), was the joint design of three PhD students, namely Ellen A. Kalinga (myself), Suzan K. Lujara and Fatuma Simba.

To develop a functional database as per the context of a certain organization depends a lot on how end users are involved during the whole process of development. Finding appropriate system requirements depends on how close the developer is to the system stakeholders. Focus group discussion as employed by the qualitative research methodology is the key to being close to the actors. Naslund (2002) states that qualitative researchers believe that they can get closer to the actor's perspective through detailed interviewing and observation, emphasized as the techniques to be adopted by qualitative research methodology.

In this regard, the student registration database was developed with the purpose of building a good relationship and sense of trust between the UDSM and Wali-ul-Asr Girls' Seminary. For the success of the development of the TanSSe-L system, it was very important to be close to end users because they are the ones who, to a large extent, know what the deficits are in the education system and what they really need in order to improve their performance. The students' registration database was the starting point from which to be close to stakeholders of the TanSSe-L system. The students' registration database also introduced to the basics and an overview of designing relational databases using a structured approach (Kalinga, 2008).

2.3.2 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 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.

2.4 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 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 designing the TanSSe-L system:

2.4.1 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.

Yourdon (1991) says that the structured approach has since been reckoned to be the most widely used. Yourdon (1991), Davis (1983) and Kendall (1996), also explain that the structured approach prescribes analyzing and designing software through functional decomposition. It examines an information system in terms of the functions it performs and the data it uses and maintains. The structured approach identifies the major functions or processes of a system, then breaks or decomposes each function down into its smaller composite steps (Davis, 1983; Kendall, 1996). Furthermore, techniques which are invariably present in many methodologies, such as entity relationship diagrams, dataflow diagrams and data dictionaries, are also clearly mentioned.

Thomann (1994) indicates that the OO approach has been identified as the new paradigm for system development. OO 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. Davis et al. (1988) argue that SDLC is the basis

for most software development methodologies. Pressman (1997) adds to this by pointing out that a system's life cycle consists of four principal phases:

- *Requirements Phase* 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 et al. 2005).
- *Analysis Phase* 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* 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* 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 insuring the quality to highest possible standard.

This research adopted the OO software development approach with UML. Using this approach Booch et al. (2001 and 2005) 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, and 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 behaviours 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 MDA approach.

2.4.2 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 PSM from the PIM.

The MDA guide indicates that the PIM represents the functionality and behaviour 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 focus-

ing 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 2.1.

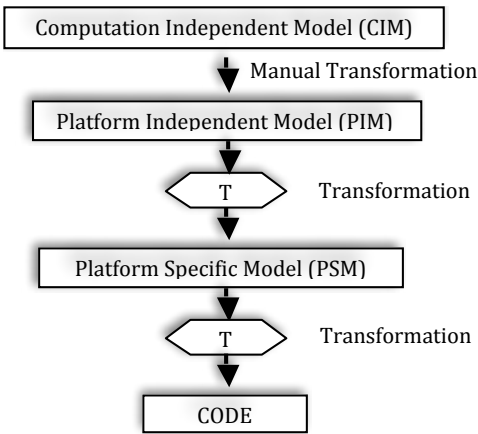


Fig. 2.1: MDA Conceptual Framework

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.

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

TanSSe-L system development integrates the OOSA&D approach with MDA as an added approach. When relating OOSA&D to the MDA conceptual framework, as shown in Figure 2.2, the CIM for TanSSe-L system is a modelling system showing specifications requirements. UML's use case diagrams are used to model the users' requirements and their boundaries. The CIM also shows the TanSSe-L system's architecture and standard specifications.

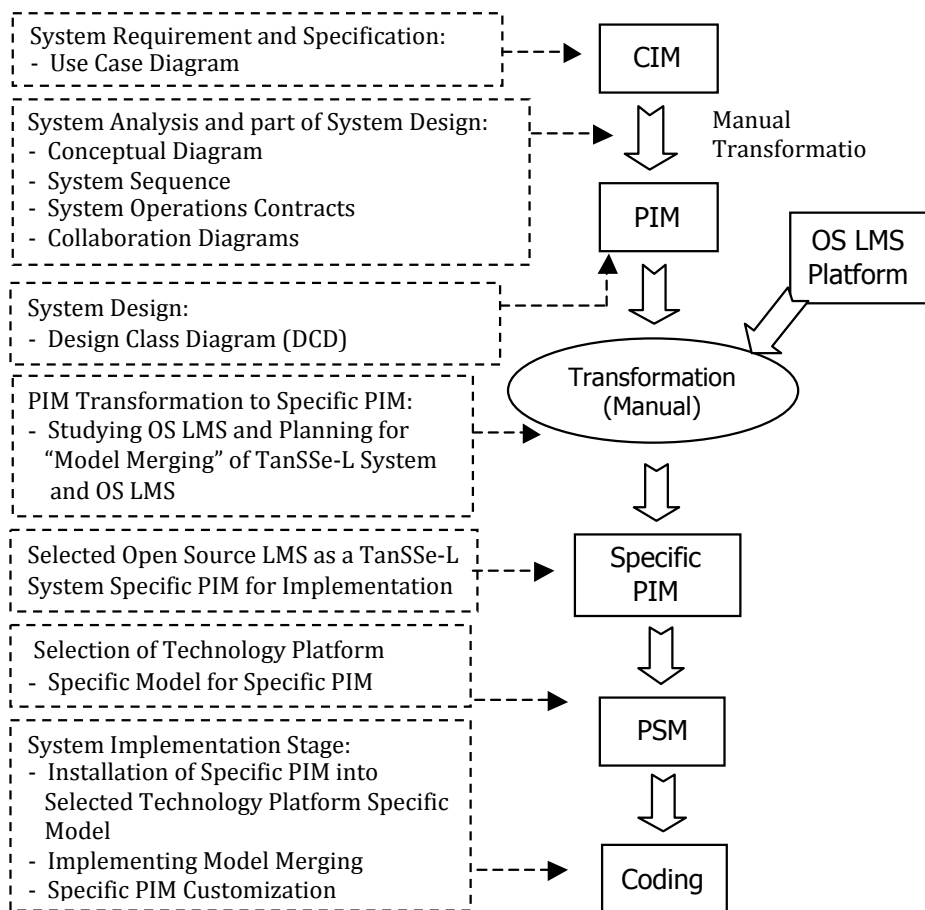


Fig. 2.2: TanSse-L System OOSA&D Integration with MDA

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. But 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 of this 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 2.2 is related to the design class diagram (DCD) of the TanSSe-L system design phase as per 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 is 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.

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 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, customizing codes, page interfaces and Structured Query Language (SQL) of the TanSSe-L system-specific PIM.

2.4.4 Related Works

Related approaches to model a system using object oriented system analysis and design with UML and transforming models using MDA has been done as shown in the following works:-

- (a) *“Apply Object-Orientation and UML to the Development of Web-based Learning System”* by Choe Sun Yong and Zhiming Liu (2003)

In this report Yong and Liu have shown how object-oriented techniques and UML, through the requirements capture, analysis, design, and implementation, can be used in the development of a Web-based learning system. As the starting cycle in the rational development process of the whole system, they carried out the required analysis and design of the sub-system that is only concerned with Web-based learning in computer science as a case study. The structure of the database obtained was the DCD.

The steps of designing a system in this document include:

- Providing goals for the system to be developed;
- Stating functions that a system is supposed to do;
- Creation of use case and use case diagrams;
- Creation of a system conceptual diagram;
- Creation of system sequence diagrams and identifying system operations;
- Creation of contracts for system operations;
- Creation of interactive diagrams (sequence and collaboration diagrams);
- Creation of a DCD;
- Creation of UML packages; and
- Mapping a design to code.

- (b) *“Unified Modelling Language Guide Version 0.2.1 May 13, 2001”* in the URL <http://www.comptechdoc.org/independent/uml/begin/> (Basic UML Guide, 2001).

This document addresses the steps involved in the design process of a system. The UML design process as explained in this document involves the creation of various graphical or text-based documents. In UML, these documents are called artifacts and they describe the output of a step in the process. The UML design process has two main parts which are:

- Analysis - What is the problem?
- Design - How should the problem be solved?

The reason for this analysis and design process is to allow the project to be broken down into components. The artifacts created as per this document are as shown in Table 2.1 (normally in the order shown).

Table 2.1: Artifacts for Analysis and Design Phases	
Phase	Artifact
Analysis Phase	1. Use Case Diagram
	2. High Level Use Case
	3. Expanded Use Case
	4. System Sequence Diagram
	5. Domain Model (formally called conceptual model)
	6. Operation Contract
Design Phase	• Collaboration Diagrams (Also called interaction diagrams)
	• Design Class Diagram

The above documents explain clearly the steps in the design process using OO and UML. Implementation in an OO programming language requires writing source code class definitions and method definition based on DCDs. It is basically required to define classes with methods and simple attributes, add reference attributes, and define methods from collaboration diagrams.

In the course of this research, the DCD reached by the two documents referred above is the PIM of the TanSSe-L system as applied in MDA. The actual DCD to be implemented is hereby known as the specific PIM from MDA that was reached after being transformed as stated earlier. The research closely related the OO system analysis to the system design approach and MDA, in both cases using UML.

(c) “*Model Driven E-learning Platform Integration*” is the paper authored by Bizonova et al, (2008).

This paper provides a generalized e-learning architectural framework enabling an integrated specification of platform architectures. This platform-independent framework can then be used to specify and classify existing or future LMS and to simplify migration of data between different kinds of e-learning systems.

Bizonova et al, (2007) have compared PIMs of different existing open source LMSs to create a PIM that covers common functionalities of all LMSs. Their goal was to define a generalized model of the LMS system consisting of features of all other LMS systems that can be incorporated into it. The paper introduced a new strategy called the reversed MDA paradigm, by first using real LMS systems to define and abstract a model of a generalized LMS as shown in Figure 2.3.

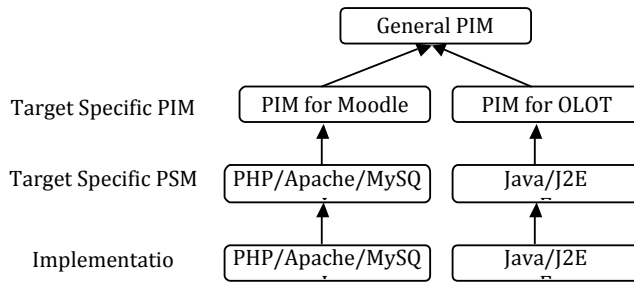


Fig. 2.3: Reverse MDA Concept for creation of General PIM (Bizonova et al, 2007)

In the course of this research, the approach used was first to create the DCD as a TanSSe-L system PIM using the OO system development approach. This TanSSe-L system PIM was then used to reach to the specific PIM and PSM in forward order.

2.5 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). Moore et al. (1996) and Carlson (1998) argue that the design and implementation of such systems is not an easy task since they are complex systems that incorporate a variety of organizational, administrative, instructional and technological components.

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.

2.6 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 dif-

ferent regions. The TanSSe-L system server is centrally placed at the CoET, UDSM. 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 implements one of the specific objectives of this research, that is to enable publication of learning materials. 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 Thompson (1997), is to enable remote users to continue working even if the connection to the central site is down.

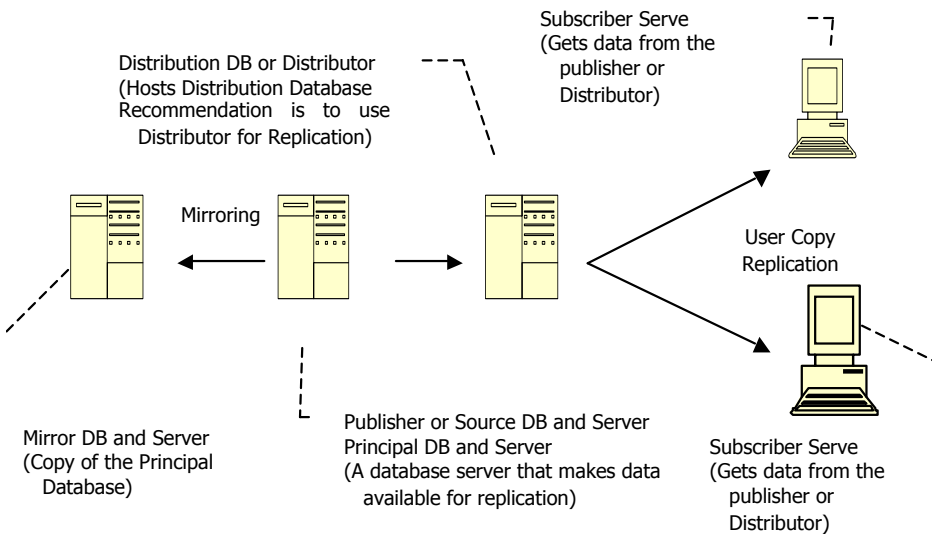


Fig. 2.4: Architecture for Database Mirroring and Replication

To ensure high availability of learning content from the database, replication was also supported by mirroring of the database as shown in Figure 2.4 so as to overcome the planned and unplanned downtime.

Mishra (2006) observes 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.

Thompson's (1997) analysis 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 involves 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 requires careful analysis and planning before the implementation of replication. Thompson (1997) emphasizes that all database administrators must make sure that the design takes the distributed database into account.

2.6.1 Intranet Network in Education

Access through web browsers, mainly Internet Web browser, somehow creates doubt to many people on reliability due to limited bandwidth and affordability of the Internet in terms of cost. Replicating the database on local servers can be part of the solution due to reliability as mentioned in TanSSe-L system database mirroring and replication. Other options may take care of the problem, such as using Intranet network in education to reduce costs and increase reliability. As defined by Kuzic et al. (2006) Intranet is a computer network, based on Internet technology that is designed to meet the internal need of sharing information within a single organization or company. Intranet supports exclusive sharing of information among a prescribed community of users – typically, members of an organization. Kamthan (1998) argues that Intranets in education are most useful to organizations that are geographically dispersed, share common educational objectives, have common information communication needs, value collaboration, and are strongly concerned about information security and privacy.

Kamthan (1998) mentions that there are several advantages in creating an educational Intranet, some of them being:

- *Cost-Effectiveness*

Intranet tools are inexpensive to buy and deploy. A variety of client and server-side software is almost free for academic or non-commercial use. The Intranet's platform-independence usually eliminates the need to create different versions of the same application.

- *Asynchronous Global Information*

Information can be accessed anytime and anywhere, thus overcoming the limitations of time and space.

- *Universal Communication*

With proper authorization, an individual on an Intranet can interact with any other individuals and beyond to the outside world.

- *Security*

Protecting information, even within an educational network, is critical. Intranets are protected by a firewall, a network configuration usually created by hardware and software that forms a boundary between networked computers within the firewall and those outside the firewall. For Internet access, Intranets rely on proxy servers, a special server that typically runs in conjunction with a firewall and allows access to the Internet from within the firewall. This enables institutions to make only necessary information available to the outside world (based on the means of privileged access, such as username/password-based authentication) thereby avoiding the problems of security breach, server overload and access to illegal information.

Marotta (2006) contributes on this by emphasizing that an Intranet typically has three features lacking on the Internet: Speed - broad bandwidth, Security - private internal network (LAN/WAN), protected from Internet users by a firewall and Control - enterprise network management to ensure reliability.

2.6.2 SEACOM, a Prospective Network Connectivity in Tanzania

Tanzania is among the luckiest countries in Africa, which was connected to the network world using fibre optic cable in 2009 by the company called SEACOM, which is an underwater fibre optic telecommunications cable. It is the first cable to provide broadband to countries in East Africa, in which South Africa, Mozambique, Tanzania and Kenya are interconnected via a protected ring structure. Additionally, a second express fibre pair is being provided from South Africa to Kenya. These two fibre pairs have a combined capacity of 1.28 Terabits per second.

SEACOM is privately funded and over three-quarters of African countries own this cable that assists communication carriers in south and east Africa through the sale of wholesale international capacity to global networks via India and Europe. This cable system provides African retail carriers with equal and open access to inexpensive bandwidth, removing the international infrastructure bottleneck and supporting east and southern African economic growth.

In Tanzania, SEACOM has 3 points of presence (PoP), namely the University of Dar es Salaam, TTCL Kijitonyama and Silver Sands landing station for easy access of customers. SEACOM owns 65% of a Tanzanian entity with a local partner owning 35%. According to the SEACOM Website, TTCL is now connected to SEACOM, enabling TTCL to provide its customers with some of the fastest communication services in the country. TTCL's internet traffic was switched entirely to the cable on 28 July 2009.

Making effective use of SEACOM through TTCL in future, we expect a reasonable improvement in Internet connectivity in Tanzanian regions and districts, meaning that

even Tanzania secondary schools will be able to access the Internet at reasonably, probably low cost.

2.7 Discussion

The software design approach is 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 world.

A model is used for a proper understanding of a system before its actual implementation. Integration of the power of models as emphasized by OMG with software development life cycle stages describes 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 as referred to by Gibbons et al. (1994).

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. The next Chapter discusses the theoretical background that is relevant to this research.

CHAPTER THREE: THEORETICAL BACKGROUND

3.1 Introduction

Information and Communications Technology (ICT) can be defined in many ways, depending on the area in which ICT is applied. Generally, ICT covers any product that will store, retrieve, manipulate, transmit or receive information electronically. In addition, ICT is also concerned with the way these different uses can work with each other.

This chapter reviews the areas employed in this research. However, some parts of the theoretical background were incorporated when describing the research methodologies in Chapter 2. The idea is to emphasize the relevance of the methodology and how it applied to TanSse-L system development. The areas covered in this chapter are:

- The use of ICT in education;
- Web based technologies;
- Database management systems;
- Unified Modelling Language (UML);
- MDA modelling approaches;
- GRASP: Patterns for assigning responsibility;
- Open source software (OSS); and
- Database Mirroring, Replication and Backup.

This chapter also shows how the theory can easily be understood when “learning by doing” is employed through designing a Web based database system. Here an e-book-store was developed for this purpose.

3.2 The Use of ICT in Education

The use of ICT in education involves supporting teaching and learning, and providing a range of activities in the learning environment. Such ICT-related activities include, for example, the use of micro-computers with appropriate keyboards, and devices to facilitate communication for pupils with special needs, etc (Kozma et al., 1999).

To see how ICT can be used for education, the key question to ask is what parts of the teaching and learning process can be helped through ICT, which enables information, knowledge and experience to be presented in new ways, so that new learning outcomes can be achieved.

ICT has a very broad and persistent impact on the entire education process (OECD, 2001):

- *On the learning environment:* ICT enables learning to take place in different places, both physically and virtually. Learners can choose where they want to study and what they want to learn.
- *On the content of learning:* With the implementation of ICT, learners, increasingly, have easy and independent access to a vast amount of information of potential relevance, e.g. via the Internet.
- *On the empowerment of the learner:* ICT can empower the learner by offering choice and potentially a more engaging and effective way of learning.
- *On the forms of communication used:* ICT enables communication to happen one-to-one, one-to-many, many-to-many and many-to-one.

E-learning is mostly associated with activities involving computers simultaneously with interactive networks. The main goals of e-learning are (OECD, 2001):-

- To make training available any time, not just at scheduled times;
- To give students and teachers access to information technology in their classrooms, communities and homes;
- To make learning materials available online for students to supplement their lectures;
- To enable teachers use the technology effectively to help students achieve high academic standards;
- To improve research and evaluation of teaching and learning;
- To support asynchronous or synchronous interaction between teachers and students;
- To enhance fast communication and the sharing of resource; and
- To eliminate the costs that is related to travel expenses (bus ticket and accommodation).

3.3 Web Based Technologies

The World Wide Web (WWW or Web for short) provides a simple ‘point and click’ means of exploring the immense volume of pages of information residing on the Internet (Connolly et al., 2005). Information is presented on Web pages, which appear as a collection of text, graphics, pictures, sound and video. In addition, a Web page can contain hyperlinks to other Web pages. Much of the Web’s success is due to (Connolly et al., 2005):-

- The simplicity with which it allows users to provide, use and refer to information distributed geographically around the world;
- Providing users with the ability to browse multimedia documents independently, not based on the type/make of the computer hardware being used; and
- Compatibility with other existing data communication protocols such as File Transfer Protocol.

Computers can act in two roles in relation to the Web: as servers for providing information such as Apache server; and as clients, usually referred to as browsers, for requesting information such as Internet Explorer (Connolly et al., 2005). The theoretical review of the Web-based technologies studied included HTML, XHTML, cascading style sheets (CSS), Extensible Markup Language, Java Scripting language and PHP server-side scripting language. More in this was to understand a MySQL database management system.

3.3.1 Websites

A Website is a collection of documents written in HTML. When a user searches a Website with a browser (e.g. Netscape, Internet Explorer, Mozilla Firefox, etc), the browser is able to follow the instructions presented to it in HTML to make a Website appear in a certain way. A Website can either be static or dynamic.

- *Static Website*

Connolly et al. (2005) explain that an HTML document stored in a file is an example of a static Web page. The content of the document does not change unless it is changed, that is, if the user were to reload a static Website, they would see the exact same content every time. Static Website contents are written directly by an author, when a user goes to the site, that code is downloaded on to a browser and interpreted.

- *Dynamic Website*

In contrast to a static Website, a dynamic Website is one whose content is regenerated every time a user visits or reloads the site. Connolly et al. (2005) comment that a dynamic Web page is generated each time it is accessed. As Website is dynamic, the content is changed as a user creates, inserts, updates and deletes data. Generating dy-

dynamic Web pages is a much more appropriate approach than creating static ones. This method is gaining popularity as the technology exists to generate Web pages instantly from a database query. A dynamic Web page is stored on the Web server with no actual data but, instead a template for the HTML code and a query. When a client accesses the page, the query is executed, and an HTML page containing the data is generated. There are a variety of languages available to make a dynamic Website, one of them is PHP: Hypertext Preprocessor (PHP).

3.3.2 Web-Based Technologies Used for e-Bookstore System Design

The knowledge of database systems, Web technologies and Web-based database systems as a whole was a new area for this research. Designing database systems involves the real application of programming. This research work involved the development of a Web-based LMS. In order to proceed well with this research it was wiser to start with a simple application of Web-based technologies. The easiest way to learn a new area, especially programming, is by employing the “learn-by-doing” technique. Nellen et al. (2000) emphasize this by saying that if knowledge is power, then we gain that knowledge by doing.

Learning by doing involved the development of a web-based e-bookshop. The goal of this exercise was to create a base for understanding Web-based technologies in a practical way for designing a Web-Based platform and for learning the basics in designing Web-based databases, as well as for learning useful technologies applied in Web-based platforms from a practical viewpoint. These technologies include HTML, XHTML, XHTML Document Type Definition, CSS, XML, the Web-based JavaScript Language, server-side PHP scripting language, here PHP 5 was studied, MySQL Database Server and Apache application server. The design was implemented in MS Windows, Apache, MySQL and PHP.

The motive for this was that the TanSSe-L system to be developed would be Web-based system and would need the application of this knowledge. The power of “learning-by-doing” was appreciated after starting to develop the TanSSe-L system. It was noticed that the knowledge gained when developing e-bookstore was the base for:-

- Understanding and easy follow-up of open source codes for open source e-learning platform during customization;
- Creating new codes for the TanSSe-L system; and
- Modifying open source codes to suite TanSSe-L system requirements.

3.4 Database Management Systems

Connolly et al (2005) define the database as a shared collection of logically related data and description of this data, designed to meet the information needs of an organization. Connolly adds that a database is a single, possibly large repository of data that can

be used simultaneously by many departments and users. Database is a shared corporate resource. Again Connolly et al (2005) define a DBMS as a software application that enables users to define, create, maintain and control access to the database. It is the software that interacts with the users' application programs and the database.

A database provides the following facilities (Connolly et al, 2005):-

- It allows users to define a database using a Database Definition Language, which allows users to specify data types, structures and constraints of the data to be stored in the database;
- It allows users to insert, update, delete and retrieve data from the database using a Database Manipulation Language, which acts as a central repository for all the data and data description and provides a general inquiry facility to this data, called a query language. Data operations usually include the following:-
 - Insertion of new data into a database;
 - Modification of data stored in a database;
 - Retrieval of the data contained in a database; and
 - Deletion of data from a database.
- It provides controlled access to the database, for example it may provide:-
 - A security system which prevents unauthorized users from accessing the database;
 - An integrity system which maintains the consistency of stored data;
 - A concurrency control system which allows shared access of the database; and
 - A user-accessible catalogue which contains a description of the data in the database.

Connolly et al (2005) define an application program as a computer program that interacts with the database by issuing appropriate requests (typically SQL statements) to the DBMS. Application programs are used to create and maintain the database and to generate information.

3.4.1 The Three-Level ANSI-SPARC Architecture

Connolly et al (2005) pointed out that an early proposal for standard terminology and general architecture for the database was produced in 1971 by the Database Task Group, appointed by the Conference on the Data System and Languages, which recognized the need for a two-level approach with a system view called a schema and a user view called a subschema. Connolly et al (2005) stated that American National Standards Institute – Standard Planning and Requirements Committee (ANSI-SPARC) produced a similar terminology and architecture in 1975. ANSI-SPARC recognized the need for a three-level approach with a system catalogue. Although the ANSI-

SPARC model did not become a standard, it still provides a basis for understanding some of the functionalities of DBMS (Connolly et al., 2005).

The levels that form the three-level architecture comprise external, conceptual and internal levels as shown in Figure 3.1:

- *External Level*

This is the user's view of the database. It describes that part of the database that is relevant to each user. It consists of a number of different external views of the database. It includes only those entities, attributes or relationships in the real world that the user is interested in.

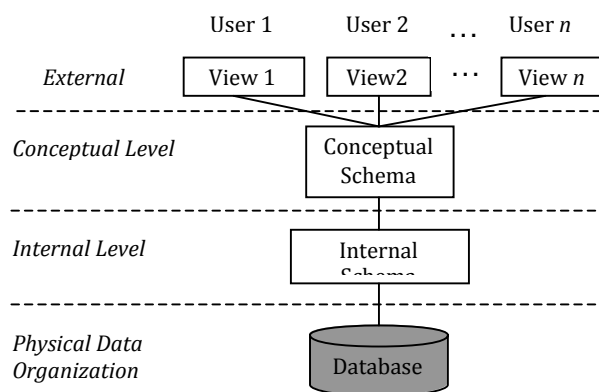


Fig. 3.1: The ANSI-SPARC Three-Level Architecture

- *Conceptual Level*

This level describes what data is stored in the database and the relationships among the data. It contains the logical structure of the entire database. It is a complete view of the data requirements of the organization that is independent of any storage consideration.

- *Internal Level*

This is the physical representation of the database on the computer. It describes how the data is stored in the database and covers the data structure and file organization used to store data on storage devices. Below the internal level a physical data is organized so that it can be managed by the operating system under the direction of the DBMS.

3.4.2 Client-Server DBMS Architectures

A database is a shared resource. Each user may require a different view of the data held in the database. To satisfy these needs, the architecture of most DBMSs available today is based to some extent on ANSI-SPARC architecture. Connolly et al, (2005) state that client-server architecture refers to the way in which software components interact.

There is a client that requires some resources, and a server that provides the resources. There is no requirement that the client and server must reside on the same machine. In practice, it is quite common to place a server at one site in a local area network and the clients at the other sites. There are two basic client-server architectures:

- *Traditional Two-Tier Client-Server Architecture*

Two-tier client-server architecture provides the separation of the two components. The client (tier 1) is primarily responsible for presenting the data to the user, and the server (tier 2) is primarily responsible for supplying data services to the client as shown in Figure 3.2. Presentation services handle user interface actions, the main business and data application logic. Data services provide limited business application logic, typically that the client is unable to carry out validation due to lack of information, and access to the requested data, independent of its location. Typically, the client can run on end-user desktop and interact with a centralized database server over a network.

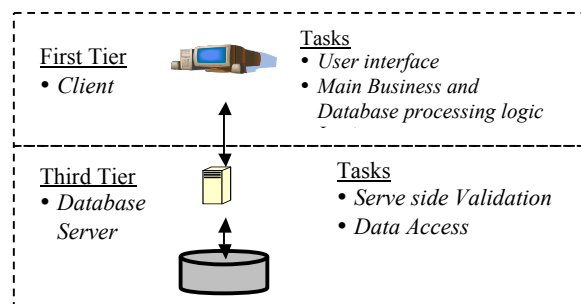


Fig. 3.2: Traditional Two-Tier Client-Server Architecture

A typical interaction between the client and server is as follows:-

- The client takes the user's requests, checks the syntax and generates database requests in SQL or another database language appropriate to the application logic. The client then transmits the message to the server, waits for the response, and formats the response for the end user.
- The server accepts and processes the database requests, then transmits the results back to the client. The processing involves checking authorization, ensuring integrity, maintaining the system catalogue and performance query and updating. In addition, it also provides concurrency and recovery control.
- *Three-Tier Client-Server Architecture*

One drawback of the traditional two-tier client-server is that it does not constitute a distributed DBMS, which as defined by Connolly et al (2005) is a logically inter-related collection of shared data (and a description of this data), physically distributed over a computer network. The need for enterprise scalability challenged this traditional two-tier client-server model. In the 1990s, as applications become more complex and potentially could be deployed to hundreds or thousands of end-users, the client side presented two problems for true scalability:

- Considerable resources were required for the client's computer to run effectively. This includes disk space, RAM and CPU power
- Significant client-side administration overheads

To solve this problem, in 1995 a new architecture was proposed, having three layers, each potentially running on a different platform as below:-

- The user interface layer, which runs on the end-user's computer (the client)
- The business logic and data processing layer. This middle tier runs on a server and is often called the application server; and
- A DBMS, which stores the data required by the middle tier. This tier may run on a separate server called the database server (or "back end").

As illustrated in Figure 3.3, the client (or "front end") is now only responsible for the application's user interface and, perhaps, performing some simple logic processing, such as input validation, thereby providing a "thin" client. The core business logic of the application now resides in its own layer, physically connected to the client and database server over a local area network (LAN) or a wide area network (WAN). One application server is designed to serve multiple clients.

Database server concentrates on the following tasks:-

- Managing a single database of information among many concurrent users;
- Controlling database access and other security requirements;
- Protecting database information with backup and recovery features; and
- Centrally enforcing global data integrity rules across all client applications.

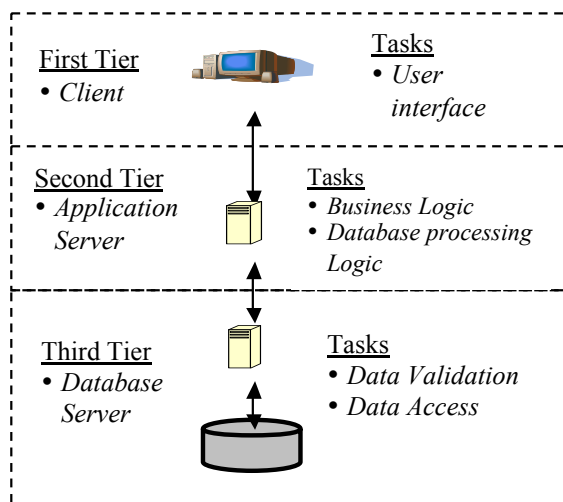


Fig. 3.3: Three-Tier Client-Server Architecture

3.4.3 Database Security

As the use of the Web grows on both Intranets and the public Internet, information security is becoming crucial. The Web provides a convenient, cheap, and instantaneous way of publishing data. With many systems creating dynamic Web pages from a database, corporate information security is even more vital, since anyone with a Web browser can view data in a database that is not properly protected. For Web security, there are the following three primary areas to address (Rahmel, 1997):-

- *Server security* -- ensuring security relating to the actual data or private HTML files stored on the server. It involves limiting access to data stored on the server. The process of publishing data on the Web often requires information system specialists implementing a security policy
- *User-authentication security* -- ensuring login security that prevents unauthorized access to information. Authentication security governs the barrier that must be passed before the user can access particular information (Wiedman, 2008). The user must have some valid form of identification before access is granted. Logins are accomplished in two standard ways: using an HTML form or using an HTTP security request. This method has the advantage of letting the database administrator define a particular user's privilege. By using a table created by the database administrator, numerous security privileges specific to a particular project can be defined
- *Session security* -- ensuring that data is not intercepted as it is broadcast over the Internet or Intranet. After the user has supplied proper identification and access is granted to the data, session security ensures that private data is not intercepted or interfered with during the session. It involves encrypting all of the information that flows both ways

3.4.3.1 Computer-Based Security Controls

Data is a valuable resource that must be strictly controlled and managed. The term security refers to the protection of the database against unauthorized access, either intentional or accidental. Database security is concerned with avoiding theft and fraud, and loss of confidentiality (secrecy), privacy, integrity and availability. Security considerations apply not only to the data held in a database, but also to hardware, software and people. Connolly (2005) clearly indicates that the type of countermeasure to threats to computer systems range from physical controls to administrative procedures. He continues by describing computer-based security controls for a multi-user environment to be:

- *Authorization*: granting of a right or privilege that enables a subject to have legitimate access to a system or a system's object. The process of authorization involves authentication (that is a mechanism that determines whether a user is who he

or she claims to be) of subjects requesting access to objects, where the ‘subject’ represents a user or program and the ‘object’ represents a database table (‘NISCC, 2003).

- *Access Control*: a database system is based on the granting and revoking of privileges. A privilege allows a user to create or access (that is read, write or modify) some database objects (such as relation, view or index) or to run certain DBMS utilities. Privileges are granted to users to accomplish the tasks required for their jobs (NISCC, 2003).
- *Views*: the dynamic result of one or more relational operations operating on base relations to produce another relation. A view is a virtual relation that does not actually exist in the database, but is produced upon request by a particular user, at the time of the request. The view mechanism provides a powerful and flexible security mechanism by hiding parts of the database from certain users.
- *Backup and Recovery*: backup is the periodic making of a copy of the database and log file (and possibly programs) and storing them offline. A DBMS should provide backup facilities to assist with the recovery of a database following failures.
- *Integrity*: to ensure that the data is accurate. For example, relational integrity constraints are entity integrity (in a base relation, no attribute of a primary key can be null), and referential integrity (if a foreign key exists in a relation, either the foreign key value must match a candidate key value of some tuple in its home relation or the foreign key value must be wholly null). Integrity constraints also contribute to maintaining a secure database system by preventing data from becoming invalid, and hence giving misleading or incorrect results.
- *Encryption*: this is the encoding of the data by a special algorithm that renders the data unreadable by any program without the decryption key.
- *Redundant Array of Independent Disks*: The hardware that the DBMS is running on must be fault-tolerant, meaning that the DBMS should continue to operate even if one of the hardware components fails. This suggests having redundant components that can be seamlessly integrated into the working system whenever there is one or more component failure. The main hardware components that should be fault-tolerant include disk drives, disk controllers, CPU, power supply and cooling fans.

3.4.3.2 DBMS and Web Security

Internet communication protocol relies on TCP/IP as the underlying protocol. However TCP/IP and HTTP were not designed with security in mind. With a three-tier architecture that is popular in a Web environment, ensuring secure access to, and from,

⁵ NISCC - National Infrastructure Security Co-ordination Centre

the database is complex. The security of such architecture requires different products and mechanisms (Connolly, 2005). Some of the issues associated with database security in the Web environment are:

- *Proxy Servers*: A proxy server is a computer that sits between a Web browser and a Web server. The two main purposes of a proxy server are to improve performance and filter requests. A proxy server saves the results of all the requests for a certain amount of time. It can significantly improve performance by simply returning the requested Web page from the cached page that it had already fetched. A proxy server can also be set to prevent users from accessing a specific set of Websites.
- *Firewalls*: A firewall is a critical part of the security of any Internet site. It is a system designed to prevent unauthorized access to or from a private network. A firewall improves the security of a site by limiting the access of that site to an absolute minimum.

3.5 Unified Modelling Language

3.5.1 The UML as a Notation Language

This research used UML as the documentation language to a large extent in modelling the TanSse-L system with OO system analysis and design. Hence, it finds important to provide the historical background.

The norm for engineering analysis and designing systems emphasizes modelling of the system before implementation. This can be done mathematically or by any other common notation understood by many engineers in the same field worldwide. Ariadne, (2001) explains that software engineering had lacked such a notation. Between 1989 and 1994, more than 50 software modelling languages were in common use – each of them having their own notations. Each language contained syntax peculiar to itself, whilst at the same time each language had elements which bore striking similarities to the other languages, although none of these languages was complete.

- In the mid 1990's, three methods emerged as the strongest, each containing elements of the other two. Each method had its own particular strengths (Ariadne, 2001):-
- Booch was excellent for design and implementation. Grady Booch had been a major player in the development of OO techniques for the language;
- Object modelling technique was best for the analysis of data-intensive information systems; and
- Object oriented software engineering featured a model known as Use Cases, which are a powerful technique for understanding the behaviour of an entire system (an area where OO has traditionally been weak).

In 1994, Jim Rumbaugh, the creator of the object modelling technique joined Grady Booch at Rational Corp. The aim of the partnership was to merge their ideas into a single, unified method. By 1995, the creator of OO software engineering, Ivar Jacobson, had also joined Rational, and his ideas (particularly the concept of “Use Cases”) were fed into the new unified method – now called the UML. The team of Rumbaugh, Booch and Jacobson are affectionately known as the “Three Amigos”. The new method began to find favour amongst the software industry, and a UML consortium was formed. Heavyweight corporations were part of the consortium, including Hewlett-Packard, MS and Oracle. The UML was adopted by the OMG in 1997, and since then the OMG have owned and maintained the language. Therefore, the UML is effectively a public, non-proprietary language (Ariadne, 2001). The UML is a graphical modelling language aimed at providing syntax for describing the major elements of software systems. Liu et al. (2003) state that the UML represents a collection of best engineering practices that have proved successful in the modelling of large and complex systems.

UML includes a set of consistent diagrams that may be used to describe and communicate a software system’s requirements, design, and code. It can be used to provide views of the system design and requirements at different levels of abstraction and its artifacts (Cantor, 1998). Ariadne (2001) states that UML is a generic broad language enabling the key aspects of a software development to be captured on paper. In other words, the UML is simply a language, a notation and syntax, but it does not state how to develop software. It can be applied in any software development process; waterfall and spiral model and iterative, incremental frameworks.

The UML guide contributes to this by saying that UML is a notation (graphical language) with rules for creating analysis and design methods. The UML design process involves the creation of various graphical or text-based documents. In UML, these documents are called artifacts and they describe the output of a step in the process. The UML design process has two main parts which are:-

- Analysis - What is the problem?
- Design - How should the problem be solved?

3.5.2 UML Language Architecture

The architecture of the UML, as analyzed by OMG (2003b), is based on a four-layer metamodel structure, which consists of the following layers: user objects, model, metamodel, and meta-metamodel as shown in Table 3.1. UML is primarily concerned with the metamodel layer, which is an instance of the meta-metamodel layer. The UML metamodel is a logical model and not a physical (or implementation) model. The advantage of a logical metamodel is that it emphasizes declarative semantics, and suppresses implementation details. The UML metamodel is described in a combination of graphic notation, natural language, and formal language.

The complexity of the UML metamodel is managed by organizing it into logical packages: Foundation, Behavioural Elements, and Model Management as shown in Figure 3.4. The Foundation and Behavioural Elements packages are further decomposed, as shown in Figures 3.5 and 3.6. For example, the Foundation package consists of the Core, Extension Mechanisms and Data Types sub packages (OMG, 2003b).

Table 3.1: Four Layer Metamodel Architecture of UML		
Layer	Description	Example
Meta-metamodel	The infrastructure for a metamodeling architecture. Defines the language for specifying metamodels.	MetaClass, MetaAttribute, and MetaOperation
Metamodel	An instance of a meta-metamodel. Defines the language for specifying a model.	Class, Attribute, Operation, and Component
Model	An instance of a metamodel. Defines a language to describe an information domain.	StockShare, askPrice, sellLimitOrder, andStockQuoteServer
User objects (user data)	An instance of a model. Defines a specific information domain.	<Acme_SW_Share_98789>, 654.56, sell_limit_order, and <Stock_Quote_Svr_32123>

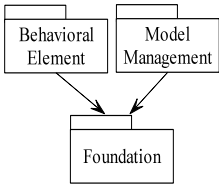


Fig. 3.4: UML Metadata Top Level Packages

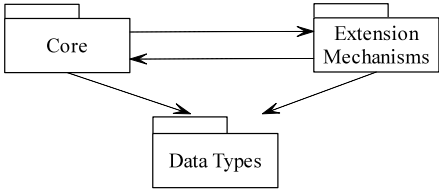


Fig. 3.5: UML Metadata Foundation Packages

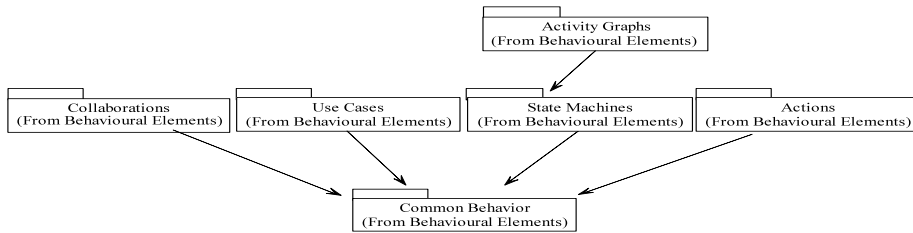


Fig. 3.6: UML Metadata Behavioural Elements Packages

The Foundation package is the language infrastructure that specifies the static structure of models. The Foundation package is decomposed into the following subpackages: Core, Extension Mechanisms, and Data Types. The Core package specifies the basic concepts required for an elementary metamodel and defines the architectural backbone for attaching additional language constructs, such as metaclasses, metaassociations, and metaattributes. The Extension Mechanisms package specifies how model elements are customized and extended with new semantics. The Data Types package defines basic data structures for the language (OMG, 2003b).

The Behavioural Elements package is the language superstructure that specifies the dynamic behaviour of models. The Behavioural Elements package is decomposed into the following subpackages: Common Behaviour, Collaborations, Use Cases, State Machines, Activity Graphs, and Actions. Common Behaviour specifies the core concepts required for behavioural elements. The Collaborations package specifies a behavioural context for using model elements to accomplish a particular task. The Use Case package specifies behaviour using actors and use cases. The State Machines package defines behaviour using finite-state transition systems. The Activity Graphs package defines a special case of a state machine that is used to model processes. The Actions package defines behaviour using a detailed model of computation (OMG, 2003b).

3.5.3 Object Oriented with UML

The UML has been designed to support Object Orientation. It has a lot of different diagrams (models) to get used to. The reason for this is that it is possible to look at a system from many different viewpoints:

- The Use Case is a description of the system's behaviour from a user's viewpoint. This diagram is a valuable aid during analysis – developing Use Cases helps in understanding the requirements.
- Class Diagram or conceptual diagram is an essential aspect of any OO method. UML provides the appropriate syntax. Class Diagram can be used at the analysis as well as the design stage. Class Diagram syntax is used to draw a plan of the major concepts for system stakeholders to understand. Together with Use Cases, a Conceptual Model is a powerful technique in analyzing requirements.

- Collaboration diagrams: in developing OO software, anything that software needs to do is going to be achieved by objects collaborating. Collaboration diagrams are used to describe how the objects collaborate.
- The sequence diagram is, in fact, directly related to the collaboration diagram and displays the same information, but in a slightly different form. A sequence diagram is a description of how the objects in a system interact over time.
- State diagram; some objects can, at any particular time, be in a certain state. For example, a traffic light can be in any one of the following states: off, red, amber or green. As state transitions can be quite complex, the UML provides a syntax that allow them to be modeled.
- Package diagrams; any non-trivial system needs to be divided into smaller, easier to understand “chunks”, and the UML Package Diagram enables us to model this in a simple and effective way.
- The Component Diagram is similar to the package diagram - it allows notating how a system is split up, and what the dependencies between each module are. However, the Component Diagram emphasizes the physical software components (files, headers, link libraries, what is executable, and packages) rather than the logical partitioning of the Package Diagram.
- Deployment diagrams; The UML provides a model that allows us to plan how our software is going to be deployed.

The UML guide gives the categories of UML documents relating to software development phases as shown in Table 3.2.

Table 3.2: Categories of UML Documents		
Development Phase	Static	Behavioural
Requirements		Use Cases
		High Level Use Cases
Analysis	Domain Model or Conceptual Model	
		System Sequence Diagrams
		Operation Contracts
Design		Collaboration Diagrams
	Design Class Diagrams	

Object oriented system analysis and design with UML as was applied in TanSSe-L system has a number of components in each phase as summarized in Table 3.3.

Table 3.3: Development Phases in TanSSe-L System

Development Phase	Description	
Requirements	<ul style="list-style-type: none"> The phase from SDLC in OOSA&D to meet the system's requirement is related to the CIM of the MDA. In this phase the UML captures the requirements of the users of the system, creates the system functions and describes the sequence of interactions between actors (users) and the system, using a use-case model. The requirement specification phase of the TanSSe-L system adopts the steps of defining them as presented by Yong et al., 2003 and Bouras et al. (2002). Bouras et al. (2002) explain the need to provide technology, standardization, and system architecture while stating requirement specification. The following components have been provided for TanSSe-L system:- 	
	System Functions	<ul style="list-style-type: none"> System functions are what a system is supposed to do (Liu, 2001; Yong et al., 2003). In other words, system functions are a list of the specific capabilities a system should have. They define the specific behaviour or functions of a system. The system's functions are categorized into two groups (Liu, 2001; Yong et al., 2003): <ul style="list-style-type: none"> ✓ Evident functions: are functions that are performed by the system and users are able to tell if they have been performed ✓ Hidden functions: are functions that are performed by the system but users are not able to tell that they have been performed
	Non-Functional Requirements	<ul style="list-style-type: none"> System non-functional requirements are also called system attributes. They are constraints imposed on the system and restrictions on the freedom of the designer (Liu, 2001). System non-functions define how a system is supposed to behave and they are often called qualities of the system.
	Use Case Model	<ul style="list-style-type: none"> Showing a number of actors of the TanSSe-L system and their interaction to the system. Use case diagrams provide a graphic over view of system functionality
	Technology and Standards	<ul style="list-style-type: none"> Web based technologies, SCORM Standard and IEEE were employed
	System Architecture	<ul style="list-style-type: none"> Client-server, Three-tier architecture were used having the following specific advantages as stated by Kinshuk et al., 2003:- <ul style="list-style-type: none"> ✓ Easy to modify or replace any tier without affecting the other tiers ✓ Separating application and database functionality means better load balancing ✓ Adequate security policies can be enforced with the server tier without hindering the clients
Analysis	<p>From research methodology Chapter 2, subsection 2.4.3, Figure 2.2, system analysis was the starting point for manual transformation from the TanSSe-L system CIM to the TanSSe-L system PIM. The following components have been provided for TanSSe-L system:-</p>	
	System Concepts	<ul style="list-style-type: none"> The aim of this step is to decompose the problem into individual concepts. Liu (2001) insists that a central distinction between OOA and structured analysis is decomposition of concepts rather than decomposition of functions. The key point in this decomposition is to find what can perform what, and then to decide later on in the design and implementation how concepts behave to realize system functionality. Identification of the objects that make up classes is central to OOA. There are two strategies used to identify concepts as mentioned by Yong et al. (2003). <ul style="list-style-type: none"> ✓ First is to find concepts from the textual descriptions of the problem domain according to a concept category list. This strategy is to create a list of all candidate concepts from the clients' requirements obtained during focus group discussion, initial investigation reports, system function definitions, and use cases. ✓ Another useful and simple technique for identification of concepts is to identify the noun and noun phrases in the textual descriptions of a problem domain, and consider them as candidate concepts or

Development Phase	Description	
		attributes.
	Conceptual Model	<ul style="list-style-type: none"> Liu et al. (2003) state that a conceptual model for an application is a class diagram consisting of <i>classes</i> (also called <i>concepts</i>) and <i>associations</i> between classes. A class represents a set of <i>conceptual objects</i> and an association determines how the objects in the associated classes are related (or <i>linked</i>). Liu et al. (2003) add that a class diagram is conceptual at this level because it is not concerned with what an object does, how it behaves, or how an attribute is represented. The decision on these issues will be made during design when the <i>responsibilities</i> of a use case are decomposed and assigned to appropriate objects. Before creating a conceptual model, attributes for individual classes have to be determined. Each object or class may have some useful properties. Liu (2001) emphasizes that an <i>attribute</i> of a class is the abstraction of a single characteristic or a property of entities that have been abstracted as objects of the class. At any given moment, the <i>attribute</i> of an individual object in the class has a logical data value representing the corresponding property of the object, and called the <i>value of the attribute of the object</i> at that time. One object has exactly one value for each attribute at any given time. Therefore, the value of an attribute of an object may change over time.
	System Sequence Diagram	<ul style="list-style-type: none"> System sequence diagram as explained by Liu (2001) identifies the operations that the system needs to perform, in what order the system need to perform these operations to carry out a use case and the effect of such an operation on the system. System sequence diagram, which appears in system analysis, differs from object sequence diagram (simply called sequence diagram) which appears in system design. As distinguished by Liu (2001): <ul style="list-style-type: none"> ✓ A system sequence diagram illustrates the interaction between the whole system and external actors, while an object sequence diagram shows the interactions between objects of the system. ✓ A system sequence diagram shows only a system's external events and thus identifies system operations, while an object sequence diagram identifies the operations of objects. ✓ System sequence diagrams are created during the analysis phase, while object sequence diagrams are models created and used in the design phase. Larman (2004) defines a system sequence diagram to be a picture that shows, for one particular scenario of a use case, the events that external actors generate in their order, and inter-system events. In a system sequence diagram the system is treated as a <i>black box</i> so that the behaviour is a description of <i>what</i> a system does, without explaining <i>how</i> it does it. The main interest is in identifying and illustrating the system operations that an actor request of the system, that is, interested in finding system input events by inspecting the use cases and their scenarios (Liu, 2001).
	System Operation Contracts	<ul style="list-style-type: none"> System sequence diagram does not describe the effect of the execution of an operation invoked. It lacks the details necessary to understand the system response, i.e. its behaviour. Understanding system behaviour means understanding the changes that take place when the system has been operated (Liu, 2001). The UML guide (2001) clearly describes the need for operation contracts. Effectively, it defines what each operation of the system does. The contract of an operation is defined mainly in terms of its <i>pre-conditions</i> and <i>post-conditions</i> (Liu, 2001): <ul style="list-style-type: none"> ✓ Pre-conditions are the conditions that the system is assumed to satisfy before execution of the operation ✓ Post-conditions are the conditions that the system has to satisfy <i>after</i> execution of the operation
Design	Collaboration Diagrams	<ul style="list-style-type: none"> Liu (2001) insists that during design phase, there is a shift in emphasis from application domain concepts to software objects and from <i>what</i> to <i>how</i>. The objects discovered during analysis serve as the skeleton of the design. The

Development Phase	Description
	<p>system operations identified during the analysis must be assigned to individual objects or classes.</p> <ul style="list-style-type: none"> • The design as explained by Liu et al. (2003b) is to transform the model of the requirements into a model of the design that consists of a design class diagram and a family of interaction diagram. Interaction diagrams, representing the interactive view of the design, show how objects of the system interact and collaborate with each other. The creation of interaction diagrams involves the assignment of responsibilities to objects so that their interactions correctly realize the use cases. Use case decomposition and responsibility assignment are carried out according to the knowledge that the objects have. What an object can do depends on what it knows, though an object does not have to do all that it can do. What an object knows is determined by its attributes and associations with other objects. • Software design is about behaviour; and behaviour is dynamic (Martin, 1997). Object oriented design is a technique used to separate and encapsulate behaviours, therefore an emphasis on dynamic models is very important. Martin (1997) advances that more important, however, is the interplay that exists between the static and dynamic models. A static model cannot be proved accurate without associated dynamic models. Dynamic models, on other hand, do not adequately represent considerations of structure and dependency management. Thus, the designer must iterate between the two kinds of models, driving them to converge on an acceptable solution. • Dynamic diagrams fall into the category called interaction diagrams, both present in the UML. Interaction diagrams are used when we want to model the behaviour of several objects in a use case. They demonstrate how the objects collaborate. An interaction diagram typically captures the behaviour of a single operation of the system. They do not capture the complete behaviour, only typical scenarios. Two types of interaction diagrams are commonly used, which are sequence and collaboration diagrams. They both describe the flow of messages between objects. <ul style="list-style-type: none"> ✓ Sequence diagrams generally show the sequence of events that occur. Sequence diagrams focus on the order in which the messages are sent. Martin (1997) emphasized that sequence diagrams or object sequence diagrams (not system sequence diagram as described in system analysis) are useful for describing the procedural flow through many objects, and the diagrams are read from left to right and descending. Sequence diagrams emphasize the sequence of the messages instead of the relationships between the objects (Martin, 1998). ✓ Collaboration diagrams, which have been used in this research, demonstrate how objects are statically connected, focus on the relationships between the objects and show the order of messages passed between them. They are very useful for visualizing the way several objects collaborate to get a job done (Martin, 1997). The objects are listed as icons, and arrows indicate the messages being passed between them. • The major task of the design phase is to create collaboration diagrams for the system operations identified and the most important and difficult part in the generation of collaboration diagrams is the assignment of responsibilities to objects (Liu, 2001). Collaboration diagrams express both the context of a group of objects and the interaction between these objects. They require that use case, system operation contracts and a domain (conceptual) model exist (Basic UML Guide, 2001). • As suggested by Liu (2001) and Yong et al. (2003) in creating collaboration diagrams, it is important to add more object controllers to handle system input events in groups. Liu (2001) defines a controller as a non-user interface object responsible for handling a system input event, and the controller defines the method for the system operation corresponding to the system input event.

Development Phase	Description	
	Design Class Diagram	<ul style="list-style-type: none"> UML DCD shows software class definitions which are based on collaboration diagrams. Attribute visibility is shown for permanent connections (Basic UML guide, 2001). DCD was the TanSse-L system PIM.
Implementation	<ul style="list-style-type: none"> The system implementation phase using the OOSA&D approach is the writing of code. McFadden et al. (1999) state that database implementation includes coding and testing database processing programs, completing database documentation and training materials, installing the database and converting data if necessary from prior systems. At the end of system implementation, we expect a functioning system that meets the user's requirements as analyzed in earlier phases. System implementation for TanSse-L system involved customization of an open source LMS. 	

3.6 GRASP: Patterns for Assigning Responsibilities

The most important part in creating interactive diagrams is the assignment of responsibilities to objects, mainly in collaboration diagrams. A responsibility is a contract or obligation of an object. Responsibilities are related to the obligations of objects in term of their behaviour. There are in general two types of responsibilities:

- *Doing responsibilities*: these are about the actions that an object can perform including:
 - doing something itself
 - initiating an action or operation in other objects
 - controlling and coordinating activities in other objects
- *Knowing responsibilities*: these are about the knowledge an object maintains:
 - knowing about private encapsulated data
 - knowing about related objects
 - knowing about things it can derive or calculate

There are several different sets of patterns. The patterns used for collaboration diagram responsibility assignment are *General Responsibility Assignment Software Patterns* (GRASP), which are presented in the following format (Liu, 2001):

Pattern Name	:	the name given to the pattern
Solution	:	description of the solution of the problem
Problem	:	description of the problem that the pattern solves

Liu (2001) and UML Guide (2001) indicate that *General Responsibility Assignment Software Patterns* include the following five patterns: *Expert*, *Creator*, *Low Coupling*, *High Cohesion*, and *Controller*.

- *Expert*

Responsibility is assigned to the information expert – the class that has information necessary to fulfill the responsibility. Who has the required information? Who is the expert with the requested information? Experts do things relating to the information they know.

- *Creator*

Creator is the one who creates something. The creator pattern is used when one or more of the following are true:

- The creating class aggregates the class to be created.
- The creating class contains the class to be created
- The creating class closely uses the class to be created
- The creating class records the class to be created

- *Low Coupling*

Coupling is a measure of how strongly one class is connected to, has knowledge of, or relies upon other classes. That is, coupling measures how much one class relies on another class or is connected to another class. If there are many lines between objects, coupling is high. A class with low (or weak) coupling is not dependent on too many other classes. A class with high (or strong) coupling relies upon many other classes. Such classes are undesirable and suffer from the following problems:

- Changes in related classes force local changes, i.e. changes in this class.
- Changes in this class force changes in many other related classes.
- Harder to understand in isolation.
- Harder to reuse as its reuse requires the use of the related class.

When a responsibility is assigned to a class, we would like to assign responsibilities in a way so that coupling between classes remains low.

- *High Cohesion*

Cohesion is a measure of how strongly related and focused the responsibilities of a class are. A class with high cohesion has highly related functional responsibilities, and does not do a tremendous amount of work. Such classes have a small number of methods with simple but highly related functionality. A class with low cohesion is undesirable as it suffers from the following problems:

- Hard to comprehend
- Hard to reuse
- Hard to maintain

High cohesion - Keep the class as uncomplicated as possible

- *Controller*

The controller is the interface between two layers such as the user and domain layer. This pattern supports low coupling and high cohesion. It handles event messages and serves as a wrapper for a lower or domain layer. Events are received and passed through the controller, and the responsibility for handling a system (input) event to a class is assigned one of the following choices:

- Represents the “overall system” (facade controller).
- Represents the overall business or organization (facade controller).
- Represents something in the real-world that is active (for example, the role of a person) that might be involved in the task (role controller).
- Represents an artificial handler of all system (input) events of a use case, usually named “<UseCaseName> Handler” (use-case controller).

With reference to TanSse-L system development, GRASP knowledge was needed when assigning responsibilities to identified objects in collaboration diagrams.

3.7 Sharable Content Object Reference Model (SCORM)

SCORM is a suite of technical standards that enable Web-based learning systems to find, import, share, reuse, and export learning content in a standardized way. The SCORM is a conceptual model describing how to manage, package and deliver learning information so that it can be easily shared on the Internet. As shown in Figure 3.7 (Albert et al., 2003), the basic overview of SCORM is that it assumes the existence of a suite of services called by some a “Learning Management System” and by others a “Learning Content Management System” (Albert et al., 2004), and formerly called a “Computer Managed Instruction” system. In the SCORM world a set of services launches learning content, keeps track of learner progress, figures out in what order (sequence) learning objects are to be delivered, and reports student mastery through a learning experience. During the evolution of the SCORM suite of specifications, a standardized way was needed to send information back and forth between the learner (content) and the LMS.

SCORM has two main parts:

- Content Aggregation Model which is concerned with how to put learning content together so it can be moved and reused
- Run-Time Environment which is concerned with how the learning content is going to be launched and the learner’s progress to be tracked and reported back

Albert et al. (2004) defined SCORM as a set of interrelated technical specifications built upon the work of the Aviation Industry Computer-Based Training Committee, Instructional Management Systems and Institute of Electrical and Electronic Engineers (IEEE) to create one unified “content model” and enable the reuse of Web-based learning content across multiple environments and products.

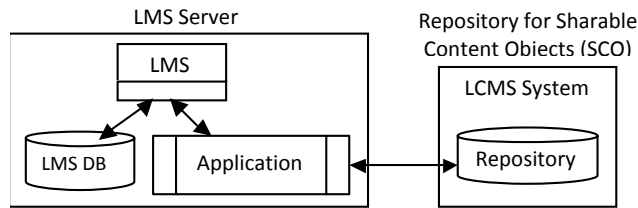


Fig. 3.7: An Overview of SCORM Implementation

3.8 Open Source Software

3.8.1 Significance of Open Source Software

Open source software (OSS) can be defined as software that is free in terms of its source code being available, as well as free in terms of purchase charges, and software licensing (OSS Africa, 2005). OSS code is freely available to individuals to customize according to their own needs and distribute provided they abide by the accompanying licence. This differs from commercial software which may only be obtained by some kind of payment, either by purchasing or leasing. OSS is based on open distribution of the source code that forms its foundation. This means that any technically competent programmer can examine the inner workings of the source code and make changes in the operation of the software. OSS is typically provided free of charge or for a nominal distribution cost. Some open source licences require that any change to the source code be redistributed on the same open source licence terms as the original source code (Dalziel, 2003; Hall, 2008).

The benefits of OSS as published by Hall (2008) include:

- *Low initial cost*: it is free to download
- *Flexibility and customizability*: one can modify the software whenever the need arises
- *Extensive active user communities*: participating in open source projects is a source of distinction among developers
- *Multi-platform capabilities*: many open source applications run on multiple platforms including Windows and Linux
- *Adherence to standards*: interoperability is a high priority for many open source developers
- *Tendency to use and link to other open source software*: including popular languages and platforms such as PHP and MySQL database

3.8.2 Open Source Software Licensing

The primary underlying difference between the open source and commercial software is in the licensing of software. Commercial software providers typically adopt the traditional software licensing approach where permission to use the software is granted to a customer in return for a fee. The customer is usually permitted to use, reproduce or adapt the software only in accordance with the terms of the licence (Hiong, 2005).

OOS is made available under a variety of licensing approaches with certain common features, such as the right to modify and the right to redistribute the software. The copyright within the software is the foundation of the licensing contract, as in the case of commercial software. Rights and permissions are granted subject to conditions. In general, these conditions restrict how the software may be further changed or distributed, rather than imposing a requirement that a fee be paid for it.

There are two principal open source licensing approaches (Hiong, 2005):

- *The GNU'S Not Unix General Public Licence*

Under the General Public Licence, all derivative works of the software and subsequent versions down the chain must be licensed and distributed on the same terms as the original software. Source code subject to the general public licence permanently remains subject to it. This permanent nature of the licence, as intended by its authors, constrains the options available to developers building on general public licence software in creating, distributing or commercializing products using its existing source code.

- *Berkeley Software Distribution Licence*

In contrast, under the Berkeley Software distribution Licence, developers have the freedom to integrate the licensed software with the developers' own source code to create new products with few restrictions. The Berkeley Software Development Licence, for example, allows programmers to use, modify and redistribute the source code and binaries of the original software. However, unlike the general public licence approach, programs containing code subject to the Berkeley Software Distribution Licence do not have to be distributed under that Licence.

From the same perspective ILTA (2006) explains that there are a number of open source licences, but they basically fall into two general categories:

- *Copyleft licence*

Copyleft is a concept created by Richard Stallman. It is designed to be a pun on the word "copyright". Copyleft says that if you make changes to an open source program and distribute the resultant work, you have to make the source code of that new work available under the same licence so that others can share and similarly modify the software. The best example of a Copyleft licence is the General Public Licence.

- *Non-Copyleft*

In contrast to copyleft, software that is published under a non-copyleft open source licence has no such source redistribution requirements. This makes it possible for OSS to be incorporated into proprietary software, subject to all the restrictions in a vendor's standard licence agreement. The best example of a non-copyleft licence is Berkeley Software Distribution.

This research used an open-source LMS for developing an interactive electronic learning management system (e-LMS) for Tanzanian secondary schools (TanSSe-L system). This approach is not new since open-source LMSes are widely used world-wide, such as Moodle, Sakai, Ilias, ATutor, Eledge, OpenUSS, LearnLoop and Claroline. Moodle, however, is the most popular of the bunch by far.

The main advantages of Moodle include reliability, robustness, security, extensibility, flexibility, great collaboration features, loads of free add-ons and plug-ins, regular releases (monthly), a large development team (there were 70 contributing developers in 2006), and innovative, good support through the Moodle partners network.

In contrast to Moodle LMS which is meant to be used by a single institution, TanSSe-L system has the strength as it is being intended to be used by a number of scattered Tanzania secondary schools.

3.9 Database Mirroring, Replication and Backup

The terms replication and mirroring are frequently used interchangeably because their meanings are very similar. When searching for the best answers on the differences between mirroring and replication, answers.yahoo.com, (2009) gives the best answer with which this research agrees as follows:

- Replication is the process of duplicating primary data volumes over an Internet Protocol connection to a storage subsystem at an alternative location. This redundant copy can then be used by business applications if access to the primary data is interrupted. The source and target of a replication are usually separated by a significant distance to safeguard data from disasters that affect a specific geographic location, such as a region-wide power outage (answers.yahoo.com, 2009).

Replication techniques have two principle modes: asynchronous and synchronous. With asynchronous replication, the primary and secondary data volumes are no more than a few milliseconds out of sync, so that replication is nearly in real-time. With synchronous replication, the primary and secondary copies are always identical, providing a true real-time duplication (answers.yahoo.com, 2009).

- Like replication, mirroring uses redundancy to guarantee data availability. A mirrored data volume consists of two identical copies of the data connected a fibre channel. Both sides of the mirror process read and write input/output requests to ensure each copy is a real-time duplicate of the other. The mirror copies are housed

in separate data centres connected over a local- or metro-area network. If a disaster interrupts access to one side of a mirror, the surviving copy will continue to service application input/output requests and therefore minimize the disruption to business users (answers.yahoo.com, 2009).

To emphasize on the differences between the two terms, especially on how they are being used in real implementation, some other random answers searched for which are worth quoting indicate that:-

- Replication is used primarily to distribute portions of your primary database -- the publisher -- to one or more subscriber databases. This is often done to make data available (typically for read only) on remote servers so that remote clients can access the data locally (to them) rather than directly from the publisher across a slower WAN connection.
- Mirroring is a feature that creates a copy of your database at bit level. Basically you have the identical database in two places. You cannot optionally leave out parts of the database. You can have only one mirror, and the 'mirror' is always offline (it cannot be modified). Mirroring works by shipping the database log as it is being created to the mirror and applying (redoing) the log on the mirror. Mirroring is a technology for high availability and disaster recoverability

Most important data are stored on hard drives which are convenient and fast. These hard drives are not normally 100% reliable, and they fail either instantly or slowly. Factors which cause hard drives to fail include age as hard drives just grow old and die, power failures and power fluctuations, viruses that can make the hard drive unreadable, physical damage, or defects in the hard drive. The failure of hard drive causes stored data to be lost, so that is when the importance of data backups comes in. Data are at the heart of any database system to be developed, and so they need to be protected.

To protect computer data a backup and recovery plan is needed. Backing up files can protect against accidental loss of user data, database corruption, hardware failures, and even natural disasters. Preston (2007) explains that, in information technology, backup refers to making copies of data so that these additional copies may be used to restore the original after a data loss event. These additional copies are typically called "backups." Backups are used for two purposes. The first is to restore a state following a disaster (called disaster recovery). The second is to restore small numbers of files after they have been accidentally deleted or corrupted. Data loss is also very common. 66% of internet users have suffered from serious data loss.

3.9.1 Rsync, SSH, and Cronjob

Rsync is a utility that will copy files from one machine to another. In addition, rsync will determine if it needs to copy the entire file, or just changes, making it very fast in subsequent transfers. Haas (2003) states that rsync uses a quick and reliable algorithm to very quickly bring remote and host files into sync. Rsync is fast because it just sends

the differences in the files over the network (instead of sending the whole files). Rsync is often used as a very powerful mirroring process.

There are two different ways for rsync to contact a remote system: using a remote-shell program as the transport (such as secure shell) or contacting rsync daemon directly via Transmission Control Protocol. As defined by Stahnke (2006) and Barrett et al. (2005) secure shell is a network protocol that allows data to be exchanged using a secure channel between two networked devices. It is a program to log into the computer over a network, to execute commands in a remote machine and to move files from one machine to another. Secure shell uses public-key cryptography to authenticate the remote computer and allows it to authenticate the user, if necessary. Secure shell use encryption to provide confidentiality and integrity of data over an insecure network, such as the Internet, and can be used in many ways, one being in combination with rsync to back up, copy and mirror files efficiently and securely.

Rsync can be used to keep an exact replica of the entire directory over secure shell on an external server, without having to use all the CPU and the resources of other mirroring methods. This task can be automated using a “cronjob” with no user-interaction and creating public and private keys for the secure shell is necessary (Pruett et al., 2001). Finally, it is important to provide a simple shell script that prevents anyone from logging into your account with created keys for any purpose other than to rsync. When using rsync you must specify a source and a destination, one of which may be remote, AskApache, (2009).

Radhika, (2009) defines a cronjob as an automated program developed for UNIX and Linux systems. It allows the user to execute several commands at a specific time on a precise date. A cronjob is an important tool that can be used for anything from running scripts and re-indexing a web page to providing backup for a database. A cronjob can also be used as a reminder for downloading email. The user only needs to set the program up once in order for it to continuously complete the job.

Replication, mirroring and backup is very important to make sure that TanSSe-L system is highly available to end users. It was of no doubt that means of replicating, mirroring and backing-up a system to be thoroughly understood by the researcher.

CHAPTER FOUR: ICT SURVEYS

4.1 Introduction

The ICT for e-learning research project, which is elaborated on in sub-section 4.6.4, is the project conceived at the CoET of the UDSM. The project aims to support the teaching and learning in secondary schools, thereby, improving the performance of students. The ICT project was started in 2004 with a thorough study conducted by the research group. The aim of this study was to find out the ICT application status of secondary schools and their environment in different regions in Tanzania. The research group included lecturers from the department of ECSE of the CoET, researchers from Faculty of Education, officers from TTCL and PhD students from the UDSM. The survey was conducted in two phases. The entire research group took part in the first phase of the survey in 2004 to be analyzed in Part A. PhD students took part again in the second phase of survey in 2006/2007 to be analyzed in Part B. The main purpose of the first survey was to study the level of e-readiness for project implementation. The second survey was for system requirement and analysis, whereby the basic needs of secondary school stakeholders were identified.

PART A: ICT Application Status in Tanzania by 2004

Ten areas from Tanzania regions and districts were chosen for the survey. A total of 40 schools (three – four from each area) were selected, visited and surveyed. These areas were: Bagamoyo, Iringa, Kibaha, Kilwa, Mkuranga, Moshi, Morogoro, Mwanga, Arumeru and Same. The e-readiness for ICT survey included findings from the National ICT policy of Tanzania, MoEVT ICT policy for basic education, data communication service providers, e-readiness at secondary schools in terms of computer availability, availability of the necessary infrastructure such as electricity and telephone, e-learning projects for Tanzanian secondary schools which include ICT for e-learning project and finally supportive data from the MoEVT.

4.2 National ICT Policy of Tanzania for e-Learning

Problems facing the Tanzania education system have alerted the Government to realize the need to use ICT in education and to take initiatives to incorporate e-learning objectives in the National ICT policy. The National ICT Policy of Tanzania (MoEC, 2003) points out that ICT encompasses telecommunications services, computers and associated peripherals, Internet services, e-mail, fax, broadcasting, television and other media. One of the objectives of the National ICT Policy of Tanzania is to use ICT to improve the quality of education and training in all areas including distance learning.

The National ICT Policy of Tanzania for e-learning clearly mentions the following objectives showing its support for the education sector as a whole:

- Expand and develop the teaching of ICT at all levels of the national system of formal education, informal education and training
- Expand and improve adult-education, life-long learning and both general and digital literacy programmes, notably for retraining and re-skilling the existing workforce
- Give special attention to providing new learning and ICT access opportunities for women and youth, the disabled and disadvantaged, particularly disenfranchised and illiterate people, in order to address social inequities
- Develop and deploy a nationwide e-education system that supports schools, and higher education/training facilities across the country by connecting them with each other and with relevant knowledge centres, and providing curriculum integration, while also generating information to shape policies, strategic plans and tactical decisions for developing education and vocational training in Tanzania

4.3 MoEVT ICT Policy for Basic Education

The MoEVT also believes that the use of ICT in teaching and learning as well as administration and management represents a powerful tool with which to achieve educational and national development objectives. The Ministry has therefore formulated

the “Policy for Basic Education” to guide the integration of ICT in basic education (MoEVT, 2007). Some of the objectives of this Policy relating to e-learning are:

- Promote the harmonization of activities, approaches and standards in the educational uses of ICT
- Ensure that there exists equitable access to ICT resources by students, teachers and administrators in all regions and types of educational institutions and offices
- Ensure the proper management and maintenance of ICT resources and tools
- Ensure the organized provision of ICT training to students, teachers and educational administrators
- Facilitate the implementation of communication and information systems for the effective management of the education sector
- Facilitate the use of ICT as a tool for assessment and evaluation of education, as well as administration and management
- Facilitate the use of ICT resources in schools and colleges by the neighbouring community
- Facilitate the development and use of ICT as a pedagogical tool for teaching and learning, and for the professional development of teachers, administrators and managers
- Promote the development of local content for basic education and other stakeholders

4.4 Data Communication Service Providers

Eight out of ten of the surveyed areas show that there is a PoP offering dedicated leased circuits (data) over the Public Switched Telephone Network from SIMUNET to clients with bandwidth ranging from 64Kbps to 2Mbps. Areas without a PoP are Mkuranga and Kilwa. SIMUNET Company Limited is one of the directorates of TTCL. In addition to SIMUNET there is an alternative private data provider, SIMBANET, offering wireless Internet connectivity to these areas too. Mwanga is using data connectivity from Moshi town by Wireless Local Loop and the available data speeds are: 64kbps, 128kbps, 128kbps, 512kbps and 2Mbps which are shared or dedicated.

All surveyed areas have Internet Service Providers and mobile companies that are operational, providing communication services to complement the wired network provided by TTCL. Mobile companies available are Celtel (now Zain), Vodacom, and Tigo. Twaakyondo et al. (2002) indicate that mobile operators lease backbone transmission capacity (leased line) and interconnect through TTCL.

Nation-wide, TTCL is a leading Government-affiliated integrated telecommunications company, with a comprehensive portfolio of products and services including local, national and international telecommunications services as well as data communication, internet, and Information Technology solutions. TTCL offers a wide range

of telecommunication services to large corporations and companies, government, diplomatic missions, small and medium business enterprises, residential customers and the general public (Twaakyondo et al., 2002).

TTCL has the most extensive telecommunications network covering all regions on Tanzania Mainland and the Isles. TTCL data services cover the need for communication between data nodes in different parts of the network. These include the provision of Internet bandwidth and local connectivity between sites in different locations. TTCL data services comprise the following (TTCL, 2008):

- Broadband
- Internet Bandwidth
- Internet Protocol (IP)
- Virtual Private Network
- Leased Circuits

Yonah (2002) indicates that Tanzania now has over 30 PoPs, located in over 15 regions - Dar es Salaam, Arusha, Moshi, Tanga, Dodoma, Morogoro, Iringa, Mbeya, Singida, Tabora, Shinyanga, Mwanza, Musoma, Moshi, Mtwara, and Zanzibar.

Apart from having TTCL, Tanzania now has six more companies licensed by the Tanzania Communication Regulatory Authority to provide data communication services. These companies include: Wilken Afsat, Datel Tanzania, Equant Tanzania, Simbanet Tanzania, Soft Tech Tanzania and Fastcom Africa. Out of these, Wilken Afsat, Datel and Simbanet appear to be the most active (Miller et al., 2001; Twaakyondo et al., 2002). These companies are permitted to install infrastructure for data communication purposes but not for voice.

4.5 e-Readiness in Tanzania Secondary Schools

When looking at the availability of telecommunications services, Internet services, computers and associated peripherals in Tanzanian secondary schools, the survey analysis shows that many of the surveyed secondary schools have acquired computers, either by their own efforts by purchasing them with their schools' fund or from donors and some from the Government. Due to the high costs, very few schools have managed to acquire Internet services.

Table 4.1 and Figure 4.1 show the analysis on the availability of working computers in 40 surveyed secondary schools in the ten surveyed areas on Tanzania mainland. From the analysis, it can be seen that in 2004 only 14 (35%) out of forty (40) secondary schools had no computers, 65% had one or more computers, of which 10 (25%) schools had from one to three computers being used for secretarial services, 5 (13% approximately) schools had between 4 and 15 computers being used for secretarial services and computer literacy training and the remaining 11 (27% approximately) schools had more than 16 computers also being used for secretarial services and com-

puter literacy training. It is likely that the number of computers has increased in these surveyed secondary schools because the pace of at which computers are being acquired is growing rapidly national-wide.

Table 4.1: Number of Computers versus Number of Secondary Schools in 2004		
Computers availability in schools	Number of Schools	% out of 40 Schools
0	14	35
1 – 3	10	25
4 – 15	5	13
≥16	11	27
Source: Group ICT Survey Reports		

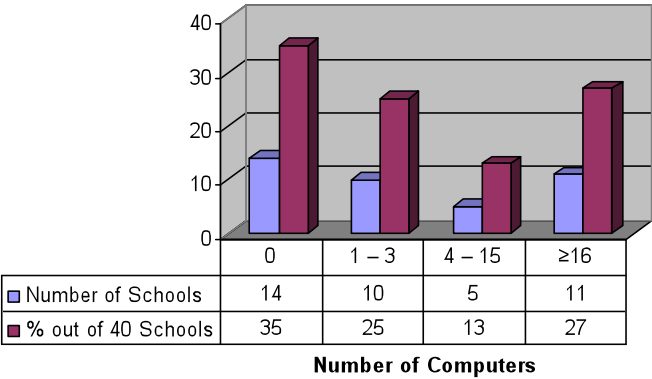


Fig. 4.1: Graphical Representation of Number of Computers versus Number of Schools

It can also be seen from Table 4.2 that approximately 10% of the 40 surveyed secondary schools had Internet services. Though the services are mainly accessed by the head of the computer unit, headmasters/headmistresses and/or staff, it is still a good start to the use of ICT in education.

Table 4.2: Number of Schools with Internet Services		
Description	Number of Schools	Percentage (%)
With Internet Service	4 Schools	10
Without Internet Service	36 Schools	90
Source: Group ICT Survey Report		

Coming to electrical power availability, 34 schools (85%) out of the 40 schools visited use Tanzania Electric Company Limited (TANESCO) power. 3 schools (7%) use generators. The remaining 3 school had no power. The majority of schools had working

telephone facilities. A few of the schools had well secured computer laboratories, and the rest were getting ready to construct computer laboratories.

Issues relating to electrical energy displayed on the TANESCO Website (<http://www.tanESCO.com>) accessed in 2008 shows the status of electricity in 2006. Part of the statement says that: “By the end of 2006, Tanzania Mainland had 21 regions and 113 districts. All the Regional Headquarters so far have electricity. Of the 113 districts, 95 district headquarters have electricity while 18 do not” (TANESCO, 2008). TANESCO is a parastatal organization created in 1964 and is under the Ministry of Energy and Minerals. The company’s core business is to generate, transmit, distribute and sell electricity to customers in Tanzania mainland and bulk supply to the island of Zanzibar.

The adequacy of infrastructure and logistics in schools is necessary for the availability and use of ICT. In this respect Addo (2001) argues that the critical requirements include computers, a computer laboratory, a school library; electricity, a telephone and security for safeguarding expensive computer systems.

4.6 e-Learning Projects in Tanzanian Secondary Schools

The effort shown by the Tanzania Government to improve teaching and learning is to raise the standard of teachers’ preparation, increase the number of teachers with degrees and improve the teaching of classroom strategies. The Government is making a big effort to improve the situation but is overwhelmed by the increased number of secondary schools and students. Learning resources and teachers are stretched to the limit. One of several ways to overcome these constraints is to make use of ICT. The following sections describe some projects which have attempted to incorporate ICT in learning.

4.6.1 Implementation of IP Based VPN Connectivity in Tanzania

Simba (2005) in her Master’s Degree research titled “Implementation of Internet Protocol Virtual Private Network (IP Based VPN) Connectivity in Tanzania”, successfully designed and implemented a WAN to interconnect a number of individual secondary schools’ computer LANs which are geographically dispersed within Tanzania by using the IP Security/Virtual Private Network technique.

TanSSe-L was developed as a Web-based learning management system to serve a number of secondary schools in different locations. Data exchange and sharing can be performed by computer network systems via the Internet. The TanSSe-L system database was installed in a centralized server located in the department of ECSE of the CoET, UDSM. It is designed to be viewed in a shared manner with all users (stakeholders) of the system using their computers (referred to here as clients) which support standard Web browsers. These clients are designed to be networked to the TanSSe-L system database server.

With Simba’s work means that it can be possible to incorporate the TanSSe-L database server in the already developed WAN and enable many schools to access and use learning materials stored in the TanSSe-L database.

4.6.2 IICD Projects

Efforts to improve secondary education in Tanzania using ICT are also seen in the many other projects undertaken by non-governmental organizations. The International Institute for Communication and Development, which is an independent non-profit foundation established by the Netherlands' Minister for Development Cooperation in 1997 is one of them, and supports the ICT projects of many countries including Tanzania, where, ICT projects supported by the Institute include:

- The project titled "Tanzania Education (TanEdu) Website" (<http://www.tanedu.org>) aims to provide timely, accurate and reliable information about education services all over Tanzania. The Website also includes information about secondary schools' examinations, schools' administration and the latest news on the education sector. The news bulletin contains articles targeted at students, teachers and parents (TanEdu newsletter, 2005).
- The Distance Learning and Education Services project, in collaboration with the Royal Dutch Embassy displays on its Website (<http://www.diles.or.tz>) that it aims to deliver educational materials to secondary school students in Tanzania free of charge. Many of the Websites available are static and access to them is limited to urban school students who have access to Internet cafes.

4.6.3 Projects with the MoEVT

The MoEVT has planned many projects, and some have already started. One of them is called "ICT Implementation in Teachers' Colleges" (<http://www.teachers.or.tz>). In August 2005, the Tanzanian Government, in collaboration with the Swedish Government through Sida, initiated a project for introducing ICT into all government teachers' colleges. The project's main goal is to improve the quality of pre-service and in-service teacher education by using ICT. It is expected that principals, tutors and students will be trained in ICT to be able to use it as a tool for teaching and learning as well as for management and administration (MoEVT, 2007). The MoEVT (2006) in its eSchool programme document states that:

"Already colleges of education in the country are being provided with ICT facilities so that when teachers graduate they are ICT literate and can use computers for teaching and learning"

ICT Implementation in Teachers' Colleges is a very important project in relation to e-learning in Tanzanian secondary schools, because it facilitates and enhances the use of the TanSse-L system in secondary schools, even at development stage, by making it easy to use the participatory approach.

In order to support and implement some of the objectives of the National ICT policy, the MoEVT through its semi-autonomous agency the Tanzania Institute of Education has developed an ICT syllabus for primary and secondary education: Teknolojia ya Habari na Mawasiliano for primary schools and Information and Computer Studies

for secondary schools. The Institute is currently finalizing the ICT syllabus for teacher education. Two syllabuses have been proposed: ICT Academic as a specialization subject and ICT Pedagogy as a compulsory subject for all student teachers (MoEVT, 2007).

“Acquisition of ICT Resources for Public Secondary Schools in Tanzania Mainland” is a project what was prepared by MoEVT in Nov. 2008. The main objective of this project is to enhance the capacity of Tanzania Mainland secondary schools to provide quality education through the use of ICT. The project comprises three specific objectives (MoEVT, 2008) to:

- Support teaching and learning through the installation of ICT facilities and providing of access to learning resources (Hardware and Software);
- Provide the opportunity for teacher professional development and develop teacher competence through the use of ICT;
- Develop, produce, evaluate and deliver self-learning materials based on the existing curricula.

The draft proposal shows that the first phase will cover 891 secondary schools in seven regions; Lindi, Kigoma, Rukwa, Tabora, Mtwara, Shinyanga and Ruvuma. Each school will be required to have a computer, an LCD projector, Projector screen, a Television set (29 inches), Satellite dish, electricity, Digital Versatile Disk player and an ICT-trained teacher to run the programme. The plan is to start with six subjects, namely, Geography, English, Physics, Chemistry, Biology and Mathematics.

4.6.4 ICT for e-Learning Project for Tanzanian Secondary Schools

To complement such efforts in a more dynamic way, the UDSM through its CoET conceived a research project to develop a tool to enable ICT support rural secondary schools, by providing teaching materials, which are user friendly and facilitating self-learning and information sharing, starting with science and mathematics.

This research work was based on three pillars as shown in Figure 4.2. These are “*establishment of suitable and effective connectivity and configuration*”, “*development of a context centred platform which includes an e-learning management system using open source software*” and “*development of learning content materials for self-learning and sharing*”. To minimize operational costs an open source platform was chosen. This research sought to develop an interactive e-learning management system (shaded area in Figure 4.2) for Tanzanian secondary schools, taking the name TanSSe-L system, but in reality it embraced the other two research components.

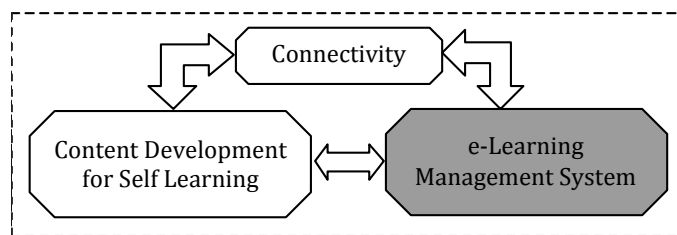


Fig. 4.2: e-Learning Project Components

4.6.4.1 Development of e-LMS (TanSse-L System)

Learning design has the potential to develop e-learning by capturing the process of education, rather than simply content in the form of content objects (learning materials). Learning involves a number of different users/roles with different ways of participating in the e-learning process. For the creation of distance learning to a distributed number of schools, Web-based learning environments are usually being used (Recesso, 2001). Akeroyd (2005) insists that at one extreme the best use of e-learning is to utilize Web technology to facilitate the whole cycle of learning from initial sign-on to final certification, with a range of operations in between, and with little or no, physical interaction among learners. The birth of the Web opened up a new dimension for computer-based training. The Web enables learners to learn online anywhere at any time and it makes it possible to avoid the huge costs of corporate training. Online learning has created excellent opportunities for accessing learning and new ways of collaborating.

Watson et al. (2004) contribute more to this by saying that the e-learning industry, which includes different groups of users and different knowledge requirements, requires a more manageable system, one that can monitor the learners' learning and that can measure and provide reports on learning efficiency. This requires constant tracking of the learners' actions and results of online tests, and this can be achieved by the use of an LMS, which provides a technological, parameter-driven framework to allow individual academics to develop and deliver learning content, to interact with students and to facilitate open discussion.

Watson et al. (2004) continue to argue that many LMS have been developed to provide a wide range of different features to enable e-learning. All of them aim to deliver four main features: delivering training content, tracking student performance, managing learning materials and learners, and providing tools for student collaboration.

The basic LMS is a Web application where the learner logs on and accesses the learning materials allocated to her/him. While the learner, is going through the learning materials, the LMS stores information about the learner's interactions, such as scores and answers to the questions. The LMS uses this information to analyze how well the learner is performing, and is able to provide reports to the administrators and tutors, identifying how well individuals or groups are performing using the learning materials or curricula. The LMS usually contains an interface for managing users, adding/

deleting new learners, organizing learners into hierarchy and allocating access rights to users (Watson et al., 2004).

4.6.4.2 Kibaha Pilot Site

Tanzania has only one curriculum for all secondary schools registered under the Mo-EVT, which are the majority in Tanzania. During the TanSSe-L development stage it was not easy to involve all scattered Tanzania secondary schools, and so it was decided to start with a pilot site. The criteria for selecting the pilot site were that, the schools needed to be accessible and to have both ordinary-level and advanced-level students taking science subjects with different performance rankings and of both genders. Kibaha was one area which happened to meet those criteria.

Kibaha as shown in Figure 4.3 is one of the six districts and the regional headquarters of Pwani region in Tanzania. Kibaha is 40km from Dar es Salaam and easily reached by road (about 30-40 minutes' drive). Kibaha is supplied with TANESCO National Grid. Most of the Kibaha residents depend on one or more of the following activities for their livelihood: employment, business and agriculture. The community has exposure to ICT through the existence of two computer-training centres (Njuweni Hotel and Kaece Computer Centre), Internet cafes and several secretarial shops offering computer-based services. Normal telephone services are also available.

TTCL regional office has a PoP, offering dedicated leased circuits to clients with scalable bandwidth ranging from 64Kbps to 2Mbps. The maximum distance for data connectivity using leased lines is 3-5 km (2 wires). Also there is a wireless option for Internet connectivity via a radio link.

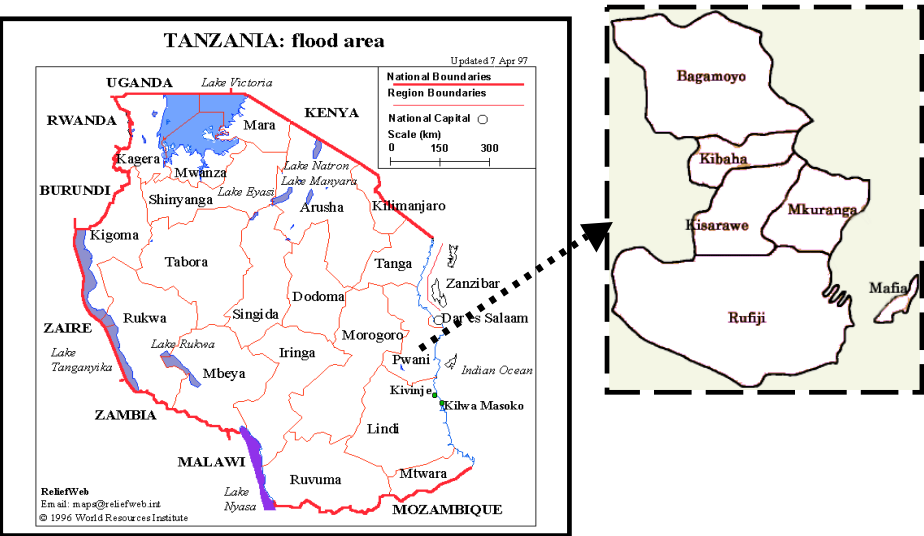


Fig. 4.3: Map of Tanzania Showing Kibaha District in Pwani Region

In Kibaha area, the survey covered four secondary schools. These were Kibaha Sec-

ondary School, Wali-ul-Asr Girls' Seminary, Tumbi Secondary School and Pwani Secondary School, each with a quite different level of performance. Kibaha Secondary School and Wali-ul-Asr girls' seminary were the schools selected to be the research pilot schools.

Apart from many other reasons used to select Kibaha town as the pilot site, the two earmarked schools have quite different motivations which could be used as a challenge to make students share resources from the TanSse-L system. Tables 4.3, 4.4 and 4.5 show the status of the two earmarked schools, Kibaha Secondary School and Wali-ul-Asr girls' seminary.

Table 4.3: Status of Kibaha Secondary School versus Wali-ul-Asr Girls' Seminary 2004	
Kibaha Secondary School	Wali-ul-Asr Girls' Seminary
Boys' boarding school	Girls' boarding school
Owned by the Government through Kibaha Education Centre	Private owned by World Islamic Propagation
Located about 2.5 km from Kibaha bus stand	Located about 2 km from Kibaha bus stand
School has both 'O-' and 'A-' level offering ICBG, PCB, PCM and ECA for A-Level	School has both 'O-' and 'A-' Level offering HKL, HGL, ECA and CBG for A-Level. Planning to add science combinations in future
There are 3 science laboratories, 1 library and one newly rehabilitated computer room	There are 2 science laboratories, 2 libraries and 2 air-conditioned computer rooms.
Four Personal Computers as yet	Has about 20 personal computers (peer-to-peer networked in one of the computer labs, an Intranet in the administration block) but without Internet connection. The computers are used for both teaching and administrative activities
Teacher to student ratio is 1:17	Teacher to student ratio is 1:15
Nine (9) out of 54 teachers are computer literate	There are four ICT teachers: 1 degree holder, 1 Diploma holder and 2 certificate holders.
One of the National earmarked special secondary schools, highly ranked as shown in Table 4.4	Poorly ranked as shown in Table 4.5
The performance for both O-Level and A-Level is on the high side	Generally, the students' performance for the past three years is moderate
Source: Group ICT Survey Report	

⁶CBG: Chemistry, Biology and Geography, PCB: Physics, Chemistry, Biology, PCM: Physics, Chemistry, Mathematics, HKL: History, Kiswahili and Language, HGL: History, Geography and Language, ECA: Economics, Commerce and Accountancy

Table 4.4: KSS Performance in O-Level in 2003					
Year	2003				
Division	I	II	III	IV	0
Number of Students	35	07	13	06	0
National Ranking	20 out of 754				

Table 4.5: Wali-ul-Asr Performance in O-level in 2003					
Year	2003				
Division	I	II	III	IV	0
Number of Students	0	1	10	27	1
National Ranking	114 out of 754				

The situation is the same for the form IV (O-Level) National examination performance statistical data viewed in the BEST of the MoEVT. Table 4.6 shows the difference in performance of the two schools in 2008.

Table 4.6: Difference in Performance in O-Level in 2008 - KSS and Wali-ul-Asr							
Year	2008						Total Candidates
Division	I	II	III	IV	0	ABS	
Number of Students for KSS	29	22	18	18	1	0	88
Number of Students for Wali-ul-Asr	0	0	8	47	13	2	70
Source: Basic Education Statistics in Tanzania from MoEVT, 2008							

PART B: Problems Revealed in 2006/2007

4.7 Second Survey Overview

The aim of the second survey was to involve Tanzanian secondary school members in finding, identifying and substantiating problems facing Tanzanian secondary schools in the form of focus group discussion. It was also important to know how secondary schools counter the identified problems for the purpose of improving school performance. Solutions on how to overcome identified problems led to the development of the TanSse-L system, having ascertained the requirements. The survey was done in 2006/2007.

Six areas were selected for this survey, namely Kibaha, Bagamoyo, Songea, Mbeya, Dodoma and Arusha. At least six schools were visited and surveyed in each area. Fur-

thermore, educational institutions were also visited to find the documented issues concerning Tanzania secondary schools. These institutions include MoEVT and the NECTA, a semi-autonomous agency of the MoEVT.

For secondary schools, open-ended questionnaires were designed to get the needed information, such as the availability of books and reference materials, whether there are enough teachers how they solve the problem. If there is a shortage, what are the subjects with a critical shortage of teaching staff, the qualifications of the teaching staff, the availability of computers at the schools, usage of computers if available at schools, etc. Open-ended questions guided the focus group discussion with secondary school stakeholders at the MoEVT and secondary schools visited.

4.8 Second Survey Results

4.8.1 Results from Focus Group Discussion

Results from the focus group discussion generally show a number of items are inadequate as discussed in almost all the Tanzania secondary schools visited. General comments on the problems facing Tanzanian secondary schools, leading to poor performance, include:

- Lack/inadequacy of resources (text and reference books, laboratory equipment)
- Lack/inadequacy of qualified teachers
- Lack of discipline in both students and teachers
- Lack of preparation and commitment to fulfill the objectives of lesson plans, due to demoralization of teachers

Below are some of the problems discussed and how administrators, teachers and students are taking an initiative to counter them.

- *Inadequacy of text and reference books*

To counter this problem, teachers normally prepare detailed notes for students to read, while the few books available are shared among students during the lesson. Some schools borrow books from neighbouring schools. Parents are sometimes asked to purchase books for their children. Students and teachers are also encouraged to use public (regional/District) libraries for reference books.

- *Inadequate number of teachers*

The inadequate number of teachers is a big problem for many schools. However Headmistresses/Headmasters reduce this problem by sometimes:

- Recruiting temporary teachers, especially Form VI students who are on leave
- Borrowing/exchanging qualified teachers from/with neighbouring schools
- Using part-time teachers

- By asking teachers to teach in extra time and at weekends, using the lecture method to combine students studying the same topic from different classes
- *Subjects with shortage of teaching staff*

Depending on the school, the following subjects were identified to be severely lacking teaching staff, as presented by teachers:

- Chemistry, physics, biology, mathematics (Science subjects and mathematics) to a large extent
- Economics, Commercial (Book-keeping and commerce) subjects
- English with linguistics at A-level
- Basic mathematics, English, commerce and book-keeping
- *Ensuring that the school is performing well*

Apart from the many problems facing Tanzania secondary schools, each school is struggling hard to make sure that students are performing well. Strategies taken by administrators (Headmistresses/Headmasters) to ensure that schools perform well include: close supervision to ensure that teachers fully cover the curriculum, if possible well in advance, so that students can have more time for revision before examinations; making sure that all periods are taught and involving teachers in serious and efficient teaching, that is motivating teachers to efficiently fulfill their responsibilities; closely following up on the attendance of teachers and students in class and motivating students in self-learning after classes; rewarding students who perform well and giving incentives to teachers who are doing well; staff meetings to discuss the problems of students and how to handle them; and emphasizing that teachers must provide more and frequent exercises.

Teachers on the other hand play an important role in ensuring good performance through: giving students enough exercises, more tests and correcting the work done to clarify areas that students got wrong; preparing lessons in order to teach and teach well; adhering to school rules and regulations, while maintaining class discipline; and working hard and using student-centred teaching techniques. Some teachers assign tasks using participatory methods, creating subject clubs and teaching in a participatory manner. Sometimes they get students to orally present what they have learned and understood, they keep students busy in finding materials by themselves under their guidance, and involve parents in school activities.

Weak students need more attention to make sure they improve their performance. Techniques used by teachers to help weak students include conducting remedial classes in the evening after normal classes and on Saturdays, providing more exercises, assignments and homework in order to keep students busy, and focusing more on academic issues. Other techniques are through:

- Counselling and talking to weak students individually, having a discussion with the parents concerned on how to assist them

- Creating small group discussions on the subject, with a mix of weak and active students
- Encouragement, close supervision and praising them when they improve
- Emphasizing the need to attend classes and to do private study

Some schools have double teaching sessions due to many students. In this case there is no time for extra classes on weekdays. Weak students are helped during the weekend, mainly on Saturdays. Some teachers do not manage to give extra teaching due to the heavy load they bear.

- *ICT use in education*

The importance of using ICT in education has not been understood by many people, specifically secondary school administrators, teachers and students. Discussion on this area showed in the difference understanding, with the ideas of students and teachers being presented separately, as shown below. These ideas show that many of them have positive thoughts on ICT use in education.

(a) *Students*

- *Communication:*

ICT use in education facilitates communication with other people and countries. It also improves teaching skills and communication

- *Learning material*

Through computers somebody gets learning materials for reference and they facilitate easy teaching by getting information from various sources. ICT use in education helps students to get different materials and learn things with a wide choice of references. ICT use in education is more than a book for getting learning materials; it encourages the use of various materials which are relevant and not only local materials. ICT use in education can be used as reference books, for searching the relevant subject material and storing for future use. ICT use in education gives more information and reduces shortcomings brought about by the lack of learning materials. ICT gives access to different materials and is useful for accessing current and modified knowledge through surfing the net for information.

- *Sharing*

ICT use in education can be used to store data and information; it facilitates the sharing of knowledge with different people in the world through Website; it enables students to increase their knowledge of academic drills, sharing different ideas about academic subjects across the world; it helps people know about social, economic, political and culture matters in different countries.

- *Learning activities*

ICT simplifies training and learning activities and people can keep up-to-date with science and technology.

- *Management of time*

People can do many things in a short time by employing ICT in education; it speeds up learning; enables teachers to teach many streams for a specific/same time; it saves time and enables people to get a lot of information rather than from books and notes; it helps teachers to simplify the work instead of using chalk.

- *Laboratory*

ICT use in education can improve the practical knowledge of students especially of Government schools since they learn more when they apply what they learn. This could be of great help since the Government doesn't support students to be practical; ICT use in education can help in laboratory studies, as it provides accurate data and expands knowledge.

- *In subjects*

ICT use in education can be used to process data for science studies and mathematical calculations; it helps in improving language (English) and learning mathematics.

- *Other positive comments on ICT use in education from students include:*

- Getting entertainment, playing games; it is a good attraction
- Important in raising education standards in schools and even in the country; both primary and secondary schools should be encourage to use ICT in education, and computer training should be introduced, especially in Government schools
- ICT use in education shows education is improving and through this the country will get educated leaders
- The use of computers in education should be stimulated and include a computer subject in Government primary and secondary schools
- It gives an understanding of a number of global issues which are essential in studies
- Learners get to expand their knowledge and needed information using ICT in education
- Provides modern technology and a wide range of information and technological development
- Provides schools with a modern way of teaching e.g. using computers and projectors to simplify the teaching process
- ICT use in education can help to know about computers better and increase the understanding of students and teachers
- ICT use in education should be taught by skilled teachers and experts
- ICT use in education needs less teachers

- ICT use in education is very good but there are no computers in schools, it is a new system
- *Negative comments on ICT use in education from students include:*
Not all members (students) were positive about accepting ICT use in education in Tanzania secondary schools. Below are some comments of students:
 - Not advised to use ICT in education because it makes students play games instead of listening to their teachers (for the students who don't understand the importance of education)
 - Wise use of ICT should be taught and encouraged to avoid immoral watching of spicy (pornographic) films
 - ICT use in education may improve the quality of education, but in some cases it will bring down the quality of education if students use it in the wrong way
 - I don't think at this level (secondary school level) computers can facilitate my learning because I disagree with the method of using ICT
 - ICT may be used at diploma and university level but not at O-level and A-level because it could cause students' brain to stagnate
 - ICT use in education at A-level should be taught as a subject, but at primary and O-level it must be prohibited since it will lead to the destruction of our (Tanzanian) culture and brain stagnation
 - They (computers) should be used but not strongly as students can become lazy in their mind instead of using their brains, they will depend on computers
 - Use ICT in higher education for diplomas and degrees

(b) *Teachers and Administrators*

- *Learning Materials*

ICT can be used in education as a source of educational materials, and is a good source of teaching and learning material if used properly. ICT use in education can be compared to the use of a library. It facilitates access to learning materials. Students can easily learn things from resources which might be difficult to get; It is like a library for a learner; ICT use in education is crucial and it is easy to get updated teaching materials using ICT in education.

- *Storage*

ICT use in education makes work easy, simplifies the storage of information.

- *Management of time*

ICT use in education reduces the waste of time; it is easy to access any needed information from distance learning.

- *Other positive comments on ICT use in education from teachers and administrators include:*

- Pupils should know how to operate computer machines when they finish their primary level of education
- Special programs for teachers should be provided especially for older ones
- Prospective users need to be trained; seminars for teachers concerning ICT need to be provided
- Schools should be provided with computers for teachers and students
- It is good, but should be accessed by all students to avoid educational discrimination
- Both teachers and students should be prepared well in ICT use, manuals on the use of ICT in education should be translated into Swahili for ease of understanding especially by students
- ICT resources must be made available and must be up to date
- It must be protected for people especially youth because some students usually open things which are not good, e.g. sex images, videos and other local sites showing sexual activities. Students should be prevented from viewing these things.
- It should be 40% of the education programme, the remainder should be used devoted to face-to-face teaching and learning activities
- ICT use in education should be extended to both rural and urban areas
- The use of ICT in education is still poor in Tanzania but because it is very important much effort must be made to introduce it in the whole country in order to facilitate the teaching and learning process
- ICT should be used from primary to University level; it must be used in all secondary/primary/colleges in the country and not only in the fortunate schools as is being done now
- Lower charges should be made for Internet so that schools can manage, and employ active service providers
- ICT use in education fosters the desire for education in most students and teachers; it helps to keep users up to date and makes teachers aware of the current issues in the world
- It simplifies work and record keeping and the work of teaching
- It is a necessity in this modern world of science and technology

- *Negative comments on ICT use in education from teachers and administrators include:*
 - NO, I totally disagree with use of ICT in education for Tanzania secondary schools (no reason)
 - No idea about computers
 - It is very important, but in our country there are several problems on the students' side, because the understanding ability of learners needs the physical appearance of teachers in order to ask questions.
 - Nothing good, it will destroy the African culture to some extent
- *Evaluating teachers by students*

Teachers need to be committed and responsible in their work. However there are some who do not follow rules and regulations. Many schools have their way of getting feedback from students concerning teachers' responsibilities. Evaluation is through:

- Filling in prepared teacher's evaluation forms
- National examination results from NACTE
- Individual performance of students in subjects
- Giving their remarks and opinions during monthly class meetings and school meetings,
- Students' Government and counselling sessions conducted in schools periodically
- Through suggestion boxes and sometimes students report to the academic master, and the mistress taking the attendance

During focus group discussion, it was realized that the Government through the MoEVT started the intermediate primary and secondary school examinations. The purpose of these intermediate examinations is to measure the level of competence of students before committing themselves to the final National examination. Secondary schools' intermediate examinations include:

- End of Form II examination coordinated regionally. Students who do not meet the minimum pass mark set at this stage are not allowed to enter Form III. Students are advised to repeat Form II
- Mock¹ examinations are also coordinated regionally. This examination is taken just before the O-Level CSEE examination.

The Government has observed that many students nowadays are learning through doing exercises, hence students do not concentrate on the concepts provided by subjects. On this basis, the Government through MoEVT is promoting a collaborative way of learning in Tanzanian secondary schools. Collaborative learning discourages individualized reading and a single final examination, but rather encourages multiple interac-

¹Mock examination is a pre-examination done one to two months before the final O-Level National examination.

tions leading a common and negotiated understanding, combining the differences in ideas, knowledge and attitudes of the participants.

4.8.2 Results from Documented Data

There are a number of real statistical data documented by the concerned organizations, which are used to show the extent of these inadequacies. With respect to the main objective of the e-learning project, which states “*To improve the quality of science education in secondary school in the rural areas of Tanzania*”, identification of the problems for Tanzanian secondary education and how to overcome them are analyzed on the same basis as the focus group discussion through answering the following three main questions:

- *What are the reasons for poor performance?*

The reasons for poor performance were obtained through focus group discussion analyzed above and are clearly identified in Chapter one under “statement of the problem” section 1.2. The reasons identified include the shortage of teachers and reference books, and other basic academic materials. These problems are being accelerated by the increased number of schools and students compared with the number of teacher and amount of learning resources.

- *To what extent is the performance poor?*

The extent of poor performance is also clearly stated and analyzed in Chapter one under “statement of the problem” section 1.2, but what is considered are performance in the National Examination, the pass grades for mathematics and science subjects (chemistry, physics and biology) in the National Examination, and performance of urban secondary schools in the National Examination compared with rural secondary schools.

- *How can students’ performance be improved?*

A number of strategies are employed by teachers and school administrators to make sure that their schools perform well, despite the problems they are facing. In summary, through focus group discussion, the following two strategies seemed to be the ones most needed by the majority of them and which could be implemented using the TanSSe-L system:

- The need to have more self-learning materials, especially in science and mathematics subjects with respect to the main objective of the e-learning project, which would ensure that teachers cover the curriculum.
- The need to have a good number of self-test questions and past paper examination questions for practice. Many schools provide enough exercises and tests as one technique for improving students’ performance.

4.9 Discussion

The surveys clearly confirm the expected fact that the conditions for providing satisfactory education at the rural secondary school level are poor due to the lack of material and human resources. The knowledge base for further education in Tanzania is thus too thin in order to meet the needs of society. Tanzanian education system at secondary school level has to undergo a substantial transformation, underscored by the growing application of ICT. The study shows that the country is gradually entering the global information society, although the available resources limit the pace considerably. There is a positive trend in encouraging the use of ICT in e-learning by all secondary school stakeholders.

The study included not only secondary schools as such but also the political framework for the school system, namely the ministry responsible, MoEVT, its policies and the staff concerned. In order to better understand the different contexts and to lay the ground for sustainable development, the triple helix mindset is used (Trojer et al, 2005). The triple helix process included in this project involved the collaboration between the three main stakeholders, the university, the Government and society (the schools), where the university (UDSM) was able to take a strong initiative.

The use of ICT provides innovative ways to complement the traditional student-teacher interaction worldwide, to optimize resource usage, sharing and collaboration. Therefore, the development of e-learning facilities for rural areas of Tanzania has been given a high priority and is therefore relevant. The application of ICT in e-learning that is accessible even in remote rural secondary schools will improve the performance of students in such secondary schools as well as raising the morale of teachers and students. The next chapter gives the TanSSe-L system's requirement specifications and analysis.

CHAPTER FIVE: TanSSe-L SYSTEM REQUIREMENT SPECIFICATIONS AND ANALYSIS

5.1 Introduction

Learning materials can be delivered to learners in many ways, including the use of LMS, compact disk read-only memory (CD-ROMs) and face-to-face delivery. Sometimes these delivery approaches can be used together during the learning process, which is referred to as the hybrid or blended mode of learning (Lating, 2006 and Lujara, 2008). ICT for e-learning for Tanzanian secondary schools focused in using the hybrid mode of the delivery of materials, which means that the development of an interactive e-LMS (TanSSe-L system) needed to be in place.

5.2 System Requirement Specifications

The followings are presented in this section:

- Identified TanSSe-L system requirements
- TanSSe-L system components
- TanSSe-L system functions
- TanSSe-L system non-functional requirements
- Stakeholders and their privileges in using the TanSSe-L system
- Technology and standards
- TanSSe-L system architecture

5.2.1 Identified TanSSe-L System Requirements

The aim of the first survey presented as part “A” in Chapter four was to study the level of e-readiness for project implementation. The findings show that there is positive movement towards the use of ICT in e-learning in the following areas⁸:-

- At national level, one of the objectives of the National ICT Policy of Tanzania is to use ICT to improve the quality of education and training in all areas including distance learning
- The concerned Ministry, MoEVT, has formulated an “ICT policy for basic education” to guide the integration of ICT in basic education, including Tanzanian secondary school education
- There are a good number of licensed data providers in the country namely; TTCL, Wilken Afsat, Datel Tanzania, Equant Tanzania, Simbanet Tanzania, Soft Tech Tanzania and Fastcom Africa
- Many of the secondary schools surveyed have basic requirements including a school computer laboratory, computers, a school library; electricity, telephone and security for safeguarding expensive computer systems
- Some of the on-going ICT projects in Tanzania will accelerate easy implementation of the e-learning for secondary schools project, one being the “ICT Implementation in Teachers’ Colleges” (<http://www.teachers.or.tz>). The project is sponsored by Sida and aims to improve the quality of pre-service and in-service teacher education by using ICT. MoEVT has also introduced a secondary school syllabus for computer studies

The aim of the second survey was to find, identify and substantiate the problems facing Tanzanian secondary schools. Solutions to overcome the identified problems led to the development of the TanSSe-L system. The following two issues were found to be the ones most needed by majority of e-learning stakeholders from the second survey as stated in part “B” of Chapter 4:-

- The need to have more self-learning materials especially in science and mathematics subjects
- The need to have a good number of self-test questions and past paper examination questions for practice

Nevertheless, the main focus of the ICT for e-learning research project for Tanzanian secondary schools was on supporting teaching and learning functions. The research seeks to provide learning materials through the TanSSe-L system. Learning materials are the main part of the TanSSe-L database structure that was developed. The findings of Lujara, (2008) shows clearly the structure of the learning materials in tree form which is shown in Figure 5.1. When analyzing the structure of learning materials, Tanzanian secondary schools were seen to have a number of subjects at each level.

⁸ Findings mentioned towards the use of ICT in e-Learning are all clearly discussed in Part A of chapter 4 (ICT Application Status in Tanzania by 2004”.

Each subject has recommended books and reference books. When looking inside these books there are a number of chapters and each chapter has a number of topics. At the end of each chapter there is an exercise.

From a broader perspective, the development of the TanSSe-L system followed the standard way of developing an LMS. As mentioned in research methodology in Chapter 2, the focus was on using an open source LMS as a virtual machine because, at the end, the TanSSe-L system would be implemented by customizing the selected open source LMS.

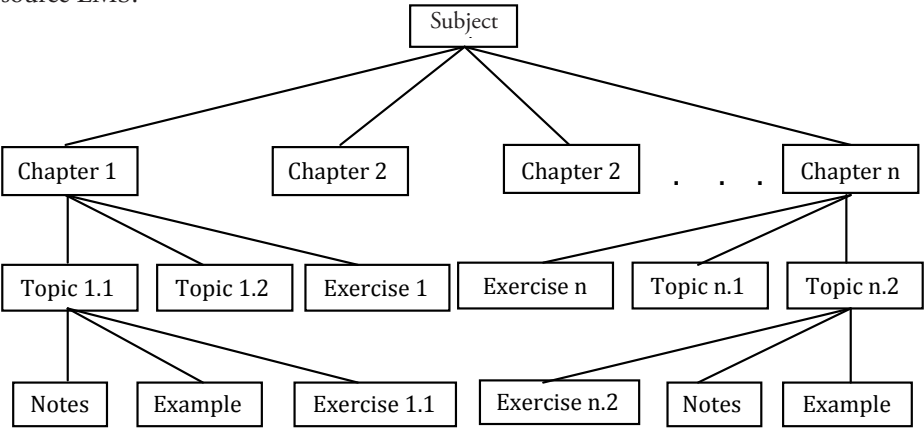


Fig. 5.1: Learning Material Tree Structure

5.2.2 TanSSe-L System Components

The TanSSe-L system is based on main four components: user component, learning material, assessment activities and communication resources. The *User component* is concerned with the main users with different roles to participate in the system. The *Learning materials* component is concerned with all areas used in delivering a subject. These are subject notes which include subject syllabus and examples. Subject notes are composed of chapters and topics. Avgeriou et al. 2003 state that Assessment activities involve all aspects dealing with evaluating or assessing the learners' understanding of the provided learning materials. *Assessment activities* contain subject self-test questions, chapter exercises and topic exercises. *Communication resources* involve all components in creating collaboration among users in the system, e.g. e-mail, help, forum and calendar. Figure 5.2 shows the TanSSe-L architecture components.

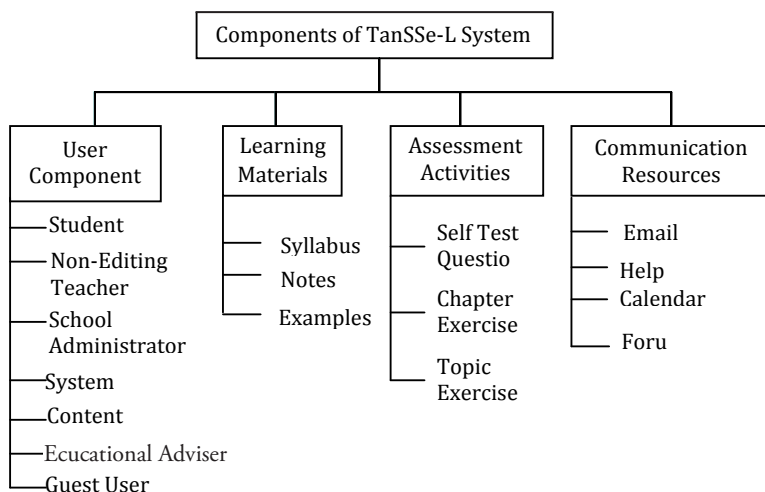


Fig. 5.2: TanSse-L System Architecture Components

5.2.3 TanSse-L System Functions

Like any other LMS, the TanSse-L system is aimed at managing users and learning activities. Referring to some of the system functions noted by Yong et al. (2003), the following as shown in Table 5.1 are the basic functions of the TanSse-L system:

Table 5.1: TanSse-L System Functions

Function Number	Function Description	Group
F 1	Defines different roles and assign privileges	Evident
F 2	Allows registration and particulars updates of users of the system	Evident
F 3	Records the detailed information of a registered user to the system	Hidden
F 4	Allows registration of subjects in the system, creation and updates of subject chapter, chapter topics and assessment activities	Evident
F 5	Records the detailed information of a subject registered in the system	Hidden
F 6	Allows registration of a user for a subject	Evident
F 7	Records the detailed information of a user registered for a subject to the system	Hidden
F 8	Validates login information (username and password) entered by the user in order to use the system and allows the registered user to login/ out of the system	Hidden
F 9	Displays the home page of the role	Evident

Function Number	Function Description	Group
F 10	Displays available resources for the user role	Evident
F 11	Finds a subject and displays links to a list of all chapters, past papers and the syllabus of a selected subject	Evident
F 12	Tracks student's interaction with the subject	Hidden
F 13	Displays syllabus of the subject	Evident
F 14	Finds a subject chapter and displays links to a list of all topics, extra chapter exercises and the topic exercises for a selected subject chapter	Evident
F 15	Tracks student's interaction with the subject chapter	Hidden
F 16	Finds a chapter topic and displays learning materials (notes, examples) for a selected subject chapter topic	Evident
F 17	Finds and displays information on resources for Assessment activities (Past papers, chapter exercises, topic exercises and self-test exercises)	Evident
F 18	Tracks user login and logout information to/from the system	Hidden
F 19	Updates information on user login and logout	Hidden
F 20	Displays information on user login and logout	Evident
F 21	Tracks student's interaction with learning materials	Hidden
F 22	Updates information on student's interaction with learning materials	Hidden
F 23	Displays information on student's interaction with learning materials	Evident
F 24	Tracks student's interaction with assessment activities	Hidden
F 25	Updates information on student's interaction with assessment activities	Hidden
F 26	Displays information on student's interaction with assessment activities	Evident
F 27	Displays relevant information needed for a guest user, e.g. available subjects, subject objectives, and/or subject table of contents	Evident
F 28	Displays help for system functionality	Evident
F 29	Displays calendar	Evident
F 30	Displays list of system users	Evident
F 31	Displays list of system subjects	Evident
F 32	Handles message transfer between users through internal mail facility and/or discussion forum	Hidden
F 33	Handles system database backups	Hidden
F 34	Handles system database restoration/recovery	Hidden
F 35	Handles system database mirroring	Hidden
F 36	Handles system database replication	Hidden

5.2.4 TanSse-L System Non-Functional Requirements

Table 5.2 shows the non-functional requirements of the TanSse-L system:

Table 5.2: TanSse-L System Non-Functional Requirements	
Attributes	Constraints
Resource Consumption	At least 160GB free of Hard disk space, 32-bits Pentium dual-core Intel 3.0GHz, 2-4GB of RAM. TanSse-L system to be installed in its own dedicated server
Usability	Self-explanatory interface pages with simple instruction to follow on how to use the system even by novice computer users
Respond Time	Fast to respond to queries in the minimum possible time when user clicks to get information from the system
Maintainability	Frequent backups of the TanSse-L database and learning material files. Mirroring and replication of the TanSse-L system in case of database disasters. Provides simple means of adding new functions without major system reconstruction
Security	Restricts unauthorized users' access to the system and the TanSse-L database, backup and restoration facility, regular updates of the customized TanSse-L system and open source MySQL server, TanSse-L system running on its own dedicated server
Fault-tolerance	TanSse-L system should be able to continue operating properly in the event of the failure of the some of the components. High availability is supported by backups and restoration, replication and mirroring.
Adaptability	Finished system must accommodate new updates without needing huge maintenance
Compatibility	TanSse-L must be compatible with Linux and Windows operating systems. The TanSse-L system must run on any web browser
Portability	The TanSse-L system will run on Apache, MySQL and PHP environment in any operating system (Linux and Windows)
Reliability	The TanSse-L system must be 100% reliable

5.2.5 TanSse-L System Users and Their Privileges

The focus of the TanSse-L system is on providing teachers and students with the necessary IT tools for accessing learning material and communicating with each other. However, the TanSse-L system considers more users on the basis of roles than only teachers and students. In each role, use case model is shown to summarize the external interactions between use cases and actors. As summarized in Figure 5.3, every user of the system is able to perform the following basic functions:-

<ul style="list-style-type: none"> • Login to the system • Logout of the system • Change password • View user particulars • Edit personal information 	<ul style="list-style-type: none"> • Call for help on system functionality • Access provided calendar • View self login report • Send e-mail to other users • Participate in forum
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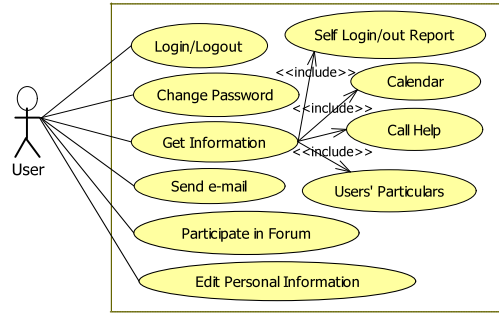


Fig. 5.3 Use Case Diagram for All User Roles

5.2.5.1 Student

“Student” represents the role of a person who uses learning resources to gain knowledge or skills. The TanSSe-L system intends to provide students with learning materials and enables them to communicate with other users by e-mail and forum. Each student may participate in more than one subject registered for and access the subject materials.

Adopting the categorization of students from Nykänen et al. (1997), students are categorized into two groups: privately registered students and school registered students. Figure 5.4 shows the categories of students in the TanSSe-L system.

- *Privately registered students* are students registered in the system privately and not via any secondary school. The registration of private students will be performed by the system administrator after a request, and after providing her/his particulars. Privately registered students will have the right to participate in all the privileges provided for the student role. The learning progress will be recorded for this group of students. To easily identify a privately registered student, private students will be provided with the unique identification, either in a place which shows the school name and/or school registration number.
- *School registered students* are students registered in the system through school enrolment. The registration of school registered students will be performed by the school administrator. School registered students will have all the rights to participate in all the privileges provided for the student role. The learning progress will be recorded for this group of students. To identify a school registered student, student information will include the name and/or registration number of the school which the student is attending.

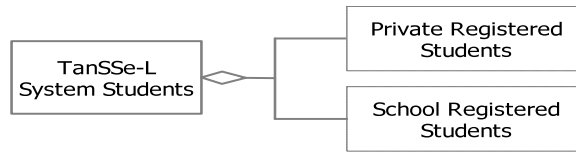


Fig. 5.4: TanSSe-L System Student Categories

As summarized in Figure 5.5, a registered student will perform the following specific functions of the system:

- View and/or download learning materials
- View and/or download assessment activities
- Send answers to self-test and other assessment exercise questions
- View own assessment reports
- View own activity reports
- View participants in a subject registered for

5.2.5.2 Non-Editing Teacher

Non-editing teachers are registered to use the TanSSe-L system by the school administrator. Some competent teachers will provide learning materials as per their area of specialization, and then these learning materials will be uploaded into the learning material repository centrally by the content administrator. In this way, teachers will make use of the system just like students to access learning materials created centrally, though they will have extra privileges like accessing reference answers if available to the given chapter and topic exercises, view provided reports on a subject, and view student performance on a subject. The non-editing teachers will support their school students during the learning process. A non editing teacher will perform the following specific functions in the system, and summarized in Figure 5.5:

- View/download learning materials
- View/download assessment questions
- View/download reference answers for all exercises
- View/download students' login history
- View/download the report on students' interaction with learning materials
- View/download the report on students' interaction with assessment activities
- View participants' particulars in a subject registered for
- View own activity reports

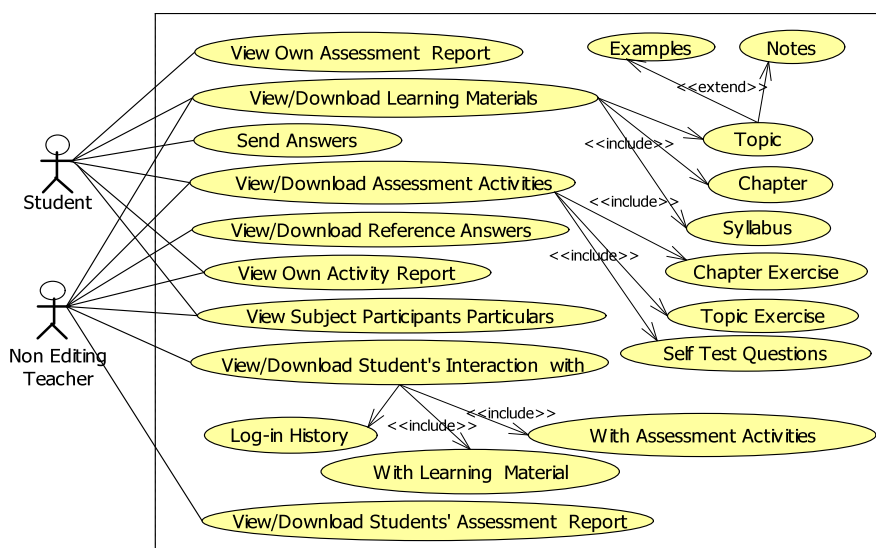


Fig. 5.5: Use Case Diagram for Student and Non-Editing Teacher Roles

5.2.5.3 School Administrator

The school will be registered with the system and identified by the school name and school registration number. A school administrator is responsible for registering the students and teachers of his/her school in the system. Any user registered through a school will be identified by the name and/or the registration number of the school after providing personal login information. The school administrator can also be registered in the system as non-editing teacher to get more privileges using different login information, since a school administrator role has limited privileges. As summarized in Figure 5.6, the school administrator will perform the following specific functions in the system:

- Register students of the school in the system
- Register teachers of the school in the system
- View users' login history of his/her school
- View students' history of interaction with learning materials of his/her school
- View students' history of interaction with assessment activities of his/her school
- View teachers' history of interaction with learning materials of his/her school
- View teachers' history of interaction with assessment activities of his/her school

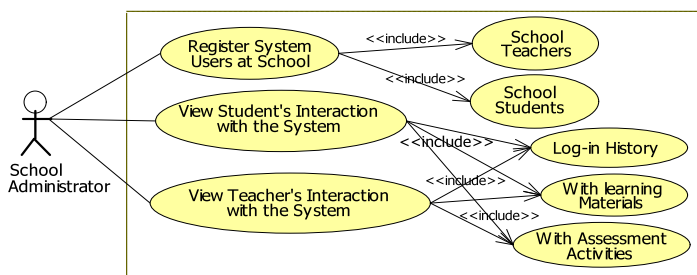


Fig. 5.6: Use Case Diagram for School Administration Role

5.2.5.4 System Administrator

The system administrator is the one in charge of the TanSse-L system, and needs complete access to the TanSse-L database to monitor the use of it. He/she manages system resources like user accounts and assigns privileges. The system administrator adds new system functions and improves the existing ones. The system administrator will perform specific functions in the TanSse-L system as summarized in Figure 5.7:

<ul style="list-style-type: none"> • Register users of the system • View/update users personal information • Delete users of the system • Get list of all users • Get list of all subjects • Enroll users in subject/s • View users' login history • View history of students' interaction with learning materials 	<ul style="list-style-type: none"> • View history of students' interaction with assessment activities • View history of teachers' interaction with learning materials • View history of teachers' interaction with assessment activities • Maintain system functionality • Update system functionality
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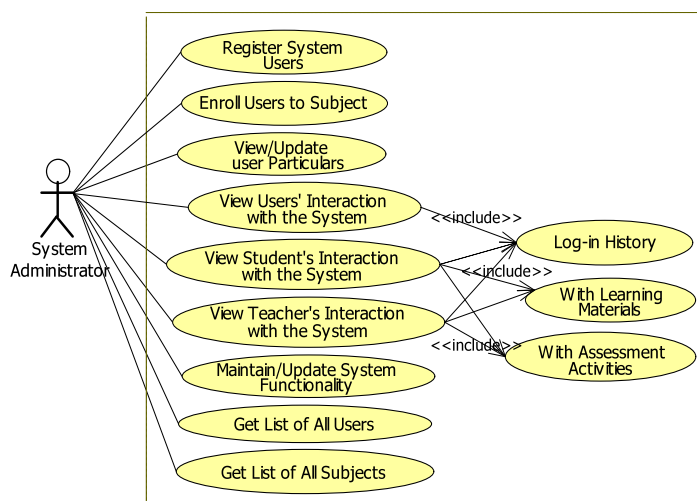


Fig. 5.7: Use Case Diagram for System Administrator Role

5.2.5.5 Content Administrator

Since learning materials are centrally created and uploaded into the system, only few people are needed to perform this creation and uploading. This research defines this role as a “content administrator”. As summarized in Figure 5.8, the content administrator will perform the following specific functions in the system:

<ul style="list-style-type: none">• Register/create subject in the system• Update subject information• Upload subject syllabus• Create/update subject chapter	<ul style="list-style-type: none">• Create/update chapter topic• Create/update chapter exercise• Create/update topic exercise• Create/update self-test questions• Create answers to self-test questions
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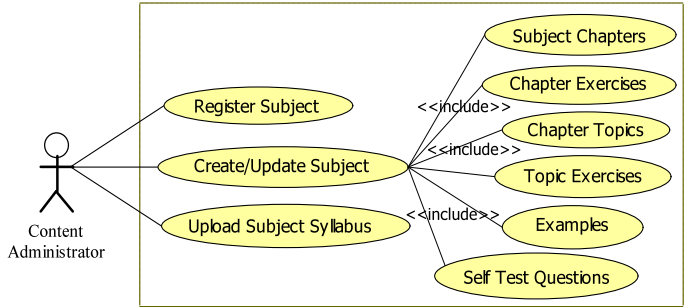


Fig. 5.8: Use Case Diagram for Content Administrator Role

5.2.5.6 Educational Advisor

The Educational Advisor is a user from the MoEVT or its affiliated agencies. This is the role of monitoring the progress of the TanSse-L system and viewing the content available in the system and the learning process. MoEVT has educational offices at regional and district level in Tanzania. The aim of these offices is to assist in providing important services closer to remote secondary schools. These offices are well equipped with resources like telephones, electricity and computers. MoEVT has also provided Internet connectivity in some of the educational centres and plan to provide all of them with an Internet. Educational advisor will come from Ministry headquarters and/or from these educational offices. The educational advisor will perform the following specific functions in the system, as summarized in Figure 5.9:

- View/download learning materials
- View/download assessment questions
- View/download reference answers for exercises
- View system user’s login history
- View history of students’ interaction with learning materials

- View history of students' interaction with assessment activities
- View history of teachers' interaction with learning materials
- View history of teachers' interaction with assessment activities

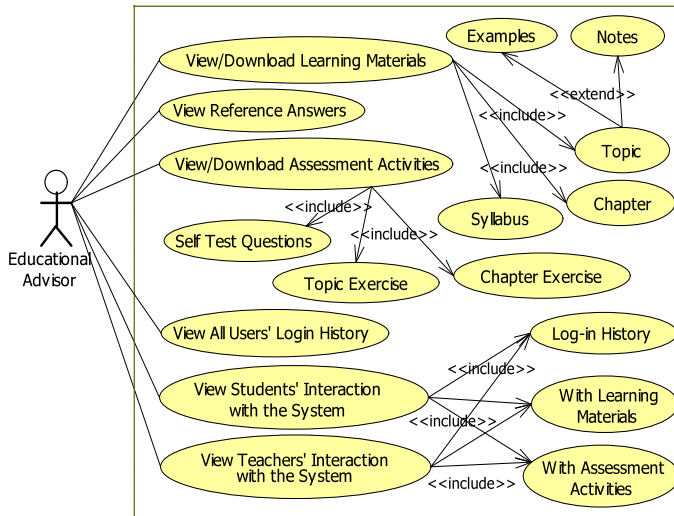


Fig. 5.9: Use Case Diagram for Educational Advisor Role

5.2.5.7 Guest

The guest user represents any user who is not registered in the system. This category is essential for motivation purposes. The guest user will not get the same rights/privileges as registered users. Usage of the system will be limited. He/she will be allowed to view the list of subjects available in the TanSSe-L system, free learning materials and any information provided for public view. Figure 5.10 is the use case diagram for a guest user.

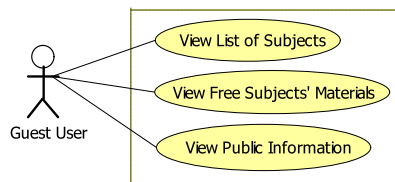


Fig. 5.10: Use Case Diagram for a Guest User

5.2.6 Technology and Standards

The TanSSe-L system is developed based on OSS Web-based technologies and standards.

5.2.6.1 Web-based Technologies

Most of these Web-based technologies and services are free and meet the standards of WWW Consortium (W3C). The technologies used include:

- HTML, XHTML, CSS and JavaScript browser scripting language for interactivity
- PHP server scripting language, Apache Web server and MySQL database engine

5.2.6.2 Sharable Content Object Reference Model (SCORM)

TanSse-L system is a Sharable Content Object Reference Model (SCORM) compliant with any learning materials which are created outside the TanSse-L system. Following the SCORM standard, TanSse-L system also makes use of a repository idea by storing learning materials in a database-based file system. Part of the hard disk is used for this purpose, and what is provided in the TanSse-L system database are links with metadata information for these learning material files whether on the hard disk files or in other repositories.

5.2.7 TanSse-L System Architecture

The TanSse-L system is a client-server, Web-based system with three-tier architecture. The system consists of three major components: the MySQL server, with the TanSse-L system database storing all the information and data needed, including the means to link to the learning content repository and/or file system; the Apache web application server that controls the communication (basic system functionalities); and the client that is used by users to access data from the server (Web interface accessible via standard Web browsers). The three components are networked to facilitate communication among them.

As illustrated in Figure 5.12, the architecture consists of the following:

- The Client Tier:* also known as the user interface layer runs on the end-user's computer. The client provides the user interface for the Web-based application. It is a front-end layer. Using a computer, the user can access the database through the Web server. Access to the database is possible by using created Web pages through any standard Web browser which supports HTML, XHTML, JavaScript, CSS and other Web technologies.
- The application Tier:* also known as the business logic and data processing layer is responsible for interacting with the client on one side and the databases (database server and content repository) on the other. The application tier receives and processes data requests from the client, retrieves information (data) from the database if needed, generates a client response and stores necessary data in the database. The application tier provides Web and data streaming services. The Apache Web server used runs on a LINUX platform. The server-side scripting language used is PHP to connect to the back-end (database).

(c) *The database Tier:* is the place where data are stored. The database server maintains the data needed for the Web application. It is the back-end layer. It stores data (including links to learning content repository) and controls basic system functionality. This tier may run on a separate server called the database server. A MySQL database running on a LINUX platform was used in this case. The database server is responsible for providing a number of functionalities to the application layer (server), such as creating the database, querying and updating it when required. The Database server also maintains data constraints and integrity and the restriction of unauthorized access. Multiple data interfaces, views, reports and the provision of replication, backup and recovery have also been implemented.

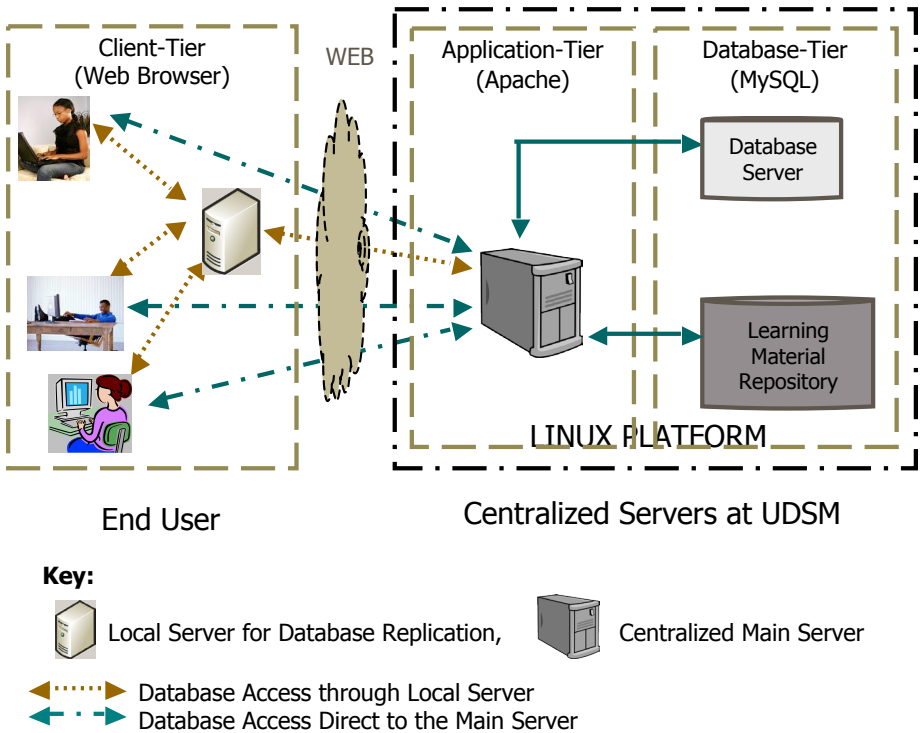


Fig. 5.12: TanSSe-L System Architecture

The application server, database server and learning material repository are centrally placed in the CoET of the UDSM. Distributed users can browse learning materials using any standard Web browsers through the application server. To increase availability and overcome lower bandwidth, the local server was placed at the Kibaha pilot site. The local server gets the replicated database from the main server. Users at Kibaha can access learning materials from the local server as well.

5.3 System Requirement Analysis

System analysis involved the creation of the TanSSe-L system conceptual diagram, identification of TanSSe-L system operations, and the creation of operation contracts. All this information was useful in the TanSSe-L system design phase when its PIM was finally obtained. The following sections are presented below:-

- Identification of TanSSe-L system concepts
- Creation of concept associations
- TanSSe-L system conceptual model
- TanSSe-L system sequence diagram and operations
- TanSSe-L system operations contracts

5.3.1 Identification of TanSSe-L System Concepts

Two activities that are fundamental to the useful application of OOA are:

- The identification of candidate objects from the problem, and
- The selection of those candidate objects that are likely to be significant to a computer-based information system and that are then developed and specified in an object model (conceptual model)

In view of the above, identified objects and classes for the TanSSe-L system are shown in Figure 5.13. Areas involved are the needs for the system identified by stakeholders, TanSSe-L system components, TanSSe-L system functions, use case diagrams and TanSSe-L system architecture. Identified objects and classes include:

- *User* representing a human actor or participant, able to interact with or use the system. “User” class is associated with other objects namely; *Student*, *Teacher*, *SystemAdministrator*, *SchoolAdministrator*, *ContentAdministrator*, *GuestUser* and *EducationalAdvisor*. All these represent *UserRole* object
- *Communication* class is associated with *Email*, *Help*, *Forum* and *Calendar* objects
- *e-LMS* representing the TanSSe-L system object controls users and subjects registration.
- *Subject* class describes the subject offered by the system and aggregates *SubjectSyllabus* object, *PastPapers* object and *Chapter* class.
- *Chapter* class aggregates five objects; *ExtraChapterExercise*, *ChapterExercise*, *SelfTestQuestions*, *SelfTestSolutions* and *ChapterTopic*. *ExtraChapterExercise* is an additional exercise for the whole chapter, and is designed to give more exercise to the student. *SelfTestQuestions* are simple multiple choice questions to provide a student with a quick evaluation of his or her understanding of the whole chapter. *SelfTestSolutions* are provided to students to self-test questions and the system will promptly display performance in the self-test questions.

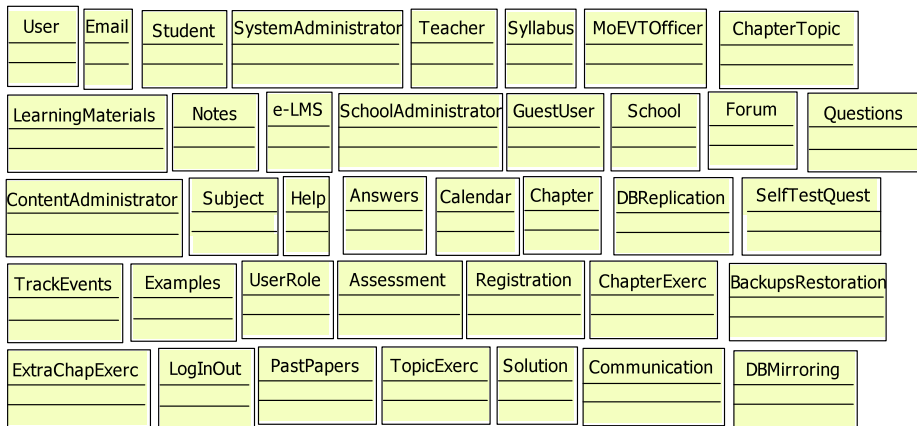


Fig. 5.13: Identified Classes/Objects for TanSse-L system

- ChapterTopic aggregates three entities; *Notes*, *Examples* and *TopicExercise*. TopicExercise describes exercises for that chapter topic. Exercises have *questions* to be created by the content creator together with its answers.
- Other objects are: *Registration*, *LearningMaterials*, *School*, *Assessment*, *DatabaseMirroring*, *DatabaseReplication*, *BackupsRestoration*, *TrackEvents*

Track events is the resource used by the system to track interaction relating to login and logout of users of the system, the interaction of users (mainly students and teachers) accessing subjects (learning materials) and exercises (chapter exercises, topic exercises, extra chapter exercises and self-test questions).

5.3.1.1 Creation of Concept Associations

A class by itself is not very useful. A large software system may have thousands of classes. Modelling the relationships between them really defines system behaviour (RMIT, 2003; RMIT, 2002). From the list of objects and concepts (classes) identified, it can be seen that several objects have a direct relationship. Relations considered in this thesis fall into two main categories.

- *Aggregation Association*

Aggregation is represented as a hollow diamond, pointing to the class which is being used. The general concept of aggregation is often referred to as a “whole-part” or “part-of” relationship. In TanSse-L system there are two aggregation associations as shown in Figures 5.14 and 5.15.

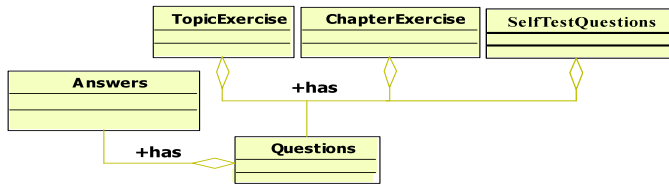


Fig. 5.14: Exercises Aggregation Association

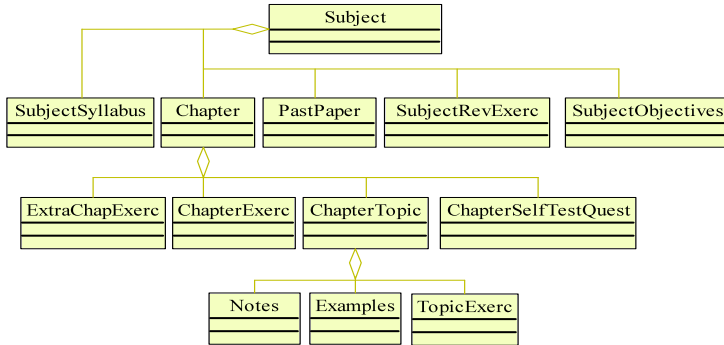


Fig. 5.15: Subject Aggregation Association

- *Generalization Association*

A generalization allows the inheritance of the attributes and operations of a super class by its sub-class. Generalization association is sometimes known as an inheritance (or parent/child) relationship. In this case the TanSse-L system has two generalization associations as shown in Figures 5.16 and 5.17.

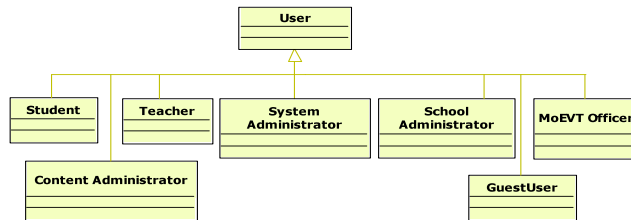


Fig. 5.16: User Generalization Association

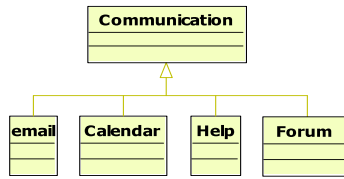


Fig. 5.17: Communication Generalization Association

5.3.2 TanSSe-L System Conceptual Model

Before creating a conceptual model, attributes for individual classes have to be determined. Each object or class may have some useful properties. Figure 5.18 shows the identified classes with attributes.

Figure 5.19 is the conceptual diagram for the TanSSe-L system, which was developed based on Figures 5.14, 5.15, 5.16, 5.17 and 5.18, while considering only useful classes in the context of the TanSSe-L system. Note that the dark shaded objects with thick borders and thick links between them in Figure 5.19 show the structure of the learning materials obtained by Lujara, (2008) and indicated in sub-section 5.2.1. This part is shared with the content development researcher.

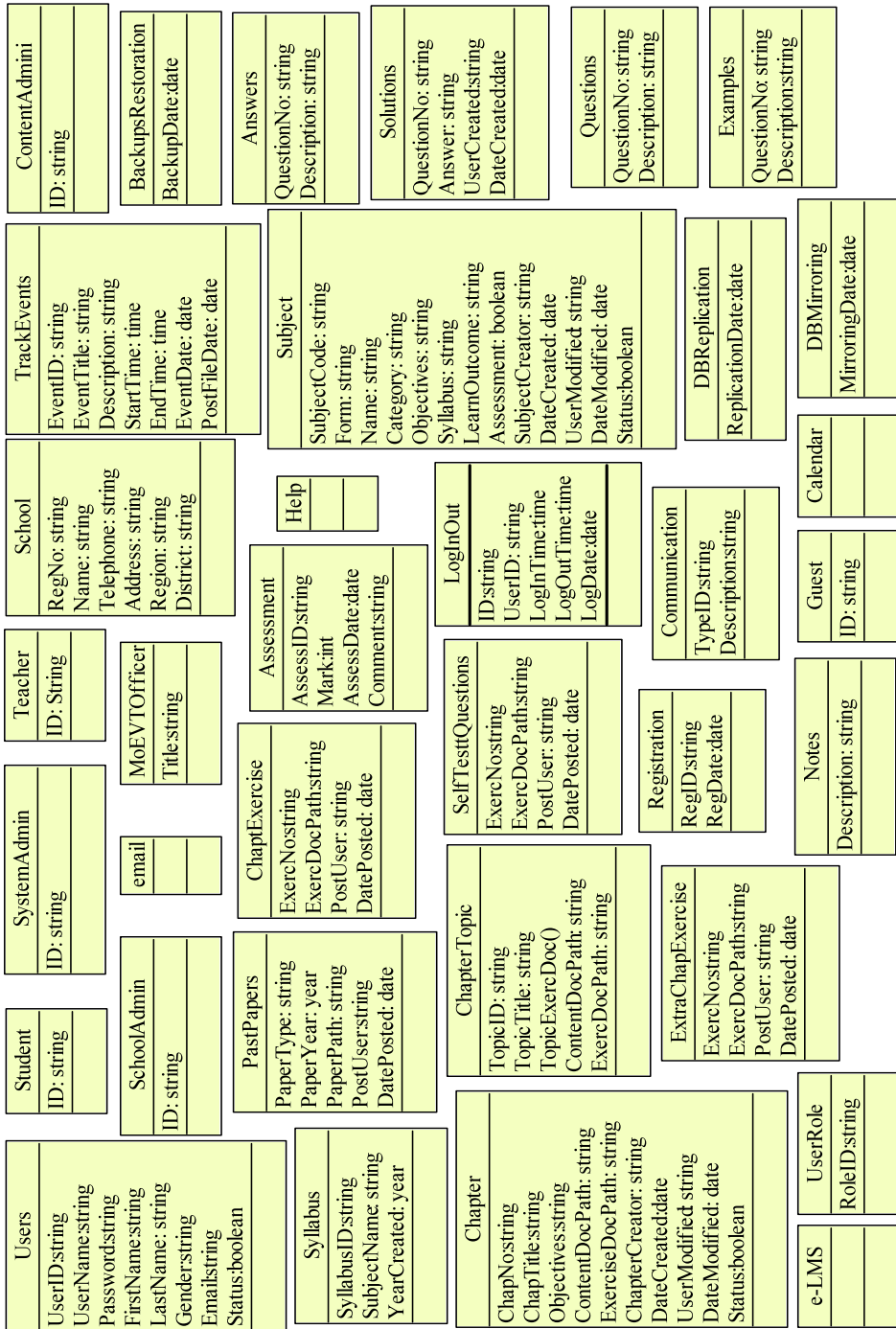


Fig. 5.18: Identified Classes for TanSSe-L System with Attributes

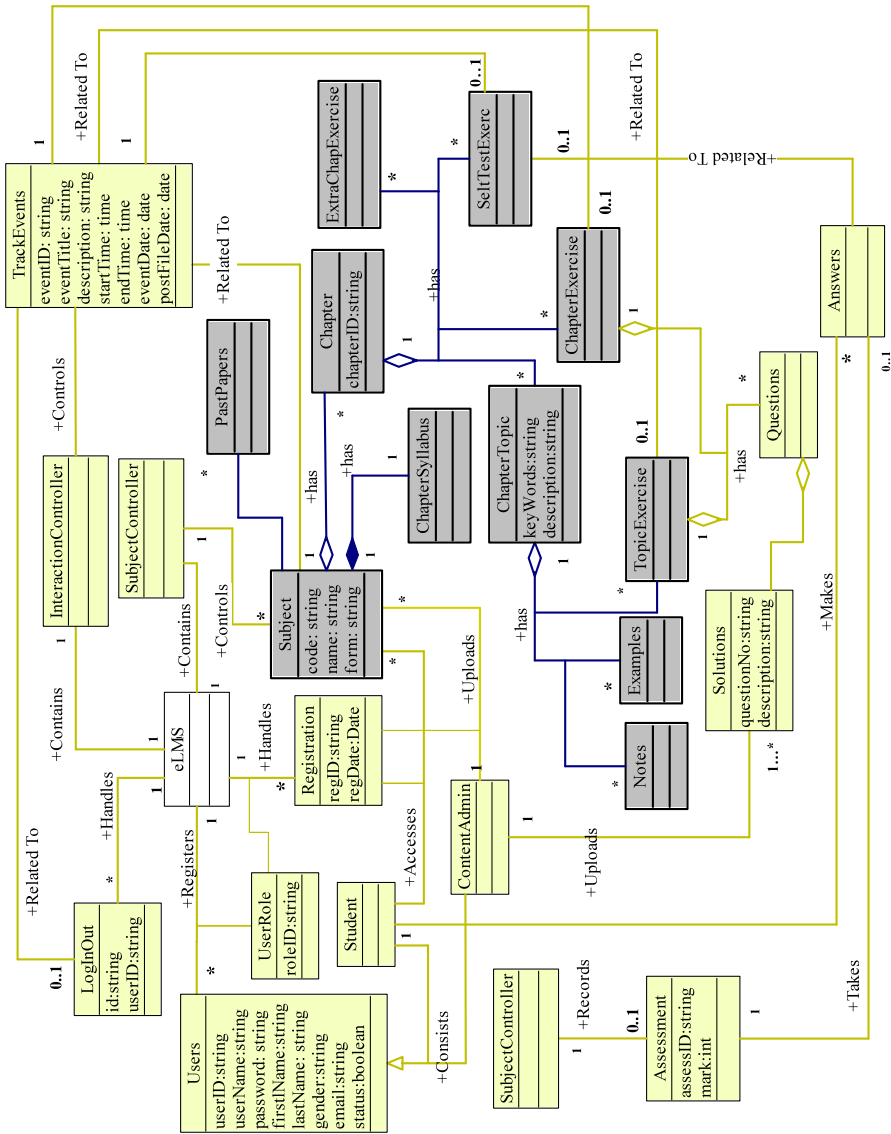


Fig. 5.19: TanSse-L System Conceptual Diagram

The information stored in the TanSse-L database only considers the basic information (metadata) of the area concerned. Links (paths) are provided to access the actual documents. It is recommended by Liu, (2001) to add more control classes to handle system operations. Here three classes are added, namely, e-LMS, SubjectController and InteractionController. Figure 5.19 includes these three added objects.

5.3.3 TanSSe-L System Sequence Diagrams and Operations

In the TanSSe-L system a number of events needed to be achieved. In this thesis report, only two use cases are used in illustrating the modelling of the system sequence diagram, namely, “view learning material” use case and “view Assessment Activity” for a student. After login, a registered student is provided with a student’s home page having a list of links to all subjects registered in. Figure 5.20 shows a system sequence diagram for “view learning material” use case.

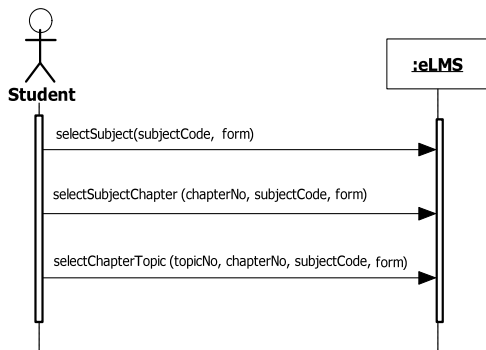


Fig. 5.20: System Sequence Diagram for “view learning material” Use Case

Viewing learning materials is first initiated by a registered student after selecting and clicking a link to a subject of interest. Logically, clicking the selected subject link identifies that subject using “subjectCode and form” parameters. The outcome of this is that the system displays links to all chapters of the selected subject with optional links to a whole chapter notes and to a list of topics in each chapter. Again a student selects a subject chapter logically identified by “chapterNo, subjectCode and form” and can opt for notes link which will make the system display chapter notes.

Figure 5.21 shows the system sequence diagram for “view assessment activity” use case, which is started by a registered student when selecting a subject of interest from the home page. Selection of a subject by a student will display a list of all the chapters and a list of all the past papers on that subject. Viewing past papers as one of the assessment activities is activated by a student when clicking the link to the past paper selected. Other assessment activities links relating to a chapter are displayed by the system after selecting and clicking the chapter of interest on that subject.

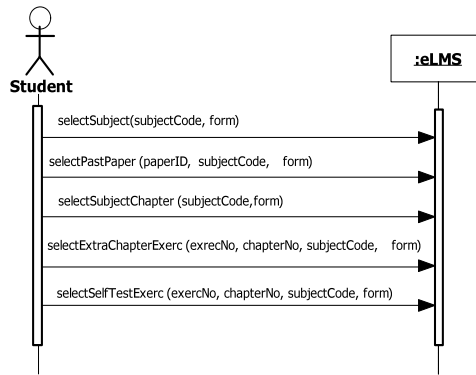


Fig. 5.21: Sequence Diagram for “view assessment activity” Use Case

Table 5.3 shows all identified TanSse-L system operations as per-use cases provided in the system requirement specifications section.

Table 5.3: TanSse-L System Operations		
Use Case	Actor	System Operations
Login/out	All	login(), logout()
Change Password	All	updatePassword()
Get information	All	getCalendar(), callHelp(), getLoginHistory()
Send e-mail	All	createMessage(), sendMessage()
Participate in Forum	All	createForum(), sendForum(), viewForum()
View personal performance report	Student	getPerformanceReport()
View/download learning materials	Student, Teacher, EducationalAdvisor	selectSubject(), selectSubjectChapter(), selectTopic(), getNotes(), getExamples(), selectSyllabus()
View/download assessment activities	Student, Teacher, EducationalAdvisor	selectSubject(), selectPastPapers(), selectSubjectChapter(), selectExtraChapterExerc (), selectTopicExerc(), selectSelfTestQues()
Send answers	Students	selectExercise(), makeAnswers(), sendAnswers()
View reference answers	Teacher, EducationalAdvisor	selectExercise(), getAnswers()
View student's interaction with the system	Teacher, School Administrator, System Administrator, EducationalAdvisor	getInteractionRecord()

Use Case	Actor	System Operations
View teacher's interaction with the system	School Administrator, System Administrator, EducationalAdvisor	getInteractionRecord()
Register users	School Administrator, System Administrator	registerUser()
Update User Particulars	School Administrator, System Administrator	updateUser()
Maintain/update system functionality	System Administrator	createFunction(), updateFunction()
Get list of users	School Administrator, System Administrator, EducationalAdvisor	getUserList()
Get list of subjects	All	getSubjectList()
Register subject	Content Administrator	registerSubject()
Register users to subject	Content Administrator	registerSubjectUser()
Create/update subject	Content Administrator	createSubjectChapter(), createChapterTopic(), updateSubject(), updateSubjectChapter(), updateChapterTopic()
Upload Subject Syllabus	Content Administrator	uploadSyllabus()
View subject's objective	Guest	getSubjectObjective()
View subject's syllabus	Guest	GetSubjectSyllabus()

5.3.4 TanSse-L System Operation Contracts

Applying the process as highlighted by Liu (2001) and the Basic UML guide (2001), contracts for the TanSse-L system operations identified in Table 5.3 are described. Only a few operation contracts are shown in this chapter, namely: “*login()*”, “*createSubject()*”, “*selectSubject()*” and “*getInteractionRecord()*” in Tables 5.4, 5.5, 5.6 and 5.7 respectively. Some more of the TanSse-L system operation contracts are shown in appendix A.

Table 5.4: Contract for “ <i>login()</i> ” operation	
Name:	<i>login(username, password)</i>
Responsibilities:	Validate user with the <i>username</i> and <i>password</i> from the user table in the database. If the user is valid, record the login information and display the home page of the user's role.
Type:	System
Cross References:	System function: F8, F9, F10, F18, F19 Use case: login/logout

Note:	Use relational SQL database access
Exceptions:	If the entered login information is incorrect display the error message
Output:	Display user's role home page
Pre-conditions:	User login information is known to the system
Post-conditions:	<ul style="list-style-type: none"> • A <i>LogInOutRec</i> was created (instance creation) • The new <i>LogInOutRec</i> was associated with the <i>InteractionController</i> object (association formed) • The <i>LogInOutRec.loginTimeStamp</i> was set to current date and time (attribute set) • The <i>User.status</i> was set to active (attribute set)

Table 5.5: Contract for “createSubject()” operation

Name:	<i>createSubject(subjectCategory,subjectCode, form, name)</i>
Responsibilities:	If the given information is valid create a new subject and record the information into database.
Type:	System
Cross References	System function: F4, F5 Use case: Register subject
Note:	Use relational SQL database access
Exceptions:	If the entered subject information is incorrect and/or incomplete, stop recording and display the error message
Output:	Display registered subject's home page
Pre-conditions:	The permitted user to register subject identification information is known to the system
Post-conditions:	<ul style="list-style-type: none"> • A new Subject was created (instance creation) • The new Subject was associated with the <i>SubjectController</i> object (association formed) • The <i>Subject.dateCreated</i> was set to current date (attribute set) • The <i>Subject.status</i> was set to Active (attribute set)

Table 5.6: Contract for “selectSubject()” operation

Name:	<i>selectSubject(subjectCategory,subjectCode, form, name)</i>
Responsibilities:	Identify subject with the subjectCode and formID from the <i>subject</i> object If the subject is found, record the subject interaction and display links to the subject components: subject chapters, subject past papers and subject syllabus.
Type:	System
Cross References	System function: F11, F12 Use case: View/download learning materials, View/download assessment activities
Note:	Use relational SQL database access

Exceptions:	If the entered subject information is incorrect display the error message
Output:	Display links to subject chapters, subject past papers and subject syllabus
Pre-conditions:	Subject information is known to the system
Post-conditions:	<ul style="list-style-type: none"> • A <i>subjectTrackRec</i> was created (instance creation) • The new <i>subjectTrackRec</i> was associated with the subject object (association formed) • The <i>subjectTrackRec.visitTimeStamp</i> for keeping interaction record was set to current date and time (attribute set)

Table 5.7: Contract for “ <i>getInteractionRecord()</i> ” operation	
Name:	<i>getInteractionRecord(userID, eventID, eventName, DBName eventDate, eventTime)</i>
Responsibilities:	If the interaction with the given information is identified display the interaction record
Type:	System
Cross References:	System function: F20, F23, F26 Use case: View student’s interaction with the system, View teacher’s interaction with the system <<include>> Login history, Interaction with learning materials, Interaction with assessment activities
Note:	Use relational SQL database access
Exceptions:	If the entered information is incorrect or not found display the error message
Output:	Display interaction report
Pre-conditions:	Interaction events was recorded to the system
Post-conditions:	<ul style="list-style-type: none"> • The <i>Interaction.present</i> was set to True (attribute modification)

CHAPTER SIX: TanSSe-L SYSTEM DESIGN

6.1 Introduction

TanSSe-L system design describes the PIM of the TanSSe-L system. Behavioural or interactive diagrams were created and used in identifying operations of classes. The DCD created save the structure of the TanSSe-L database, independent of how the database is implemented. DCD is the TanSSe-L system PIM as related to MDA.

6.2 TanSSe-L System Collaboration Diagrams

Liu (2001) states that both collaboration diagrams and object sequence diagrams can express similar constructs. Different people prefer one to the other. In this research, only collaborations interaction diagrams are modelled. The selection of collaboration diagrams is mainly due to their flexibility to add new objects in two dimensions, which use less space. In contrast, new objects in sequence diagrams must always be added on the right-hand side, which is limiting as it quickly uses the space on a page.

When creating collaboration diagrams, patterns are used to justify relationships (Basic UML Guide, 2001; Liu, 2001). Here, GRASP is used. GRASP patterns considered include: Expert, Creator, Low Coupling, High Cohesion, and Controller. The controller classes responsible for handling a system input event added to this TanSSe-L system are:

- *e-LMS* to take care of registration issues, that is registering users and subjects in the system
- *SubjectController* to take care of all issues concerning subject resources like creating subject , chapter, exercises, etc
- *InteractionController* to take care of all tracking events within the system

Below are the collaboration diagrams for the selected operations of the TanSse-L system. Only a few collaboration diagrams are shown in this chapter as examples, and they correspond to the system operations used to create system operation contracts in Chapter 5: TanSse-L System Requirement Specifications and Analysis. A few more collaboration diagrams are included in appendix “B”. A full list of operations which were obtained using collaboration diagrams are presented in Table 6.1.

(a) *Collaboration Diagram for “login()” System Operation*

Login operation contracts created in system analysis have the following post-conditions:

- A *LogInOutRec* was created (instance creation)
- The new *LogInOutRec* was associated with the *InteractionController* (association formed)
- The *LogInOutRec.loginTimeStamp* was set to current date and time (attribute set)
- The *User.status* was set to Active (attribute modification)

The e-LMS object is the controller for handling the “login()” operation. The login is initiated by providing username and password information to the e-LMS object. The e-LMS is responsible for linking user information to the User object for validation. If the user is registered with the system (that is the entered information is valid), e-LMS will send an *addRec(user)* to the *InteractionController* object purposely added for controlling interaction tracking. The *InteractionController* object is associated with the e-LMS object. The *InteractionController* object has the responsibility for adding the login record to the *LogInOutRec* object. Setting *loginTime()* and *loginDate()* (i.e. *loginTimeStamp()*) in the *LogInOutRec* object will be the responsibility of the *LogInOutRec* object because it involves modifying internal attributes. The *userStatus()* will be set to active and updating information of the user involves a change in the attribute, which is the responsibility of the User object itself.. This is also from expert pattern. Figure 6.1 shows the collaboration diagram for “login()” operation.

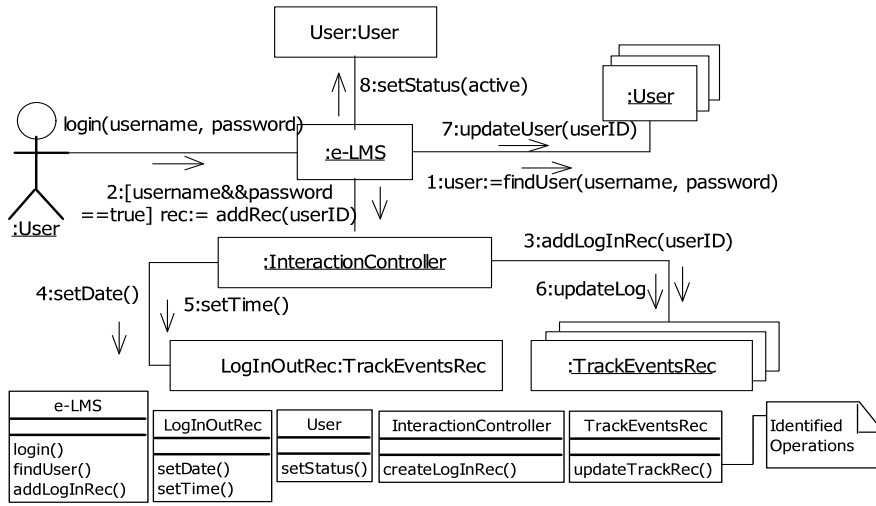


Fig. 6.1: Collaboration Diagram for *login()* Operation

(b) Collaboration Diagram for “registerSubject()” System Operation

e-LMS is responsible for registering subjects hence it is associated with the *Registration* object to add a registered subject. The *SubjectController* object is the controller of subjects. The *SubjectController* is responsible for adding a subject to this *Subject* object. The subject registered is set to active internally by *Subject* object. The date created has to be set as an internal attribute of the *Registration* object as its responsibility. Figure 6.2 shows the collaboration diagram for “registerSubject” system operation

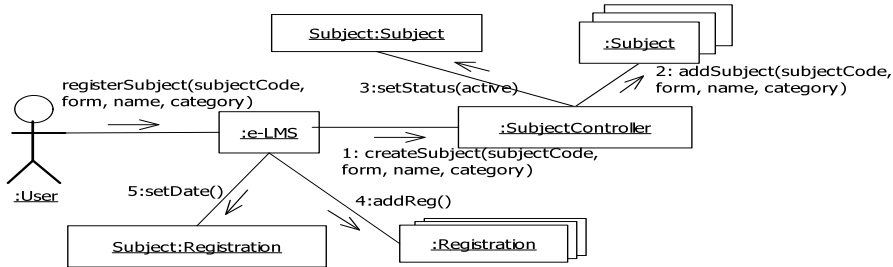


Fig. 6.2: Collaboration Diagram for *registerSubject()* Operation

(c) Collaboration Diagram for “selectSubject” System Operation

The *SubjectController* object is the controller of the subject hence it is responsible for getting the subject selected. The *SubjectController* is associated with the *Subject* object. The responsibility of this system operation is to display links to subject chapters, to subject past papers and to subject syllabus of the selected subject. The *Subject* object is responsible for finding a subject from a list of subjects, finding chapters for the subject selected, finding subject past papers and subject syllabus. The *Subject* object needs

to be associated with *Chapter* and *PastPaper* objects. A link to the subject syllabus internal to the subject object, hence the link will be displayed by the Subject object itself. Interaction with the subject has to be recorded; the *InteractionController* object is responsible for creating the subject interaction record into *TrackEventsRec* object. The *InteractionController* object is associated with the *SubjectController* object. The *SubjectTrackRec* will be responsible for setting the date and time as an internal attribute change. Figure 6.3 shows the collaboration diagram for “selectSubject()” system operation.

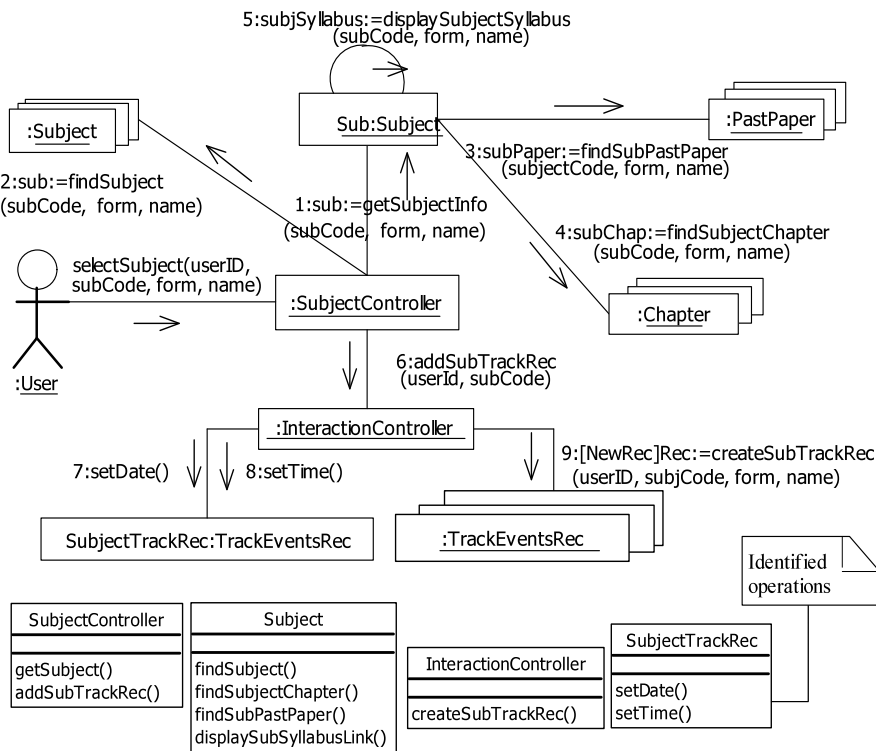


Fig. 6.3: Collaboration Diagram for *selectSubject()* Operation

(d) Collaboration Diagram for “getLogInInteractionRecord()” System Operation

The *InteractionController* object is the controller of this operation and hence is responsible for getting the user’s login interaction record with the system from *TrackEventsRec*. The responsibility of this system operation is to find the interaction and display the interaction record of that event of a particular user or a role. *TrackEventsRec* is responsible for finding *LogInInteractionRecord* from the various records in *TrackEventsRec*. The *TrackEventsRec* object is associated with the *InteractionController* object. Figure 6.4 shows the collaboration diagram for “getLogInInteractionRecord()” system operation. Note that this operation can be done for all tracking events.

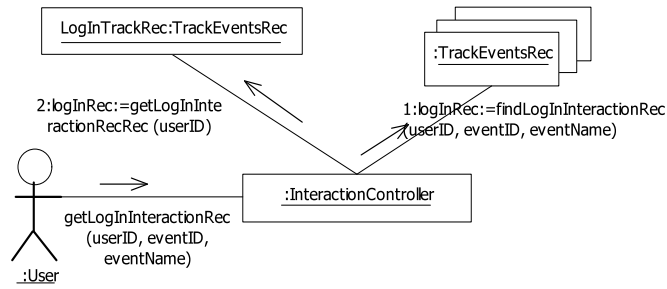


Fig. 6.4: Collaboration Diagram for `getLogInInteractionRecord()` Operation

Table 6.1 gives a summary of object operations and their attributes using collaborations diagrams of the TanSse-L system.

Table 6.1: Summary of Objects' Attributes and Operations

Object	Attributes	Operations
e-LMS		login(),logOut(), registerUser(), registerSubject(), createSubjectUser(), find-User(),
SubjectController		findSubject(), selectSubject(), addSubject(), deleteSubject(),
InteractionController		createTrackRec() findLogInTrackRec() findSubjTrackRec() findPastPaperTrackRec() findChapterTrackRec() findChapTopicTrackRec() findExtraChapExercTrackRec() findSelfTestTrackRec()
TrackEventsRec	eventID: string userID: string eventDate: date eventTime: time tableName: string refKey: string	updateEventRec() setEventDate() setEventTime()

Object	Attributes	Operations
Subject	subjectCode: string form: string name: string category: string objectives: string syllabusDocPath: string learningOutcome: string assessPresence: boolean createdUser: string createDate: date modifyUser: string modifyDate: date status: Boolean	createSubjChapter() findSubjChapter() createPastPaper() findPastPaper() findSubjSyllabusDoc() updateSubjectInfo() setDate() setStatus()
PastPaper	paperType: string paperYear: year paperDocPath: string postUser: string datePosted: date	updatePaperInfo() setDate() findPaperDoc()
Chapter	chapNo: string chapTitle: string objectives: string contentDocPath: string exercDocPath: string createdUser: string createDate: date modifyUser: string modifyDate: date status: boolean	createChapTopic() findChapterTopic() createChapterExtraExerc() findChapterExtraExerc() createChapterExercSoln() findChapterExercSoln() updateChapterInfo() findChapterContentDoc() findChapExercDoc() setDate(), setStatus()
ChapterExercSoln	questionNo: string answer: string createdUser: string createDate: date	updateSoln() setDate()
SelfTestExerc	exercNo: string exercDocPath: string postUser: string datePosted: date	updateInfo() findSelfTestExercDoc() findAnswerSheet() setDate()
ExtraChapExerc	ExercNo: string ExercDocPath: string PostUser: string DatePosted: date	updateInfo() findExtraChapExercDoc() setDate()
ChapterTopic	topicID: string topicTitle: string contentDocPath: string exercDocPath: string	findTopicDoc() updateTopicInfo() findTopicExercDoc() createTopicExercSoln() findTopicExercSoln()

Object	Attributes	Operations
TopicExercSoln	questionNo: string answer: string userCreated:string createdDate:date	updateQuestions() setDate()
User	userID: string userName: string password: string firstName: string lastName: string gender: string email: string formLevel: string specialization: string combination: string status: boolean	updateUserInfo() setStatus() setDate()
School	regNo: string name: string telephone: string address: string region: string district: string	updateSchoolInfo()
RoleRef	roleName: string	updateInfo()
UserSubject	userID: string subjectCode: string formID: string recordCreator: string regDate: date status: boolean	updateInfo() setRegDate()
EventRef	eventID: string eventDescription: string objectName: string	updateTrackRef()

6.3 TanSSe-L System Design Class Diagram

Figure 6.5 illustrates the DCD for the TanSSe-L system obtained from identified objects in the conceptual and collaboration diagrams. The TanSSe-L system involves one database for storing system functionalities, and a repository for storing learning materials (content repository). In DCD, a “*Repository*” object is added to represent the learning material repository. Links are provided to related objects and link names are called and displayed on users’ interface page. Documents inside the repository are accessed by clicking displayed navigation links. The repository can be a file system and/or any other content repository for content storage like Alfresco.

There are eight major links to the repository object:-

- Path to access a subject syllabus document from the Repository object. The link originates from the Subject object
- Path to access past paper documents from the repository object. The link originates from the PastPaper object
- Path to access full chapter document from the Repository object. The link originates from Chapter object
- Path to access the chapter exercise document of the chapter document from the Repository object. The link originates from the Chapter object and is based on internal navigation within the full chapter document
- Path to access the extra chapter exercise document from the repository object. The extra chapter exercise is provided as a separate document inside the Repository object. The path originates from the ExtraChapExerc object
- Path to access self-test questions document for a chapter which is provided as a separate document inside the Repository object. This path originates from the SelfTestQuestions object
- Path to access the chapter topic document of the chapter document from the Repository object. The link originates from the ChapterTopic object and is based on internal navigation within the full chapter document
- Path to access the topic exercise document of the chapter document from the Repository object. The link originates from the ChapterTopic object and is based on internal navigation within the full chapter document

Note that the dark shaded objects within DCD is the part shared by content development for self-learning research.

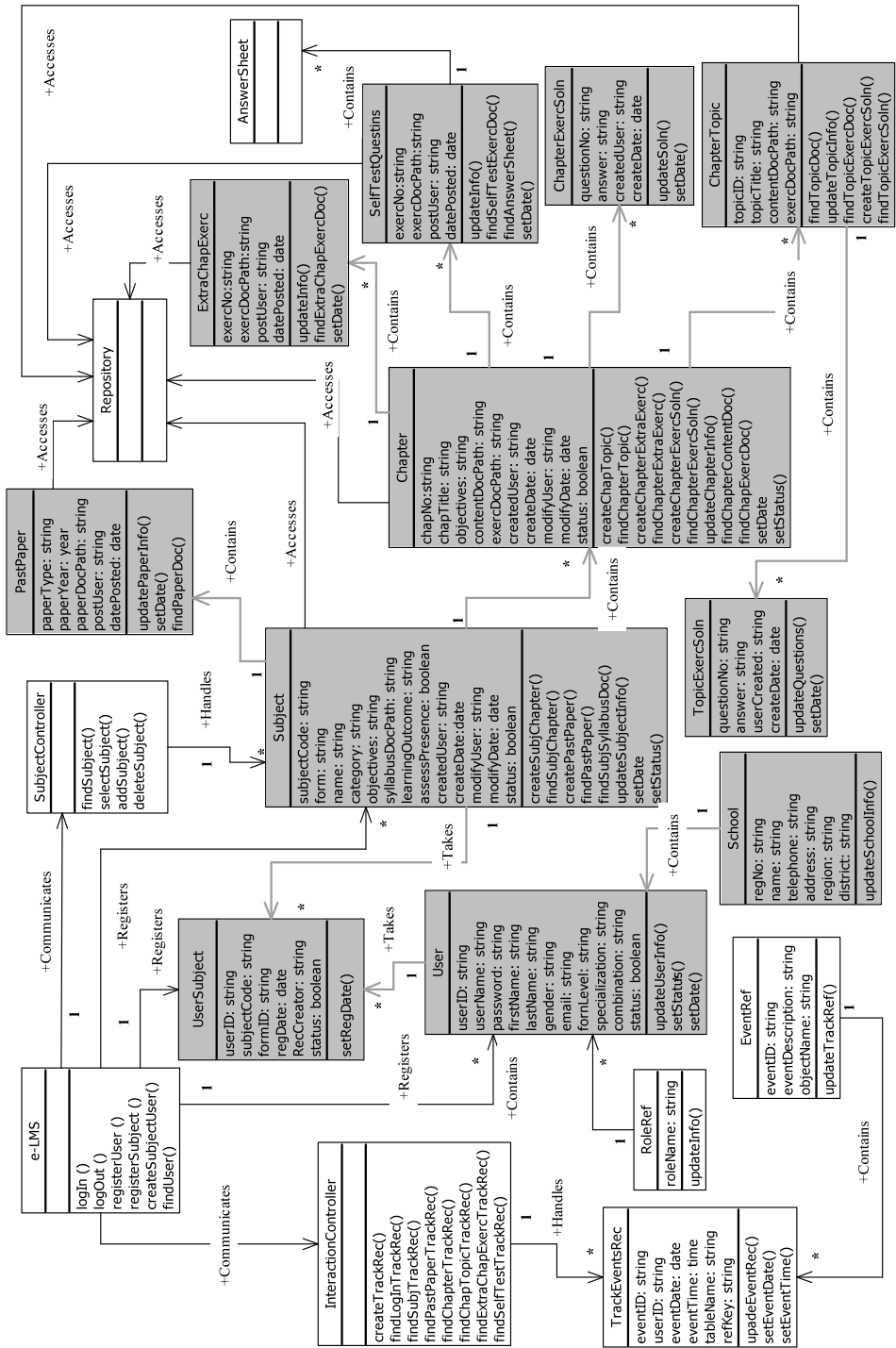


Fig. 6.5: TanSse-L System Design Class Diagram

6.4 Discussion

The DCD of this phase can be implemented using an OO programming language like Java, C++ etc, as per the OO approach, or using PHP when a database is created in a MySQL server. DCD gives all the necessary information to generate the code. It is the database structure for the TanSSe-L system. Following the MDA approach, the TanSSe-L system PIM was put.

This research was implemented by customizing the selected open source LMS. Instead of generating codes using DCD for implementation, the approach was to analyze the open source LMS with reference to the TanSSe-L system DCD as a base. This led to having a TanSSe-L system-specific PIM, alongside looking at the technology used in implementing an open source LMS. Therefore, the needed transformation of the TanSSe-L system PIM to a TanSSe-L system-specific PIM and eventually to the TanSSe-L system PSM took place, and is presented in the next chapter.

CHAPTER SEVEN: TanSSe-L SYSTEM PIM TRANSFORMATION TO PSM

7.1 Introduction

Data modelling as defined by Marchal (2004) is the description of a system. The model is not the system itself but a formalized representation of the system. It serves a very specific purpose to help designers to understand and reason about a system. A model is only a tool for achieving a specific goal more efficiently. The goal is never to build a model, but to address the system.

We have seen the modelling of the TanSSe-L database using UML from different view-points for different TanSSe-L system SDLC phases. The research now shifts from modelling view-points to real implementation of the TanSSe-L system. This chapter corresponds to the manual transformation part from PIM to PSM as shown in Figure 2.2 of Chapter 2, where open source LMS information had to be considered. Manual transformation involved the selection of an open source LMS and model merging of the TanSSe-L system (DCD) and the selected open source LMS database structure, in order to prepare the TanSSe-L system PSM for implementation, described in Chapter 8. To implement the same, two things are discussed in this chapter as follows:

- Evaluation and selection of an open source LMS for customization
- Comparison of major functionalities of open source LMS and the TanSSe-L system PIM (TanSSe-L system DCD), and highlighting major areas to be involved in model merging.

Finally, this chapter concludes with the TanSSe-L system-specific PIM which was customized and provides the TanSSe-L system PSM.

7.2 Evaluation of Moodle Open Source LMS for Customization

A number of open source LMS are used in different organizations and it is difficult to identify which one will exactly suit your needs. A few of these LMS are: Moodle, ATutor, Claroline, Kewl, ILIAS etc. According to many findings, most Open Source LMS seem to have the following:

- Similar functionalities: many have collaborative mechanisms like discussion forums, chat tools and mailing lists
- Based on similar technologies like PHP, using MySQL as the database server and Apache as the web server

Like many other reviewers, Wyles (2004) evaluates and concludes that Moodle is one of the most user-friendly and flexible open source courseware products available. Moodle has excellent documentation, strong support for security and administration, and is moving towards IMS/SCORM standards. The key strength of Moodle is that it has been developed with both pedagogy and technology in mind. It has a robust development and user community. It is great for languages although some development may be needed for robust handling of MathML and enhanced tracking features. Still, this program is highly recommended. Moodle is a student-centered course management system designed to help educators who want to create quality online courses. The software is used all over the world by universities, schools, companies and independent teachers.

As explained in previous chapters, MDA aimed to separate application or domain logic (in PIM) from the underlying implementation technology (in PSM and implementation). Having the TanSSe-L system PIM in place gave freedom to select which technology was to be used in creating PSM. To generate a timely solution to TanSSe-L system development, customization of open source LMS was selected as the best option. From TanSSe-L system specification and analysis, it was found that the majority of the open source LMS available world-wide would support the basic functions required by the TanSSe-L system. The issue was which one to use. The important thing to be reviewed from TanSSe-L system requirement specifications in Chapter 5 is that the TanSSe-L system architecture makes use of the Apache Web server as an application tier and the MySQL database server running on the Linux operating system as the database tier.

The TanSSe-L system took advantage of using open source LMS which would also use Apache and MySQL running on Linux.

There are different approaches to putting into a model the information necessary for transforming a PIM into a PSM. OMG, (2003a) explains four different transformation approaches: manual transformation, transforming a PIM that is prepared using a profile, transformation using patterns and markings, and automatic transformation. Transformation of the TanSSe-L system PIM to the TanSSe-L system PSM was done manually and the model transformation approach adopted was 'model merging'. In order to make the transformation from PIM to PSM using the manual transformation approach, design decisions had to be made. These design decisions can be made during the process of developing a design that conforms to engineering requirements for implementation. This is a useful approach, because these decisions are considered and taken in the context of a specific implementation design.

The MDA manual transformation approach adds value in two ways:

- It gives the explicit distinction between a PIM and the transformed PSM
- It provides a record of the transformation.

There are a number of inputs to the transformation, and technical choice is one of them. Technical choices of all kinds can be made at the requirement specifications phase. In view of the TanSSe-L system, the TanSSe-L system PIM was transformed for the LAMP (Linux, Apache, MySQL and PHP) environment. The result of the transformation was a model of that system specific to the LAMP platform (a PSM) and a record of the transformation showing the correspondence between the two models.

Based on what the TanSSe-L system needs in the PSM and what competences have been provided by a number of evaluators like Wyles (2004), Moodle was selected by the research group to be customized for TanSSe-L system use. However, the researcher took the initiative to provide some more competences that Moodle has from the Moodle Website: <http://moodle.org/stats/> viewed in late 2009 and early 2010, which are presented below:

- *Popularity*

<http://moodle.org/stats/> web page accessed in 07th January 2010 showed that:

- *Moodle Sites*: Moodle known registered validated sites totaled 46,553 in 209 countries. Inclusively, there were a total of 3,143,442 courses, 32,361,841 users, 1,246,223 teachers, 19,818,420 enrolments, 48,729,481 forum posts, 25,821,399 resources and 40,697,326 quiz questions.
- *Moodle number of users per site*: There were 432 sites with more than 10,000 users. The site with the most users was moodle.org with 63 courses and 839,918 users. The site with the most courses was Minha UFMG with 45,921 courses and 54,379 users.
- *Community growth (Total Moodle.org users)*: There was a total of 839,918 registered users.

- *Moodle Downloads per month:* In July 2004 there were 17,060 Moodle downloads and in February 2009 there was a total of 88,557 Moodle downloads. This is an increase of 419%.

- *Support*

Moodle provides a support through authorized Moodle partners who are serious about providing quality services to users of Moodle software, ranging from basic support to the development and implementation of complete ICT solutions. Support is also on both the technical and pedagogical sides of e-learning to help in planning and implementing an educational strategy for institutions or businesses that include Moodle as part of a complete solution. Partners also provide training if needed. All Moodle Partners contribute directly to the ongoing development of Moodle software via funding or expertise. Moodle Partners are a group of competent professionals.

- *Installation*

Moodle is easier to install than most other web applications.

- *Integration with other systems*

It is possible to integrate Moodle with other systems, which makes Moodle more powerful. Moodle can be integrated with user management systems, school administration systems, Lightweight Directory Access Protocol (⁹LDAP) server, other external databases and many others.

- *Pedagogy*

Moodle was developed with pedagogical considerations in mind. It is a student-centred content management system. Following the social constructionist it offers, people can learn better when they engage in a social process to construct knowledge in groups. The focus is on sharing ideas.

- *Platform*

Moodle can be installed in the Apache, PHP and MySQL/PostgreSQL environment.

- *Moodle documentation*

A number of relevant documents are provided to help Moodle users in customizing and using Moodle. Documentation comes through articles and discussion forums. Searching moodle.org in 2009 showed that there were 1,626 articles concerning Moodle on different topics.

⁹ LDAP is an Internet standard protocol used by applications to access information in a directory. It runs directly over TCP, and can be used to access a standalone LDAP directory service or to access a directory service that is back-ended by X.500.

Comparing Moodle to some other open source LMS like Claroline, which is equally popular, by just using few items, it can be seen clearly why Moodle has been accepted more by many organization as shown in Table 7.1.

Table 7.1: Moodle Open Source LMS Versus Claroline Open Source LMS		
Item	Moodle	Claroline
Number of countries	There was a total of 209 countries using Moodle open source LMS	There was a total of 101 countries using claroline open source LMS
Moodle number of users per site	There were 432 sites with more than 10,000 users. The site with the most users was moodle.org with 53 courses and 644,046 users.	Claroline has a large worldwide users' and developers' community (exact number was not explicitly shown)
Community growth	There was a total of 839,918 registered users (moodle.org users)	Not explicitly indicated
Moodle down-loads per month	In July 2004 there were 17,060 Moodle downloads and in February 2009 there was a total of 88,557 Moodle downloads. This is an increase of 419%.	There was more than 150 down-loads per day
Platform Server	A web server - recommend <i>Apache PHP</i> and the <i>MySQL</i> databases server Linux operating system (can also run on Windows and Mac operating systems) It can also be used in PostgreSQL database IMS/SCORM standard compliance	A web server (recommend <i>Apache</i> , but others should work too) PHP and MySQL and uses the current standards like SCORM for the exchange of content Compatible with Linux, Mac and Windows environments A Mail Transport Agent (optional)
Language Packs	Translated into 78 language packages	Translated into 35 language packages
Source: http://moodle.org/ and http://www.claroline.net/ accessed on January, 2010		

7.3 Moodle as TanSSe-L System Specific PIM

TanSSe-L system PIM development targeted the presence of open source LMS. This means that the selected open source LMS is a virtual platform for the TanSSe-L system as explained in Chapter 2.

When comparing the TanSSe-L system DCD and Moodle database structure, they can be viewed as two completely different things. This comparison can be somewhat confusing due to the huge difference, in the number of tables Moodle has of approximately 198 (Moodle version 1.9.4 by April 2009) and of only 20 (approximately) tables that the TanSSe-L system DCD has. This research focused on the functionalities and qualities Moodle offers in comparison with the TanSSe-L system functions that are

offered. MDA guide in OMG, (2003a) clearly expresses that a whole range of service requirements can be used to guide transformations.

With reference to the TanSse-L DCD, three major functional areas are needed to be thoroughly compared to the way Moodle handles these functions. These functional areas which were included in “Chapter 2: Research Methodologies” are:

- Management of users and their information
- Management of learning materials, that is, subjects and learning activities
- Tracking users’ interaction within the systems’ resources and the creation of tracking reports

7.3.1 Management of Users and Users’ Information

Recording user information is the most important step since the development of systems needs to track how users utilize the system. Tracking reports will all include appropriate user identification information as per the specific domain in relation to different visits within the system. When looking into the information used to identify a user in Moodle, it can be seen that a lot of information is missing when compared to the TanSse-L system user information. The missing information could easily be accommodated by either adding extra table/s for the missing information in Moodle or by adding extra fields within the table in Moodle (e.g. in mdl_user for user identification information) during the TanSse-L system implementation stage. This is a kind of model merge approach used.

Apart from the basic information needed to identify a user like userID, username, email, and from the point view of the TanSse-L system, the user also is needed to be identified by *region*, *district* and *school name* or *institution*. Also *form level*, *subject specialization* (e.g. science, commercial etc) and *subject combination* (e.g. Physics, Chemistry, Mathematics - PCM) are needed information to identify a student. Figure 7.1 shows this part within the TanSse-L system DCD in a UML package which provides the user information. The basic UML guide defines a package as a logical container in which related objects can be placed, that is a group of objects that provide related services.

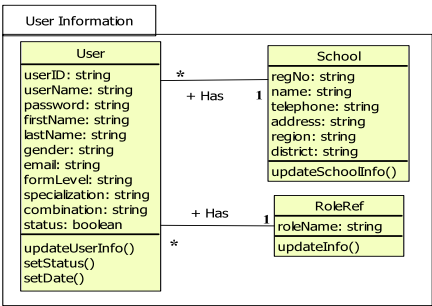


Fig. 7.1: Part of TanSse-L DCD Showing User Information

On closer evaluation, the following extra information needed to be added to Moodle during TanSSe-L system implementation:

- 'region' to get the name of the 'Region'
- 'district' to get the name of the 'District'
- 'schoolname' to get the 'School Name'
- 'gender' to get the user's 'gender'
- 'fomlevel' to get the 'Form Level'
- 'specialization' to get the subject area of specialization
- 'combination' to get subjects combination

7.3.2 Management of Learning Materials

Though it can be seen that there is only one course table in Moodle (mdl_course), the final display of the course (hereby named subject in the TanSSe-L system) content looked similar to what was needed for TanSSe-L system. What was needed by the TanSSe-L system was to adopt the way Moodle handles subject learning materials with the slight alteration of having a 'Chapter Format' instead of a 'Topic Format' in Moodle. Figure 7.2 shows how TanSSe-L system subjects were displayed when adopting the Moodle way of handling a course.

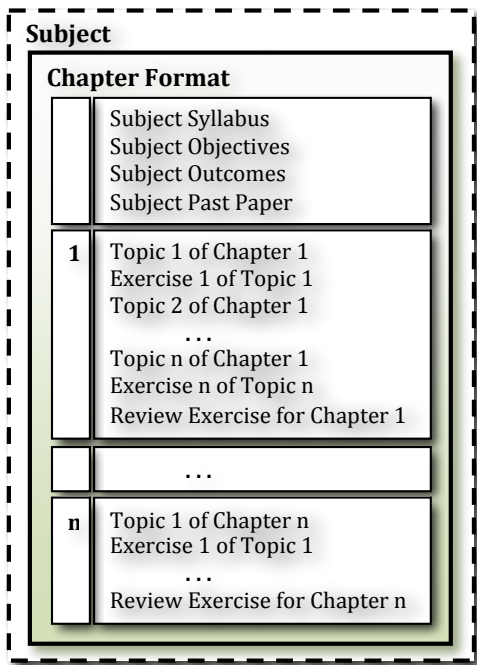


Fig. 7.2: Chapter Format for TanSSe-L System

When selecting a subject, a subject home page will be displayed in “chapter format”. Chapter format (Topic format in Moodle) comes with a number of divisions/blocks in the middle. The first unnumbered division will be used to display links to subject; syllabus, objectives, outcomes, past paper/s if any and any general information on the subject. Other numbered divisions will represent chapters of the subject, whereby a corresponding single division as a chapter will include links for all chapter topics, all topic exercises, review exercises for the chapter and extra chapter exercises if any.

7.3.3 Tracking Users’ Interactions

Tracking reports means tracking users’ events when interacting with the system, hence reports involve describing the user who did that interaction. All Moodle tracking reports suit the TanSse-L system’s needed reports. Some of the reports in Moodle display:

- List of users. A list of users can be filtered based on different information e.g. based on “subject role”, “login date”, “first name” etc
- Login report to show users’ login status
- Users’ live logs report from the past hour to the system from different places, and is updated after every 60 seconds
- Level of users’ participation in a subject
- A list of participants in a subject
- “Activity report” providing a number of views to activities which are present within that subject
- “Statistic” report. It presents the report on logs for groups of user roles graphically and in tabular form
- Users’ profile

Moodle reports needed to be modified to produce reports which identify the user as per the TanSse-L system information as explained in sub-section 7.3.1. To have Moodle as the TanSse-L system-specific PIM for this part, this research included all needed fields in SQL codes so as to add the required user information from mdl_user in tracking reports. Table 7.1 shows some of the information needed to identify a “student” user in tabular form.

Table 7.2: Some User Identification information in Report									
Full Name	email	Gender	Region	District	School Name	Form Level	Specialization	Combination	Actions taken

With the above evaluation, the TanSse-L system PIM was transformed to Moodle as a TanSse-L system-specific PIM by adding the above-named fields in mdl_user table, adopting the way Moodle handles subjects, and adding required fields in SQL codes to

get the right display of tracking reports. These modifications were realized during the implementation phase when Moodle open source LMS was customized.

7.4 TanSse-L System PSM

TanSse-L system requirement specified LAMP environment for implemented. Moodle, being the TanSse-L system specific PIM, can be installed on any computer that can run PHP and can support an SQL database (for example MySQL). Moodle can run on Windows and Mac operating systems and many flavours of Linux (moodle.org). This means that the TanSse-L system PSM is a LAMP environment which suited Moodle LMS installation too, the one that was customized. Figure 7.3 gives a summary of the transformation from TanSse-L system CIM - TanSse-L system PIM – TanSse-L system specific PIM – TanSse-L system specific PIM – TanSse-L system PSM.

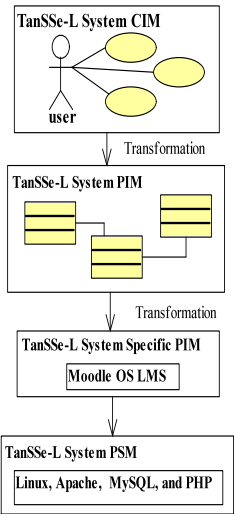


Fig. 7.3: TanSse-L System PIM Transformation to PSM

7.5 Discussion

Model transformations can be from CIM to PIM, PIM to PIM, PIM to PSM and PSM to code. A CIM can be refined and mapped to another CIM, in the same way PIM can be refined to another PIM. Moodle database structure is the PIM of Moodle. This chapter explains the transformation of the TanSse-L system DCD as its PIM into another PIM (Moodle PIM) to get the TanSse-L system-specific PIM.

Transformations may combine elements of different source models in order to build a target model. According to the number of source models involved in the mapping process, a transformation is simple or a merge. This research shows the simple transforma-

tion technique, whereby what was in the TanSSe-L system DCD was simply merged into the selected open source LMS. This chapter describes a base for customization that was used to implement the TanSSe-L system, the subject of the next chapter.

CHAPTER EIGHT: TanSSe-L SYSTEM IMPLEMENTATION AND MINI-EVALUATION

8.1 Introduction

This chapter discusses Moodle customization to suit implementation of the TanSSe-L system. The chapter starts by showing Moodle areas which were customized, followed by discussions on mirroring, replication and backup of a functional TanSSe-L system. Finally, it shows the mini-evaluation done during participatory activities involved in system deployment. The plan analyzed in Chapter 7, TanSSe-L system PIM transformation to PSM, guided the customization, when the research implemented the transformation from PIM to specific PIM.

The implementation started by having PSM (MySQL DBMS) in place, then installing the TanSSe-L system specific PIM (Moodle open source LMS) into PSM. By using the pre-prepared customization plan, model merge was performed to obtain the real TanSSe-L system PIM followed by customization of codes to suit TanSSe-L system requirements.

8.2 Moodle Customization for TanSSe-L System Use

8.2.1 Selection of Packages

(a) *“Moodle package” with concurrent versioning system (CVS) capability*

The first thing to consider when customizing an open source package is to get the right one which to a large extent matches the set of requirements for a specific context. Moodle open source LMS was selected as the best fit for TanSSe-L system implementation. A number of old and new versions of Moodle packages are free for downloading and customizing. When considering updating the Moodle version currently in use, the first thing would be to foresee the possible difficulties in upgrading the customized Moodle package. Moodle has concurrent versioning system (CVS) capability, meaning that it would be the right option to download, install and customize. Moodle.org Website states that with CVS, all modifications done during customization are tracked and stored. When Moodle is updated to a higher version, CVS compares the two packages, merges them whenever possible and makes the update easier.

Vesperman (2007) explains, that, the CVS is a free software revision control system, which keeps track of all works and changes in a set of files, and allows several developers (potentially widely separated in space and/or time) to collaborate. CVS uses client-server architecture: a server stores the current version(s) of a project and its history, and clients connect to the server in order to “check out” a complete copy of the work on this project and then later “check in” their changes. Typically, the client and server are connected over a LAN or over the Internet, but the client and server may both run on the same machine if CVS has the task of keeping track of the version history of a project with only local developers. The server software normally runs on UNIX (although the CVS server supports various flavours of MS Windows and Linux), while CVS clients may run on any major operating system.

(b) *“phpMyAdmin” package*

Gilmore (2004) indicates that, although the MySQL command-line clients like “mysql” offer an efficient and powerful means for working with the server. Many users prefer the convenience of the point-and-click interaction offered by graphical user interface, based clients. Many such clients exist, several of which are available under open-source licensing arrangements. “phpMyAdmin” is an open source Web-based MySQL graphical user interface client. PhpMyAdmin offers an easy way of managing databases in the MySQL server, such as: viewing data in tables, adding/deleting fields in database tables, managing database user privileges, passwords and resource usage, exporting (creation of database archives) and importing databases. This package was installed to make management of the TanSSe-L system database easy.

8.2.2 Customization of TanSse-L System Front Page

Moodle comes with 15 themes which are used to display the front page of the system. A standard theme was selected and customized with the new name, “tanssel”. This was done immediately after Moodle package installation so as to early start feeling the TanSse-L system environment. Figure 8.1 shows the customized TanSse-L system front/home page. Modifications made include header.php, footer.php and provided style sheet files.

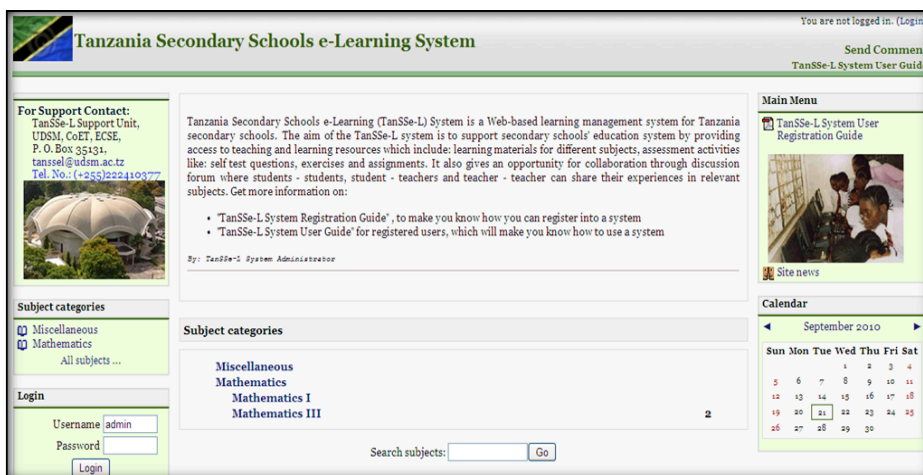


Fig. 8.1: TanSse-L System Front Page

8.2.3 Creation of More User Information for TanSse-L System

When comparing the user information portion of the TanSse-L DCD and Moodle database structure, it was found that some information was missing in mdl_user table of the Moodle database structure. Chapter 7 of this research has clearly shown this. To include this information, the followings things were done:-

- *Addition of required fields for TanSse-L system*

With the help of phpMyAdmin graphical user interface MySQL client, the extra fields needed were added to the mdl_user table, which were: 'region', 'district', 'schoolname', 'formlevel', 'specialization', 'combination' and 'gender'. However, some other Moodle fields were customized in language string to portray TanSse-L system terminologies. Fields like 'phone' and 'address' were made to read “User Phone No.” and “User Address” respectively

- *User information entry interface form*

Getting more user information for the TanSse-L system went together with the customization of the user information data entry interface form. The customized entry

form is shown in Figure 8.2. Customization included adding all the necessary fields to user table/s and simplifying data entry to some of these fields by making:

- “gender” to be selected either from ‘Female’ or ‘Male’
- “region” to be selected from the already prepared list of Tanzanian regions
- “district” to be optionally selected from districts automatically displayed based on the region selected.
- “schoolname” to be optionally selected from the school names automatically displayed based on the district selected.
- “formlevel” to be selected from the prepared list of form levels
- “specialization” to be selected from the prepared list of subject specialization, e.g. science, art, agriculture etc
- “combination” to be optionally selected from the subject combinations automatically displayed based on the specialization selected.
- “country” to be by default ‘Tanzania’

The screenshot shows the 'Add a new user' form in the TanSse-L system. The form is titled 'General' and includes a 'Show Advanced' button. The fields are as follows:

- Username* (text input)
- New password* (text input) with an 'Unmask' checkbox
- Force password change (checkbox)
- First name* (text input)
- Surname* (text input)
- Gender* (dropdown menu)
- Email address* (text input)
- Email display (dropdown menu: 'Allow only other subject members to see my email address')
- Email activated (dropdown menu: 'This email address is enabled')
- Region* (dropdown menu: 'Select a Region...')
- District* (dropdown menu: 'Select a District...')
- School/Institute Name* (dropdown menu: 'Select a School...')
- Form Level (dropdown menu)
- Specialization (dropdown menu: 'Select Specialization...')

At the top right, it says 'You are logged in as Amba Mwalukasa (Logout)' and 'Send Comment'. At the bottom right, it says 'Blocks editing on'.

Fig. 8.2: TanSse-L System User Data Entry Interface Form

8.2.4 Dealing with Subject Information

As indicated in Chapter 7, the TanSse-L system adopted the way Moodle deals with the subjects. However a few customizations were done as follows:

(a) *Subject information data entry form*

A TanSse-L subject is identified using subject name and subject code. Language string for “shortname” has been customized to read “Subject Code”. No default values were set for subjects’ “Full Name” and “Subject Code”, but they were set to force value entry as shown in Figure 8.3.

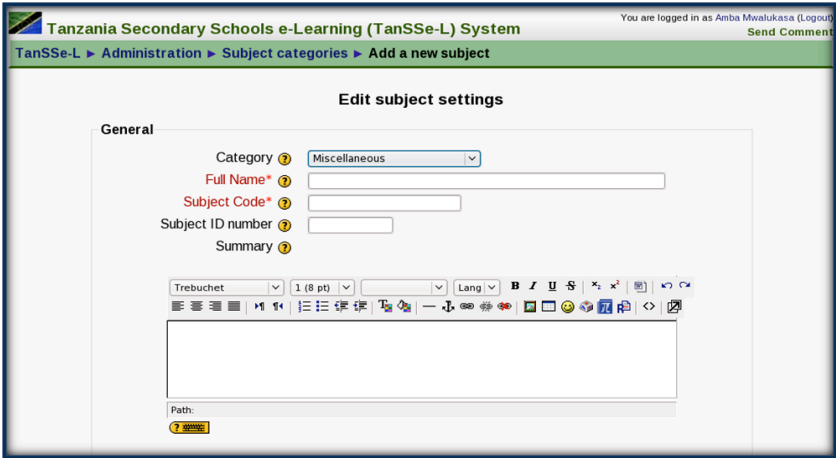


Fig. 8.3: TanSse-L System Subject Data Entry Interface Form

(b) *Filtering of subjects in tracking reports*

“Short Name” in Moodle is set locally to be unique for each subject “full name” apart from the “id” field provided in the mdl_course table in the database. This means that it is possible to have more than one subject using the same “full name”, but distinguished by subject codes as shown in the example below:-

Subject Full Name		Subject Code
Mathematics Form III	-	Math_III
Mathematics Form III	-	Math_IIIA
Mathematics Form III	-	Math_IIIB

With this arrangement, it is sometimes difficult to clearly identify which subject is being selected, especially in the cases where the display shows only the list of subjects by their full names without subject codes. The difficulty was clearly noticed in tracking reports which provide either the selection of a subject name or the selection of a subject code but not both. Modification to this can be done to either include the display of a subject code whenever the subject’s full name is displayed or to have a locally set full name of the subject that is unique as shown in the example below. For this research, both approaches were implemented; the subject’s full names were concatenated with their respective subject codes as shown in Figure 8.4, and the subject’s full names were also set locally to be unique as shown in the example below.

Subject Full Name		Subject Code
Mathematics Form III	-	Math_III
Mathematics Form IIIA	-	Math_IIIA
Mathematics Form IIIB	-	Math_IIIB

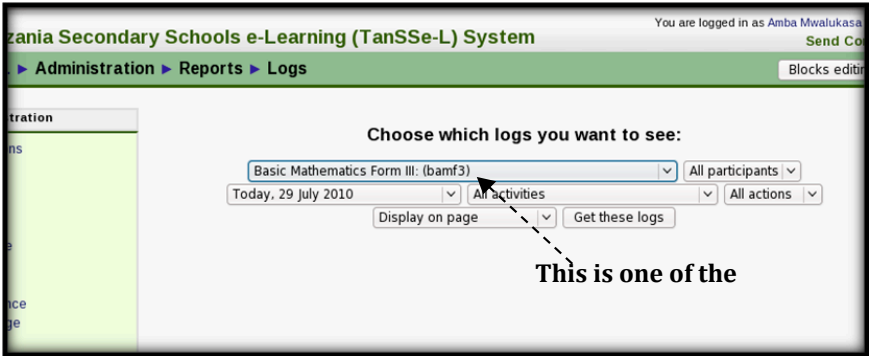


Fig. 8.4: Subjects Full name and Subject Code Concatenated

(c) *Subject format*

Moodle comes with a number of possible subject formats which can be used when creating a subject. These formats include: Topic, Weekly, Social, ¹⁰LAMS and ¹¹SCORM. Only two formats are used in the TanSse-L system: “Chapter Format” and “SCORM”. SCORM will take care of any SCORM compliance packages and “chapter format” was customized from the name “topic format” and was implemented as shown in Figure 7.2.

8.2.5 Customization of Tracking Reports

Evaluation and assessment of the usage of the TanSse-L system relies fully on how the system is able to provide relevant reports. The task of evaluation and assessment is one of the objectives of the development of the TanSse-L system. Moodle comes with a good number of tracking reports, almost all of which were needed in the TanSse-L system. However, what was lacking in these reports was extra information needed to identify TanSse-L system users. Initially, the TanSse-L system was designed to be used by the selected pilot schools. However, with time it could be extended to other Tanzanian secondary schools scattered in regions/districts. Hence the need to identify these targeted users not only by the school name registered and/or the form level, but also by the region and/or district in which the school is located. This created the motivation for adding new fields in Moodle table/s, which was done as follows:

¹⁰ Learning Activity Management System
¹¹ Sharable Content Object Reference Model

(a) *Adding needed fields in SQL codes*

In order to have information displayed from the database tables, required fields were added to the PHP query codes to obtain needed information from database tables.

(b) *Adding needed fields in files displaying reports*

All the files finally displaying reports were gone through, and table fields and table data of the information needed about a user were added. These added fields involved all reports whether displayed within the system pages or exported in text and/or Excel formats. Figure 8.5 shows one customized report, “participation report” of the students in a subject activity within the TanSse-L system, providing extra information on ‘Gender’, ‘Region’, ‘District’, ‘School/Institution Name’, ‘Form Level’, ‘Specialization’ and ‘Combination’.

The screenshot shows a web interface for 'Basic Mathematics Form III' within the 'TanSse-L' system. The page title is 'Participation report'. It includes navigation links like 'Activity module', 'Look back', 'Show only', and 'Show actions'. Below the navigation, there are forum view options: 'view discussion, search, forum, forums, subscribers' and 'add discussion, add post, delete discussion, delete post, move discussion, prune post, update post'. The report shows '1 Student'.

First name / Surname ↓	Gender	Region	District	School/Institute Name	Form Level	Specialization	Combination
Joan Chale	Female	Pwani	Kibaha	Wali-ul-ASR Girls Secondary School	Form III	Science	PGM

At the bottom, there are controls for selecting all, deselecting all, selecting all 'no', and a dropdown for 'With selected users...'. There are also 'OK' and 'Cancel' buttons.

Fig. 8.5: Participation Report of Students in a Subject Activity

(c) *Adding means of filtering user information based on new fields*

This research needed to evaluate users’ participation in the TanSse-L system to be filtered in many ways. Having added to the filtering means provided by Moodle, we were able to filter the bulk of users based on the added fields, for example, based on form level of students, region, district, gender, school name, specialization, combination or a combination of more than one filter as shown in Figure 8.6.

New filter

Full Name contains

Surname* contains

First name* contains

Gender* contains

Email address* contains

Region* is any value

District* is any value

School/Institute Name* is any value

Form Level* contains

Specialization* is any value

Combination* is any value

Subject role* any role

System role* any role

First access* ☐ is after 29 July 2010 ☐ is before 29 July 2010

Last access* ☐ is after 29 July 2010 ☐ is before 29 July 2010

[Hide Advanced](#)

Fig. 8.6: User Information Filtering Fields

Not only these filters, but also important reports like “participation report” were made possible to filter based on a school. School administrators and Non-Editing teachers can easily access their school students who participated in each assessment or resource provided in a subject as shown in figure 8.7.

Mathematics Form III

BAMF3 > Reports > Participation report

Activity module Look back Show only

Show actions

Assignment Views: view
Assignment Posts: upload

1 Student

Name / Surname ↓	Gender	Region	District	School/Institute Name	Form Level	Specialization	Combination
Joan Chale	Female	Pwani	Kibaha	Waliul ASR Secondary School	Form III	Science	

Fig. 8.7: Filtering “Participation Report” by School Name

8.2.6 New Reports Added to TanSSe-L System

(a) *Tracking access to resources provided in TanSSe-L home page*

“TanSSe-L System Visitors” is a newly created report in the site administration block intending to track the number of visitors to the TanSSe-L system home page who will have access to free resources provided in the home page of the system. The report was adopted from the “outline” report within a subject. As shown in Figure 8.8, this report will count the number of times by anyone views each resource provided in the TanSSe-L home page.

Activity	Views	Last access
TanSSe-L System Registration Guide	6	Tuesday, 29 June 2010, 07:05 AM (30 days 1 hour)
ICT for e-Learning Project Overview	5	Wednesday, 28 July 2010, 10:45 AM (22 hours)

Fig. 8.8: TanSSe-L System Visitors Report

(b) *“coursese” module for administrative report*

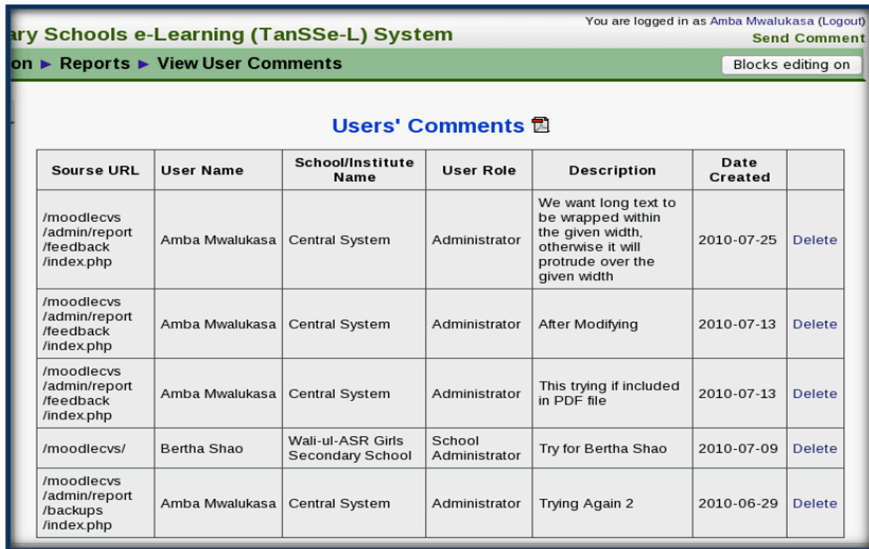
“Course size” report is an open source report module. Course size report is an excellent work contributed by Shane Elliott to the Moodle community. It displays a list of all the subjects created in the TanSSe-L system, together with associated disk usage from the data directory as shown in Figure 8.9. Size can be filtered in GB, MB, KB and Bytes. This report will help administrators knowing how much memory each subject uses in the TanSSe-L system data directory in its totality. It will also show the list of subjects and the total number of subjects in the TanSSe-L system. “Course Size” was customized to read “Subject Size” in language string.

Subject ID	Subject Code	Subject Name	Disk Size
1	TanSSe-L	Tanzania Secondary Schools e-Learning (TanSSe-L) System (Site)	65.9KB
29	bamf3	Basic Mathematics Form III	29.6MB
2 Subjects		Total Disc Size Used	29.6MB

Fig. 8.9: Subject Size Report to Display List of Subjects with Respective Disc Sizes

(c) “View User Comments”

“View User Comments” report as shown in Figure 8.10 enables an administrator to view comments, suggestions and/or advice from users concerning the usage of the TanSSe-L system.

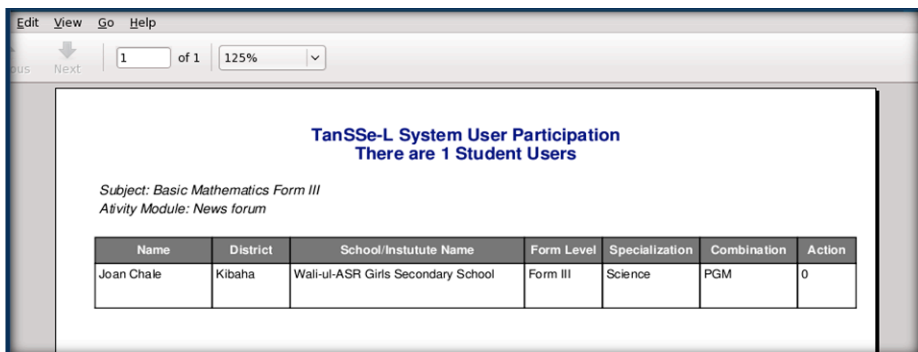


Source URL	User Name	School/Institute Name	User Role	Description	Date Created	
/moodlecvs/admin/report/feedback/index.php	Amba Mwalukasa	Central System	Administrator	We want long text to be wrapped within the given width, otherwise it will protrude over the given width	2010-07-25	Delete
/moodlecvs/admin/report/feedback/index.php	Amba Mwalukasa	Central System	Administrator	After Modifying	2010-07-13	Delete
/moodlecvs/admin/report/feedback/index.php	Amba Mwalukasa	Central System	Administrator	This trying if included in PDF file	2010-07-13	Delete
/moodlecvs/	Bertha Shao	Wali-ul-ASR Girls Secondary School	School Administrator	Try for Bertha Shao	2010-07-09	Delete
/moodlecvs/admin/report/backups/index.php	Amba Mwalukasa	Central System	Administrator	Trying Again 2	2010-06-29	Delete

Fig. 8.10: View User Comments

8.2.7 TanSSe-L System Reports in PDF Format

To make TanSSe-L reports friendlier in terms of downloading, many reports have been converted into portable document file (pdf). Figure 8.11 shows a users’ participation report presented in pdf format for a specific selected activity module done by a student.



TanSSe-L System User Participation
There are 1 Student Users

Subject: Basic Mathematics Form III
Activity Module: News forum

Name	District	School/Institute Name	Form Level	Specialization	Combination	Action
Joan Chale	Kibaha	Wali-ul-ASR Girls Secondary School	Form III	Science	PGM	0

Fig. 8.11: Participation Report in PDF Format

8.2.8 Customization of Language Strings

Many different terminologies are used in the TanSSe-L system that is not present in Moodle. Moodle has a “lang” directory with a number of files each having a list of strings which are used to convert table field names, with other strings giving a meaningful language display on Moodle web pages. Customization of language strings for the TanSSe-L system is divided into two groups:

- Adding string definition of all the new word names introduced in Moodle tables e.g. mdl_user table, and in Moodle directory files. Some examples are:
 \$string['region'] = 'Region';
 \$string['district'] = 'District';
 \$string['schoolregno'] = 'School Reg. No.';
 \$string['formlevel'] = 'Form Level';
 \$string['formi'] = 'Form I'; etc etc
- Customization of strings found in Moodle to suit TanSSe-L system terminologies was done through site administration block, and the edited strings were stored in a local “lang” directory. Examples are:
 \$string['course'] = 'Subject';
 \$string['shortname'] = 'Subject Code';
 \$string['phone'] = 'User Phone No.';
 \$string['address'] = 'User Address';
 \$string['formattopics'] = 'Chapter Format'; etc etc

Language customization also covered help files within the TanSSe-L system. Customization of the existing string was done through “Site Administration >> Language >> Language editing”.

8.2.9 TanSSe-L System User Roles

Moodle comes with a number of capabilities which can be performed within the system. What is required is to select capabilities and grant permission to those selected capabilities to a role. It was important to thoroughly study the default user roles and their permissions which come with Moodle to see if they suited the TanSSe-L system. Almost all of the default Moodle user roles were adopted except for “Teacher (editingteacher)” role since learning materials for the TanSSe-L system would be centrally created. However, some adopted roles needed modification in setting permissions to suit the TanSSe-L system’s roles. These roles include: ‘Administrator’, ‘Subject Creator’, ‘Non-Editing Teacher’, ‘Student’, ‘Guest’ and ‘Authenticated user’.

The TanSSe-L system needed more user roles to be created and set permissions accordingly. The new user roles created were: ‘School Administrator’, ‘Educational Advisor’ and ‘Content Administrator’. The creation of TanSSe-L system user roles was done with the help of the guide from moodle.org Website. Table 8.1 shows a summary of all TanSSe-L user roles.

Table 8.1: TanSSe-L System User Roles		
Moodle User Roles	TanSSe-L User Roles	Remarks
Administrator	Administrator	Adopted from Moodle
Course Creator	Subject Creator	Adopted from Moodle and modified
Non-Editing Teacher	Non-Editing Teacher	Adopted from Moodle and modified
Student	Student	Adopted from Moodle
Guest	Guest	Adopted from Moodle
Authenticated User	Authenticated User	Adopted from Moodle
-	School Administrator	Added new user role for TanSSe-L
-	Educational Observer	Added new user role for TanSSe-L
-	Content Administrator	Added new user role for TanSSe-L

8.2.10 Other Customized Areas

(a) *HTML editor with mathematical expression*

“DragMath” is an open source drag and drop equation editor. It is an excellent piece of work contributed by Marc Grober to the Moodle community. This package was integrated into the TanSSe-L system’s (symbolized as π) HTML editor provided within the system. The package can be used to create simple mathematical and science expressions like

$$x = \frac{-b \pm \sqrt{b^2 - 4 \cdot ac}}{2a}$$

whenever needed. Using DragMath, science and mathematical expressions can be written in the normal way and DragMath converts them into a variety of different linear syntax for mathematics which includes: MathML, LaTeX, Maple, Maxima or any user defined style (moodle.org, 2009). Latex equivalent expression for the given quadratic equation is

“ $\$x= \frac{-\left(b\right) \pm \sqrt{b^2-4 \cdot ac}}{2 \cdot a} \$$ ”.

Figure 8.12 shows the DragMath equation editor with a mathematical expression ready to be inserted into HTML editor.

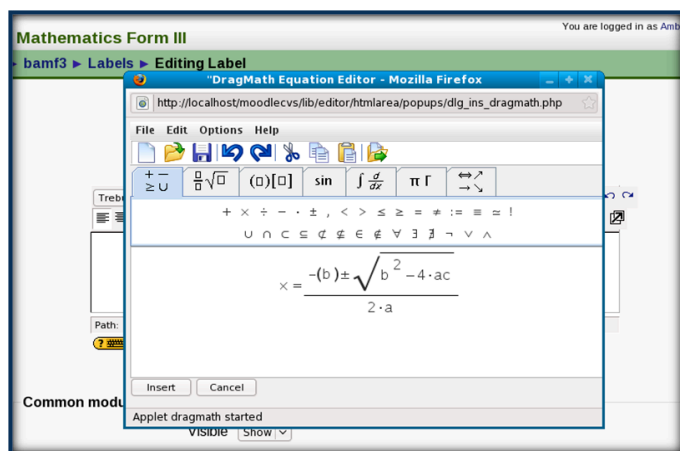


Fig. 8.12: DragMath Equation Editor with Mathematical Expression

(b) *Settings through site administration block*

Moodle provides a number of possible settings under administrative privilege. The following have been done for TanSse-L system:

- Security settings include a disabling “self-registration” feature to prevent users from registering themselves and creating accounts through email.
- Security settings include an enabling “force users to login for profiles” feature in Moodle to prevent anonymous visitors and search engines from seeing system users’ profiles.
- Moodle comes with a number of activity modules which can be used to create exercises in different formats. At the time of starting the TanSse-L system, only a few activity modules were enabled, namely: Assignments, Choice, Exercise, Forum, Quiz and Hot Potatoes Quiz. Others may be enabled latter.
- Inclusion of a “topic section” sometimes called “topic 0” can be used to display any information on the TanSse-L home page (front page).

(c) *“crontab” file*

In order to run statistical reports which use graphs, crontab must be installed and enabled. Each installed Moodle package need one crontab file. An example of a “crontab” or sometimes called “cronjob” is:

```
“*/30 * * * * wget -q -O /dev/null http://example.com/moodle/admin/cron.php”
```

(d) *Links to learning content repositories if any*

Learning content can be stored in a repository and viewed by the TanSse-L system. To provide for this, the researcher activated the instructional management system, which comes with Moodle for the TanSse-L system. Instructional management system repository was activated to take care of any IMS and SCORM learning packages.

With the content packaging specification of the instructional management system, it is possible to store chunks of materials in a standard format which can be reused in different systems.

8.2.11 Development of TanSSe-L System User Guide

TanSSe-L system user guide was among obligations to be accomplished during implementation stage. User guides for different roles were created and made available for all registered users. For easy access, a link was provided to call all user guide resources after successful login to the system as shown in Figure 8.13, and it was provided at home page such that new users can easily view the link.

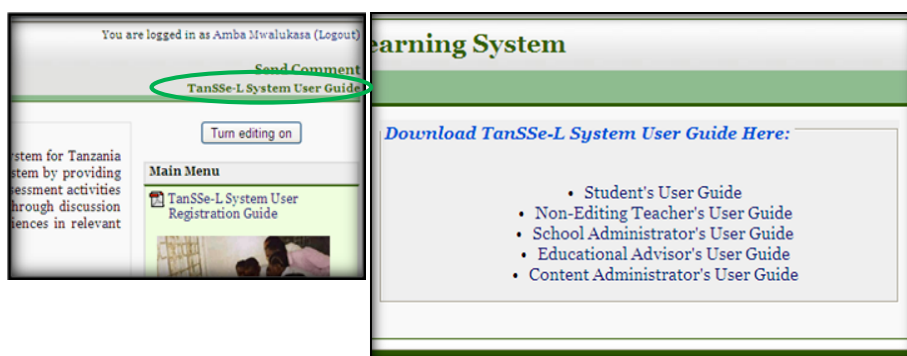


Fig. 8.13: TanSSe-L System User Guide

8.3 TanSSe-L System Mirroring, Replication and Backups

One specific objective of this research work was “to develop a module to enable the creation, storing, *publication* and sharing of learning materials”. To publish is to make publicly known, which can mean distributing paper copies to the public, or putting the content on a Website. The word publication means the act of publishing. In short, *publication* means making copies available to the public and ensuring high availability of the database system for end users.

Concerning the use of LMS, database content is published and made available to many end-users using the Web-based approach, in which the LMS is placed centrally in one location and end-users browse the LMS content from different places using web browsers through the internet. The problem of using a centrally placed LMS database is that it directly promotes the importance of producing replicas of the same database near to the users. TanSSe-L system mirroring, replication and data backing up implementation were crucial. Each component has its own potential as clearly stated in research methodology and literature review chapters, in this thesis.

8.3.1 Rsync, Secure Shell and Cronjob

The TanSse-L system uses “*rsync*” for mirroring and replicating the PHP codes and data directories on the mirror server and local server. Transferring these directories using rsync is through a “*secure shell*” connection provided within the Linux operating system. The “*cronjob*” was used to automate the mirroring task with no user-interaction.

With the help of the phpMyAdmin graphical user interface for the MySQL database server, it was possible and easy to transfer the TanSse-L database for the first time from the master server to the mirror and local servers, by exporting the TanSse-L database in SQL format and importing the same to the mirror and local servers. It was also possible to transfer the database using “*mysqldump*” in the command line by the first means, initially, when there is no database in the mirror or local servers. In the case of the database having already been installed, updates to the database can be done using the MySQL server replication facility provided.

8.3.2 Backup Mechanism

The TanSse-L system makes use of “AutoMySQLBackup” open source file bash scripts which create automatic backups of MySQL databases. It is important to back up TanSse-L system files; however the critical backup is of the database because that is where most of the content is added and updated. The automated backups can also be transferred to external storage media. The “*cronjob*” was also used to automate the TanSse-L backing task with no user-interaction.

8.4 TanSse-L System Mini-Evaluation

TanSse-L system was finally made accessible to public, and specifically to pilot schools and MoEVT. However, before final deployment, preliminary usage and evaluation were made to Dar es Salaam University College of Education and research group members.

8.4.1 With Dar es Salaam University College of Education Students

Dar es Salaam University College of Education (DUCE) is among UDSM’s colleges producing a good number of Tanzania secondary schools’ graduate teachers. This research took initiative to start with these prospective teachers in evaluating the usage of a functional TanSse-L system in the form of a seminar and noted their feedback. Some of the inputs obtained include:

- *Emphasis on providing users with the knowledge on how to use the system:*

- TanSSe-L system user guide was incorporated within the system to make users easily access and get guidance on the usage even before being trained
- Emphasized on producing more CD-ROMs for learning materials as using LMS (here TanSSe-L system) to many users need external force, due to lack of self-motivation:
 - TanSSe-L system emphasize on using hybrid mode of delivering learning material (LMS, face-face and CD-ROMs) as each mode has its own strength, as individual and as a unit
- *Develop teacher's capability in using a system then transfer knowledge to students:*
 - Training is a continuous part of the TanSSe-L system's implementation strategy to make all stakeholders be conversant in the usage of the system
- *Emphasized on training representatives of the TanSSe-L system at local or cluster level to facilitate easy and fast communication with the users and system administrator at the central server:*
 - TanSSe-L system needed close cooperation with stakeholders at school and Ministry levels to facilitate:
 - Communication means so as to accelerate the process of deployment, like the need to have at least one staff member from each entity to be a key person for communication
 - Permission to allow organizational LANs to be used by the TanSSe-L system

8.4.2 TanSSe-L System Accessed by Research Group

Researchers being part of the ICT for e-Learning project were provided with the TanSSe-L system's public address to make them view the system before final deployment. Researchers included UDSM staff from; Faculty of Education, Center for Virtual learning from Faculty of Informatics and Virtual Education, CoET, ECSE, and International coordinators from Sweden – BTH.

Having a functioning TanSSe-L system does not mean that the work of customization is over. Real evaluation can be obtained after starting to use the system. This is very important since the feedback from users will be through their usage. Apart from common means of communication like: frequent visits to pilot sites and MoEVT and using communication means like emails and phones, "Send Comments" provided together with the system was the easiest means of getting stakeholders' feedback.

8.5 Discussion

Tanzania being a developing country cannot afford the cost of commercial software. It is wiser to effectively use the opportunities brought about by the open source community. It is possible to create something concrete using the open source software. In

this research, the TanSSe-L system was fully implemented using OSS. The OSS used included Apache, a Web-based open source server, MySQL DBMS, PHP scripting language and open source LMS for customization, the Moodle open source LMS. However, care should be taken when customizing open source LMS, to make sure that customization, especially when involving changes in the code should not conflict with the original and updated files, otherwise updating customized open source LMS to use a new version will be complex.

CHAPTER NINE: CONCLUDING REMARKS

9.1 Discussion

From what has been discussed in previous chapters the following concluding remarks are made.

9.1.1 Specific Objectives Relating to Research Questions

The system requirement specifications phase was the basis for the development of the TanSSe-L system. The requirements had to be analyzed fully before system implementation and specifically for a well functioning TanSSe-L system. Development of the TanSSe-L system had three specific objectives. The requirement specifications phase started to partially answer the research questions created for each specific objective. Now, having a fully functioning TanSSe-L system we can analyze whether these questions have been answered. The research had three research questions relating to specific objectives, and was based on the following key services implemented by the TanSSe-L system.

(a) *Sharing of learning materials*

The purpose of developing the TanSSe-L system was to facilitate the sharing of learning materials. This has been done through the creation of a three-tier architecture

where learning materials have been created and stored at the central server. All users will have access to the centrally placed materials through a Web browser. Only one role “Content Administrator” is allowed to create and upload learning materials to the system. Organizing the TanSSe-L system into three-tier architecture answers research question number one.

¹²*RQ1*: How can the content of learning materials be made available and sharable among several students and teachers, taking into consideration open source/low cost system, the issue of sustainability and the context of the application?

Availability is an issue of doubt due to the high costs of the Internet. Availability of the database learning materials is being strengthened by mirroring the TanSSe-L database and replicating full or part of the content from the central TanSSe-L database to local servers. A local server is planned to service a cluster of schools in the nearby area. Currently, there is one local server for Kibaha Secondary School and Wali-ul-Asr Girls’ Seminary in Kibaha. Replication is one way of making learning materials available to end users. Research question number one answers the following specific objective number one:

¹³*SO1*: To develop a module to enable the creation, storing, publication and sharing of learning materials

(b) *Security Issues*

A critical issue in relation to databases is security. The risks of a database system include unauthorized access to confidential data, unauthorized modification of data and the loss of the data (¹⁴NISCC, 2003). End users are obligated to receive the intended information whenever they need. Data here means administrative information used by the database and all other information stored in the database including learning materials. The research question based on security issues was:

RQ2: Why is security an important dimension and what kinds of functionality are adequately efficient?

A number of security measures have already been implemented in the TanSSe-L database to counter threats. These measures as suggested by NISCC (2003) have been indicated in this research to answer research question number two as follows:

- Identification and authentication of users where username and passwords are used. In this research, the TanSSe-L system validates login information (username and password) entered by the user in order to use the system and allow the authenticated user to login/out of the system.
- Access control is another way of securing the database and the stored information. In this research, access control was taken care of by organizing users in role-based

¹² RQ - Research Question

¹³ SO - Specific Objective

¹⁴ NISCC - National Infrastructure Security Co-ordination Centre

access. Each user had to be assigned a role with the system displaying the resources available for that role. Many of the roles assigned have “read only” or “view” capability except for “content administrator” who creates and uploads learning material. Role-based access is implanted by providing proper permission settings to a role in the TanSSe-L system.

- Database backup and recovery was also strongly considered. docs.moodle.org/security states that the basic measure for database security is frequent backups which can be restored when needed. Mirroring of the database and replication on a local server is another way of backing-up the TanSSe-L system.
- The disabling “self registration” feature in TanSSe-L system which when enabled allows users to register themselves and create accounts through email, resulting in the possibility of spammers creating accounts in order to use forum posts, blog entries etc for spam.
- The enabling “force users to login for profiles” feature in the TanSSe-L system prevents anonymous visitors and search engines from seeing system users’ profiles. If this feature is disabled, some users may post advertising (spam) or other inappropriate content in their profiles, which is then visible to the whole world.
- The TanSSe-L system data directory is located outside the Website root directory so that it could not be easily accessed via the web to strengthen the security of the TanSSe-L system.
- The TanSSe-L system also considered the security of the database server itself, which was done by limiting access not only to the information stored in it, but access to the server hosting the TanSSe-L database. Database back-end should never be on the same machine as the Web server, not only for security but also for performance (Wiedman, 2008). This was done by providing database login facility to the MySQL DBMS.
- Again a three-tier architecture for the TanSSe-L system separates the database server from the users (client-tier) using a Web server (application-tier), that is, by creating multiple layers which improve security. Only the address of the approved Web server is allowed access to the database server. Since a client does not have direct access to the database, it is more difficult for a client to obtain unauthorized data. Proper configuration of the Apache web server offers reasonably good security.
- TanSSe-L system mirroring and replication was implemented through Secure Shell, which allows data to be exchanged between two networked devices using a secure channel.
- Security was ensured through proper firewall setting in order to filter network access to the database server and to ensure that TanSSe-L data is forwarded to ports to which the database is listening

The specific objective of research question number two is:

SO2: To develop mechanisms for protecting the database and the information stored, as well as for managing users of the system and the workflow of the learning materials

(c) *Evaluation and Assessment Issues*

Evaluation of the usage of the TanSSe-L system by the targeted users is a very important aspect. The system was developed for stakeholders to use. Two types of assessment are present in the TanSSe-L system; assessing the usage of the system by the users and assessing the understanding of the learning materials through the exercises given. The TanSSe-L system provides a mechanism for tracking several events for future evaluation of the usage of the system, which answers research question number three. Tracking events include:

- Tracking of user login and logout, to evaluate the number of users who log into the system.
- Tracking of students' interaction with subject learning materials. Students are the number one targeted users. The interaction with learning materials will indicate that students are really using those stored in the TanSSe-L system.
- Tracking of students' interaction with assessment activities. This also includes viewing grades for the exercises created and set to be assessed in a self-assessment manner.

RQ3: How can the TanSSe-L system monitor the learning progress of the students, as well as their understanding of the visited learning materials?

All tracking events will provide a report with the basic information needed to identify a user. Tracking the history of students' logins and participation in learning materials, especially based on the individual school, will help in evaluating the extent of usage and be a basis for motivating teachers and students to use the system.

Assessment is one of the main techniques for checking and monitoring students' level of understanding of the learning materials read (Avgeriou et al., 2003). Learning materials are accompanied by a number of exercises to enable students to assess the knowledge she/he has obtained. The TanSSe-L system provides tracking of student's interactions for this purpose. The system also provides self-test exercises, whereby students will be asked self-test questions relating to selected chapter/topic materials. He/she will answer the questions and send them to the system. The system will return the student's performance and create grading reports for that exercise. The specific objective relating to research question number three was:

SO3: To develop ways of evaluating students' learning progress through the TanSSe-L system, including means of assessment functions

It can be observed that only two needs were identified during requirement analysis, namely the need to have more learning materials and more assessment questions.

However, coming to implementation in order to meet these needs, there are lots of things that need to be considered, all of which have an impact, making it a complex system.

9.1.2 Usefulness of Web-Based Learning Environment

Web-based learning environments have been widely developed and used in many educational institutions and organizations worldwide. You can find many learning institutions fighting hard to secure funding for technology because of its usefulness/effectiveness regarding the whole issue of learning. We cannot compare different ways of learning and teaching on a cost basis, as each way has its own important impact on learning. For example, the traditional way of learning cannot be replaced, and will not probably be replaced by web-based learning, that is why a number of face-to-face sessions are being organized in distance or open learning programs to emphasize the importance of the traditional way of learning. A blended mode of learning is very important, especially now when the world is imposing the use of technology on education. Opinion concerning this is to focus on the effectiveness or usefulness of applying Web-based learning to Tanzania secondary schools as follows:-

- Normally the content of subjects changes frequently, causing the textbooks we rely on to become rapidly outdated. It is easy to find several subjects' either lacking or having outdated, in a four-year-old textbooks. Due to this, textbook publishers are obligated to create a number of new editions each year for just a small portion of added content. In turn, this forces students to purchase their textbook copies frequently, hence making them very expensive. With the Web-based environment, outdated areas can easily be updated and new ones easily added.
- Opportunities for interaction between teachers and students or between students need no longer be limited to class hours. The idea is that a teacher can reach students in remote locations, which enables them to learn subjects to which they wouldn't otherwise have access, especially in cases where there are not enough teaching staff. Some face-to-face sessions with teachers nearby can be organized for this kind of school with few teachers.
- Publication of learning materials through the Web-based environment is less expensive than the production of regular textbooks. It provides many illustrations and uses color and animation in a number of interactive materials. Sharing on-line learning materials and collaboration among users are the key strengths of Web-based learning. However, many books are teacher-led compared to student-centered offered in the Web based learning environment.

9.1.3 Experience of Focus Group Discussion

Fear of change from the traditional way of doing things to the modern way is in many people. School teachers at first showed their true feelings about the fear of losing their

jobs, thinking that they will not be needed when ICT applications in education are introduced. 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. The fear of losing control in the classroom or even employment was reduced during these discussions. The students' registration database developed for Wali-ul-Asr Girls' Seminary, as briefly indicated in sub-section 2.3.1.2, created a good relationship and trust between the researchers and school staff.

The significance of focus group discussion as advocated by participatory action research methodology is crucial, not only in social and medical sciences, but even in information systems development. 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. Knowing how the power of ICT can be used effectively to improve social lives in the two pilot schools created a noticeable interest in the technological changes they are employing now.

Experience gained in finding out users' requirements reveals that people are very willing to contribute their views when it comes to how they or the public will benefit. School teachers were free to participate in the development of the TanSSe-L system. Teachers and students were open-minded when identifying problems facing the Tanzanian secondary schools system.

9.1.4 This Research Methodology versus Consulting Work Challenge

There are many misleading concepts that this kind of research work is typical consulting work. Due to this misconception, the research finds it necessary to highlight the difference between action research and consulting work. Baskerville, (1999) states that action research (also known as participatory action research) and consulting differs in five key ways:-

- *Motivation*

Action research is motivated by its scientific prospects, perhaps epitomized in scientific publications. Consulting is motivated by commercial benefits, including profits and additional stocks of proprietary knowledge about solutions to organizational problems.

- *Commitment*

Action research makes a commitment to the research community for the production of scientific knowledge, as well as to the client. In a consulting situation, the commitment is to the client alone.

- *Approach*

Collaboration is essential in action research because of its idiographic assumptions. Consulting typically values its "outsiders," unbiased viewpoints, providing an objective perspective on organizational problems.

- *Foundation for recommendations*

In action research, the foundation is a theoretical framework. Consultants are expected to suggest solutions that, in their experience, proved successful in similar situations.

- *Essence of organizational understanding*

In action research, organizational understanding is founded on practical success from iterative experimental changes in the organization. Typical consultation teams develop an understanding through their independent critical analysis of the problem.

In summary, consultants are usually paid to dictate experienced, reliable solutions based on their independent review. Action researchers act out of scientific interest to help the organization itself to learn by formulating a series of experimental solutions based on an evolving, untested theory (Baskerville, 1997). Baskerville, (1999) states that action research, was explicitly introduced to the information system community purely as research methodology by Wood-Harper in 1985.

9.2 Main Research Contributions

9.2.1 Academic Contribution

The development of an interactive e-Learning Management System for Tanzanian secondary schools (TanSSe-L system) incorporated a number of methodologies:-

(a) *Triple Helix and Knowledge Production*

This research contributes an approach to the development of methods for triple helix research in close corporation with secondary schools and other stakeholders. The research brings together academia, the government and community to solve specific problem. It has developed OSS and applications in a knowledge production context. The work has taken part in efforts to situate research in its specific context through the integration of interviews and action research efforts with advanced software development.

(b) *OOSA &D, MDA and PAR*

The contribution to this is in showing on how to effectively exploit the power of modelling as applied by OOSA&D and MDA using UML together with participatory action research methodology (specifically focus group discussion) in real-time development of the software. Motivation has been on using UML for modelling, while designing a system based on software engineering, as a norm to the engineering disciplines.

Integration of OOSA&D and MDA has been a noticeable methodology used in this research. To get a well-formed flow of using both approaches, each conceptual frame-

work layer of the MDA was related to the SDLC phase of the OOSA&D. Figure 2.2 in Chapter 2 has clearly shown this. This relationship was used throughout this work and it accelerated the development of the TanSSe-L system PIM, which was later transformed into the TanSSe-L system-specific PIM and finally the TanSSe-L system PSM.

It can be seen that the requirement specifications for the TanSSe-L system that was developed were contextually specific to Kibaha Secondary School and Wali-ul-Asr Girls' Seminary. Modelling was used to communicate key system characteristics to various stakeholders in the Tanzanian education system at the pilot schools and Mo-EVT (students, teachers, headmaster/headmistress and Ministry officials). Action research methodology is not a common technique for solving problems, especially in the Tanzania context. Though the participatory action research methodology may be studied theoretically during research methodology courses, many people still do not use it in real life, by involving users in context-based problem solving. The TanSSe-L system that was developed is a role model of the application of focus group discussion, inspired by participatory action research methodology, the use of which will be promoted in the department of ECSE.

The approach using OOSA&D with UML in developing a functioning system like TanSSe-L is a new methodology to be introduced in the department of Electrical and Computer System Engineering and the CoET as a whole. For a long time now only one approach has been employed, that is using a structured approach to system analysis and design. Many non-Governmental and Government organizations are employing software engineering for their business applications. With this new methodology, CoET will be able to assist the Government and public in related work. Having various software development methodologies, the department of ECSE could easily establish a software engineering section, which does not exist as well as establish a new research area for software engineering at the department.

One of the obligations of higher learning institutions is to disseminate knowledge to others. Being a lecturer in the department of ECSE, CoET, this work's contribution to the CoET will be through building the capacity of learners and trainers in this area.

(c) *Customization of Open Source LMS*

The use of OOS has recently started to be employed by the UDSM community and other higher learning institutions in Tanzania. UDSM, for many years, has been using Blackboard LMS which is a commercial platform. Due to its high cost UDSM is now customizing open source LMS (Moodle) to replace Blackboard after completion. The usage of OSS is now being extended to the level of secondary education system in Tanzania by customizing Moodle open source LMS as a TanSSe-L system. Employing OSS in secondary schools is commendable, and this research is transforming Moodle open source LMS which is mainly used by higher learning institutions to make it suit lower levels of education. There are several areas in which Moodle needs to be customized in order to suit the Tanzanian secondary school context, such as terminologies used, information needed to identify a user and a subject and having Tanzanian sec-

ondary schools scattered in different regions and districts, all need to be, accordingly, customized. Having this kind of open source customization gives added value and can be applied in any context, apart from higher institution level, in the country.

(d) *Inclusion of OS LMS Customization in SDLC*

System development life cycle is described in terms of a set of activities that are needed to transform users' requirements into a product. In other words we can say that various activities that are put together to develop system products are referred to as SDLC. In system analysis and design terminology or in software engineering, SDLC is the same as the software development life cycle.

SDLC has well defined phases to follow for producing a software application. This research has included the involvement of open source customization in developing the TanSSe-L system. The research developed a TanSSe-L database structure to represent the Tanzanian secondary school context. It then, did a thorough evaluation of an open source LMS in accordance with the TanSSe-L system DCD. The areas needing to be customized were recorded and used as a guide during the implementation phase, when customization of the Moodle LMS was done.

Many of the existing open source LMS platforms can support the basic functions needed for the e-learning process, but a detailed evaluation of the specific areas needed to be customized has to take place. The idea is not to start customizing an open source LMS without knowing the specific context of the organization in detail.

9.2.2 Contribution to the Public

(a) *International Conference and Journal Papers*

Two papers were presented at international conference proceedings of the World Academy of Science, Engineering and Technology and later included in the International Journal of Social Sciences. As indicated in appendix C "Summary of Journal Papers" of this thesis, the first paper is titled "An Interactive e-Learning Management System (e-LMS): A Solution to Tanzanian Secondary Schools' Education" and the second paper is titled "Strategies for Developing e-LMS for Tanzania Secondary Schools". The materials are available publicly as references.

(b) *Licentiate Dissertation Book*

Kalinga, (2008) wrote a licentiate dissertation book titled "Development of an Interactive e-Learning Management System (e-LMS) for Tanzanian Secondary Schools". It was published by Blekinge Institute of Technology in 2008 with the Serial No. 2008:03, ISSN 1650-2140 and ISBN 978-91-7295-134-1 for the public to read and refer.

(c) *Open Source Community*

Modified source codes for the TanSSe-L system will enter into the open source world that anyone can modify and reuse them in the same way this work has customized

Moodle open source LMS to get the TanSSe-L system. This is a contribution to an open source community. Customization of open source LMS platforms was used to develop a system which is optimally fitted to the specific context of Tanzania secondary schools. Any organization with a similar context will be free to use the customized codes in the TanSSe-L system.

(d) *TanSSe-L System for Tanzania Secondary Schools*

The TanSSe-L system is a special donation to Kibaha Secondary School and Wali-ul-Asr Girls' Seminary, and hopefully later on to all Tanzanian secondary schools. It is the first one to be introduced and developed so far. The TanSSe-L system is a quality product engineered in our environment. Tanzania secondary school stakeholders from the pilot schools and later on in the whole Tanzania are free to use it.

9.3 Recommendations

(a) *TanSSe-L System Needs Consistent Support*

The use of the TanSSe-L system will provide new knowledge to most Tanzanian secondary schools. The application of ICT technology in real life application to human beings is a world-wide movement, so Tanzanian should make sure it is not left behind. The TanSSe-L system can be a starting point in its own way for employing ICT to Tanzania secondary education. However, the TanSSe-L system needs support to make it sustainable, especially, from the Government through the MoEVT. Support must be in terms of providing basic resources to Tanzania secondary schools, such as computers, projectors, electricity, frequent training in ICT for secondary school staff, employing ICT technical staff to support and solve any ICT-related problems at secondary schools, financial support for running ICT-related courses at secondary schools and things which may be relevant to make sure that ICT is comfortably applied in Tanzanian secondary schools. There have been many well established projects which vanish immediately after donors stop funding them due to the lack of basic and sustainable support, which the Government could provide. The time has reached for the Government to intentionally change on this behaviour.

(b) *Improve Working Environment of Rural Secondary Schools*

Currently, the Government has been putting extra effort to raise the funds to train more teachers at higher levels up to degree level. In future, we anticipate that number of secondary school teachers in Tanzania will rise. The TanSSe-L system needs skilled teachers for its effective usage in teaching and learning. The Government is obligated to improve the working environment, especially, in rural secondary schools so that teachers there will not run away to find and join private secondary schools, mainly in urban areas.

(c) *Adoption of Hybrid Mode of Learning*

The Government is also focusing on publishing more textbooks for secondary schools. The World Bank, (2008) states that up to 2004, all secondary school books had been

developed by the Tanzania Institute of Education on a monopoly basis. The books were state published and supplied as part of a programme for all Government and community secondary schools in agreed quantities. Little or no funding was made available to schools to buy any other books which may be relevant to the curriculum. This has led to a serious shortage of essential books. However, the Government has realized that the lack of textbooks is a problem, and has started to produce more textbooks especially for science and mathematics subjects. The Government has opened the door to private publishers to produce books. Tanzania should now promote the hybrid mode of learning where the use of ICT in education is included, instead of relying solely on textbooks and face-to-face learning.

(d) Mode 2 Approach to Knowledge Generation

This research has been done in the context of the problem. It is a problem-driven research. It is not the traditional way of doing research by academia. The research involved different stakeholders; students; teachers; school headmistresses/headmasters; MoEVT officers; the research group from UDSM BTH in Sweden and focus group discussion. It is evident that knowledge production also takes place in the context of application, not at universities only. Therefore, UDSM should now acknowledge the use of the mode 2 approach for knowledge generation.

9.4 Future Direction

(a) Evaluation of Learning Process to Improve Performance

The overall objective of the ICT for e-Learning project was to “improve the quality of Mathematics and Science education in secondary schools in the rural areas of Tanzania”. The strategy for implementing this was based on the introduction of ICT use to support Tanzania secondary schools in the teaching and learning functions and consequently improve the performance of schools, students being the a primary target. Usage of the TanSSe-L system and performance improvement will not be noticed in a short time; ample time is needed. Tanzanian secondary school stakeholders need to adopt and use the TanSSe-L system effectively; starting from the date it was installed. Tanzanian secondary school stakeholders need to be closely and consistently supported, helped and motivated when employing new knowledge.

The TanSSe-L system has provided a number of tracking reports for the usage status of students, usage logs, examined student grades, etc, which can be a starting point for evaluating the learning process. However, many findings indicate that online, Web-based learning environments are not sufficient. Employing such a system to complement lectures yields measurable enhancements. We need to evaluate actual reading behaviour and regularity in the learning process. We need to evaluate how usage of the system will affect students’ learning.

(b) Extension of TanSSe-L System to Other Secondary Schools

As stated previously, Kibaha Secondary School and Wali-ul-Asr Girls' Seminary were the two pilot sites selected for the development stage. In reality the TanSSe-L system is needed by all other Tanzania secondary schools registered with the MoEVT. The TanSSe-L system, therefore, needs to be extended to other secondary schools as well. Expansion can be in phases, by grouping schools into clusters so that schools can share the resources available. Expansion will need more resources like servers, LANs for individual schools and computers.

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APPENDIX A: TanSSe-L SYSTEM OPERATION CONTRACTS

There are a number of TanSSe-L system operations identified from system sequence diagrams in Chapter 5: TanSSe-L System Requirement Specifications and Analysis. Only four operation contracts were included in the chapter, while some more few selected operation contracts are included in this appendix “A” as shown in Table A.01 through A.15.

Table A.01: Contract for “logout()” operation	
Name:	<i>Logout (username, password)</i>
Responsibilities:	Disconnect the user with the given login information from the system. If logout is successful, record the logout information
Type:	System
Cross References:	System function: F8, F18, F19 Use case: login/logout
Note:	Use relational SQL database access
Exceptions:	If the system fails to logout the user display an error message
Output:	Display TanSSe-L system home page
Pre-conditions:	User login information is known to the system
Post-conditions:	<ul style="list-style-type: none"> The <i>LogInOutRec.LogoutTimeStamp</i> was set to current date and time (attribute set) The <i>User.Status</i> was set to Inactive (attribute modification)

Table A.02: Contract for “registerUser()” operation	
Name:	<i>registerUser(userID, username, password, role, gender, email)</i>
Responsibilities:	If the given information is valid create a new user and record the information into user object
Type:	System
Cross References:	System function: F2, F3 Use case: Register system users
Note:	Use relational SQL database access
Exceptions:	If the entered information is not correct, stop recording and display the error message
Output:	Display list of system users
Pre-conditions:	The identified information for the privileged user to create user is known to the system
Post-conditions:	<ul style="list-style-type: none"> A new user was created (instance creation) The new user was associated with the <i>e-LMS</i> object (association formed) A <i>registerUser.Date</i> was set to current date (attribute set)

Table A.03: Contract for “ <i>updateUser()</i> ” operation	
Name:	<i>updateUser(userID, username, password, role, gender, email)</i>
Responsibilities:	Find a user with the given information from user database, allow update of the information and record the update information into user database.
Type:	System
Cross References:	System function: F2, F3 Use case: View/update particulars
Note:	Use relational SQL database access
Exceptions:	If the entered user information is not correct stop recording and display the error message
Output:	Display list of system users
Pre-conditions:	The identified information for the privileged user to create/update user is known to the system
Post-conditions:	<ul style="list-style-type: none"> The <i>userRecord</i> was modified (instance modification)

Table A.04: Contract for “ <i>registerSubjectUser()</i> ” operation	
Name:	<i>registerSubjectUser(userID, subjectCode, formID, regDate)</i>
Responsibilities:	Find the user and the subject. If the given information is valid create a new subject user and record the information into subjectUser object
Type:	System
Cross References:	System function: F6, F7 Use case: Register users to subject
Note:	Use relational SQL database access
Exceptions:	If the entered information is not correct, stop recording and display the error message
Output:	
Pre-conditions:	User and subject are registered into a system and the identified information for privileged user to register users to subjects is known to the system
Post-conditions:	<ul style="list-style-type: none"> A new <i>subjectUser</i> was created (instance creation). The new <i>subjectUser</i> object was associated with the <i>subject</i> object (association formed) The new <i>subjectUser</i> object was associated with the <i>user</i> object (association formed) The new <i>subjectUser</i> object was associated with the <i>e-LMS</i> object (association formed) The <i>subjectUser.RegisterDate</i> was set to current date(attribute set)

Table A.05: Contract for “ <i>selectSubjectChapter()</i> ” operation	
Name:	<i>selectSubjectChapter(chapterNo, chapterTitle)</i>
Responsibilities:	Find chapter of a subject with the chapterNo, and chapterTitle information from the chapter object. If the chapter is found, display links to the chapter components: chapter document notes, chapter topics, chapter extra exercises, self test questions and chapter exercise solutions. Also record the chapter interaction into <i>chapTrachRec</i> object
Type:	System
Cross References:	System function: F14, F15 Use case: View/download learning materials, View/download assessment activities
Note:	Use relational SQL database access
Exceptions:	If the entered subject chapter information is not correct display the error message
Output:	
Pre-conditions:	Subject chapter information is known to the system
Post-conditions:	<ul style="list-style-type: none"> • A <i>chapter</i> object was associated with <i>chapTopic</i> object (association formed) • A <i>chapter</i> object was associated with <i>chapExtraExerc</i> object (association formed) • A <i>chapter</i> object was associated with <i>selfTestQuest</i> object (association formed) • A <i>chapter</i> object was associated with <i>chapExerSoln</i> object (association formed) • A <i>chapter</i> object was associated with learning material <i>repository</i> object (association formed) • A <i>chapTrackRec</i> was created (instance creation) • The new <i>chapTrackRec</i> was associated with the <i>InteractionController</i> object (association formed) • The <i>ChapTrackRec.visitTimeStamp</i> for keeping interaction record was set to current date and time (attribute set).

Table A.06: Contract for “ <i>selectPastPaper</i> ” operation	
Name:	<i>selectPastPaper(subjectCode, paperID,)</i>
Responsibilities:	Find subject past paper with the given information from the pastPaper object. If the past paper is found, record the user interaction with past paper and display past paper document
Type:	System
Cross References:	System function: F17, F24, F25 Use case: View/download assessment activities
Note:	Use relational SQL database access
Exceptions:	If the entered past paper information is not correct and the past paper is not found display the error message
Output:	Selected past paper content

Pre-conditions:	Past paper information is known to the system
Post-conditions:	<ul style="list-style-type: none"> • PastPaper object was associated to learning material repository object (association formed) • A pastPaperTrackRec was created (instance creation) • The new pastPaperTrackRec was associated with the InteractionController object (association formed) • The pastPaperTrackRec.visitTimeStamp for keeping interaction record was set to current date and time (attribute set)

Table A.07: Contract for “selectSelfTestExerc” operation	
Name:	<i>selectSelfTestExerc(exercNo, chapNo, subjectCode, form)</i>
Responsibilities:	Find self test exercise with the given information from the selfTestExerc object. If the self test exercise is found, record the user interaction and display self test exercise sheet
Type:	System
Cross References:	System function: F17, F24, F25 Use case: View/download assessment activities
Note:	Use relational SQL database access
Exceptions:	If the entered self test information is not correct and the self test exercise is not found display the error message
Output:	Display self test exercise
Pre-conditions:	Self test exercise information is known to the system
Post-conditions:	<ul style="list-style-type: none"> • A <i>selfTestTrackRecord</i> was created (instance creation) • <i>selfTest</i> object was associated with learning material <i>repository</i> object (association formed) • The new <i>selfTestTrackRec</i> was associated with the <i>InteractionController</i> object (association formed) • The <i>selfTestTrackRecord.visitTimeStamp</i> for keeping interaction record was set to current date and time (attribute modification)

Table A.08: Contract for “makeAnswer()” operation	
Name:	<i>makeAnswers(QuestionNo, ExercNo, ChapterNo, , SubjectCode, Form)</i>
Responsibilities:	Provide the student with the selected self test exercise and the corresponding exercise answer sheet for the self test exercise
Type:	System
Cross References:	System function: F17, F24, F25 Use case: View/download assessment activities, send answers, view personal performance report
Note:	Use relational SQL database access
Exceptions:	If the entered information is not correct or not found display the error message
Output:	Display performance report for the exercise

Pre-conditions	Chapter self test exercise information and the answer sheets information are known to the system
Post-conditions:	<ul style="list-style-type: none"> • An <i>selfTestExercRecord</i> was created (instance creation) • The <i>answerSheet</i> object was associated with <i>selfTest</i> object (Association formed) • The new <i>selTestTrackRec</i> was associated with the <i>InteractionController</i> object (association formed) • The <i>selfTestTrackRec.visitTimeStamp</i> for keeping interaction record was set to current date and time (attribute set)

Table A.09: Contract for “ <i>createSubjectChapter()</i> ” operation	
Name:	<i>createSubjectChapter(chapterNo, subjectCode, form, chapTitle)</i>
Responsibilities:	If the given information is valid create a new subject chapter and record the information into chapter object.
Type:	System
Cross References:	System function: F4, F5 Use case: create/update subject
Note:	Use relational SQL database access
Exceptions:	If the entered subject chapter information is not correct, stop recording and display the error message
Output:	
Pre-conditions:	The concerned subject and the identification information for the permitted user to create/update subject is known to the system
Post-conditions:	<ul style="list-style-type: none"> • A new subject <i>chapter</i> was created (instance creation). • The new <i>chapter</i> was associated with the <i>subject</i> object (association formed). • The <i>Chapter.DateCreate</i> was set to current time (attribute modification) • The <i>Chapter.Status</i> was set to Active (attribute modification)

Table A.10: Contract for “ <i>createChapterTopic()</i> ” operation	
Name:	<i>createChapterTopic(TopicNo, chapterNo, subjectCode, form, topicTitle, createDate)</i>
Responsibilities:	If the given information is valid create a new chapter topic and record the information into chapterTopic object
Type:	System
Cross References:	System function: F4, F5 Use case: create/update subject
Note:	Use relational SQL database access
Exceptions:	If the entered chapter topic information is not correct and/or incomplete, stop recording and display the error message
Output:	

Pre-conditions:	The concerned subject, concerned chapter The identified information for the permitted user to create/update subject are known to the system
Post-conditions:	<ul style="list-style-type: none"> • A new <i>chapterTopic</i> was created (instance creation). • The new <i>chapterTopic</i> was associated with the <i>chapter</i> object (association formed). • The <i>ChapterTopic.DateCreate</i> was set to current time (attribute modification).

Table A.11: Contact for “updateSubject()” operation	
Name:	<i>updateSubject(subjectCode, form)</i>
Responsibilities:	Find a subject with the given information from the database, allow update of the information and record the update information
Type:	System
Cross References:	System function: F4, F5 Use case: create/update subject
Note:	Use relational SQL database access
Exceptions:	If the entered subject information is not correct stop recording and display the error message
Output:	
Pre-conditions:	The identification information for the permitted user to create/update subject is known to the system
Post-conditions:	<ul style="list-style-type: none"> • The <i>subjectRecord</i> was modified (instance modification) • The <i>subject.UpdateDate</i> was set to current time (attribute set).

Table A.12: Contact for “updateSubjectChapter()” operation	
Name:	<i>updateSubjectChapter(chapterNo, subjectCode, form)</i>
Responsibilities:	Find a subject chapter with the given information from the database, allow update of the information and record the update information
Type:	System
Cross References:	System function: F4, F5 Use case: create/update subject
Note:	Use relational SQL database access
Exceptions:	If the entered subject chapter information is not correct stop recording and display the error message
Output:	
Pre-conditions:	The identification information for the permitted user to create/update subject is known to the system
Post-conditions:	<ul style="list-style-type: none"> • The <i>subjectchapterRecord</i> was modified (instance modification) • The <i>subjectChapter.ModifyDate</i> was set to current time (attribute set).

Table A.13: Contact for “ <i>updateChapterTopic()</i> ” operation	
Name:	<i>updateChapterTopic(TopicNo, chapterNo, subjectCode, form)</i>
Responsibilities:	Find a chapter topic with the given information from the database, allow update of the information and record the update information
Type:	System
Cross References:	System function: F4, F5 Use case: create/update subject
Note:	Use relational SQL database access
Exceptions:	If the entered chapter topic information is not correct and/or incomplete, stop recording and display the error message
Output:	
Pre-conditions:	The identification information for the permitted user to create/update subject is known to the system
Post-conditions:	<ul style="list-style-type: none"> The <i>chapterTopicRecord</i> was modified (instance modification) The <i>ChapterTopic.UpdateDate</i> was set to current time (attribute set).

Table A.14: Contact for “ <i>getUserList()</i> ” operation	
Name:	<i>getUserList(userID, username, role, gender, email)</i>
Responsibilities:	Find all users of the system from user object. It can be all users or categorized users based on role, school etc and display the list of users
Type:	System
Cross References:	System function: F30 Use case: Get list of users
Note:	Use relational SQL database access
Exceptions:	If the system fails to display user list, stop and display the error message
Output:	
Pre-conditions:	Users are registered into the system and the identified information for the privileged user to view user list is known to the system
Post-conditions:	<ul style="list-style-type: none"> A <i>user</i> object is associated to <i>e-LMS</i> object (association formed).

Table A.15: Contact for “ <i>getSubjectList()</i> ” operation	
Name:	<i>getSubjectList(subjectCode, form, name, category, RegDate)</i>
Responsibilities:	Find subjects registered into the system from subject object. It can be all subjects or categorized subjects based on category, form, registration date etc and display the list of subjects
Type:	System
Cross References:	System function: F31 Use case: Get list of subjects
Note:	Use relational SQL database access

Excep- tions:	If the system fails to display subject list, stop and display the error mes- sage
Output:	
Pre-conditions:	Subjects are registered into the system and the identified information for the privileged user to view user list is known to the system
Post-conditions:	A <i>subjectController</i> object was associated with the <i>e-LMS</i> object (associa- tion formed).

APPENDIX B: TanSse-L SYSTEM COLLABORATION DIAGRAMS

Figures B.1 through B.8 shows some more created collaboration diagrams for TanSse-L system operations.

(a) Collaboration Diagram for “registerUser()” System Operation

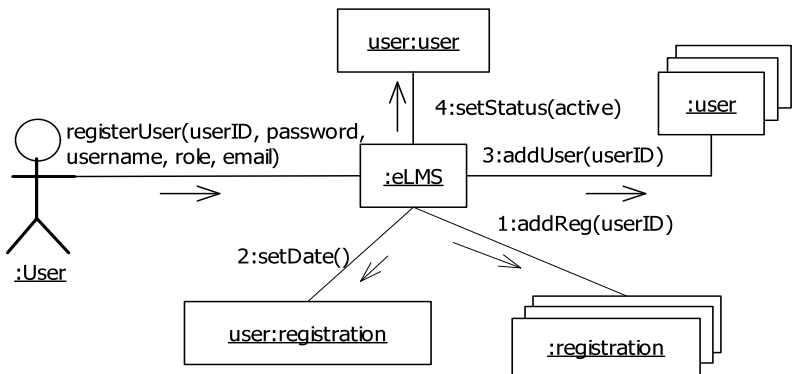


Fig. B.1: Collaboration Diagram for “registerUser()” System Operation

(b) Collaboration Diagram for “logout()” System Operation

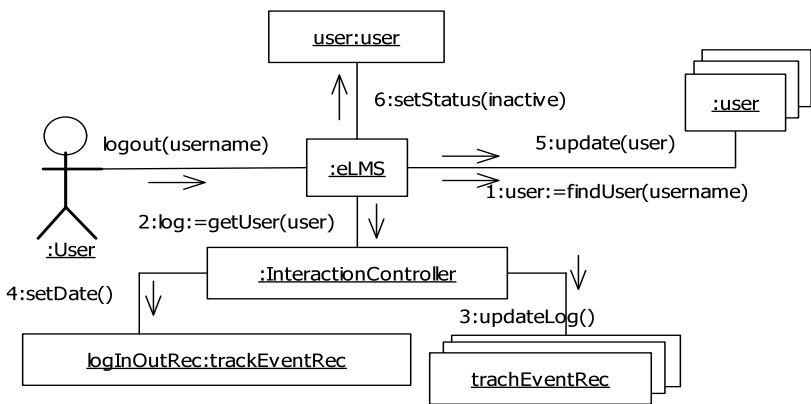


Fig. B.2: Collaboration Diagram for “logout()” System Operation

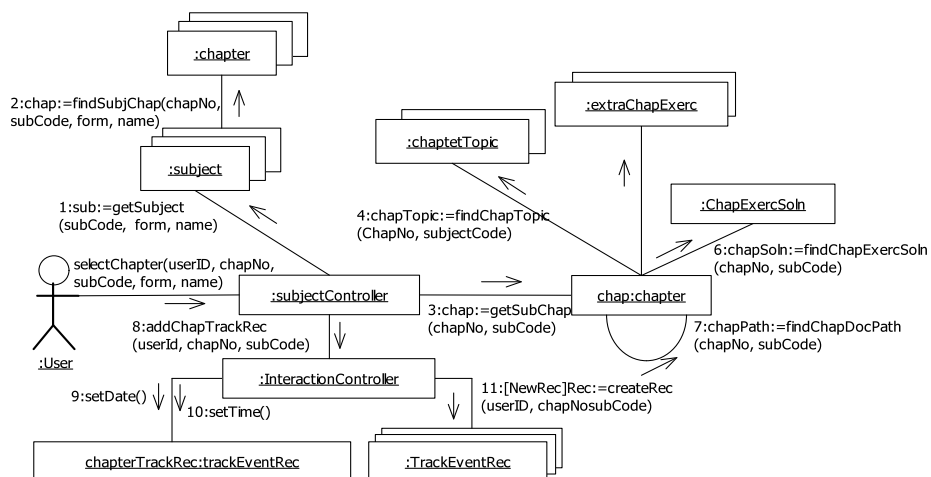
```

sequenceDiagram
    actor User as :User
    participant SC as :subjectController
    participant S as :subject
    participant CH as :chapter

    User->>SC: createChapTopic(TopicNo, ChapNo, subjectCode, form)
    SC->>CH: 3:createChapTopic(chapNo, subjectCode, form)
    CH->>SC: 3:setCreateDate()
    SC->>S: 1:subj:=getSubject(subjectCode, form, name)
    S->>CH: 2:chap:=getSubjChap(chapNo, subjectCode, form, name)
  
```

The diagram illustrates the sequence of interactions for the `createChapTopic()` operation. It involves a `:User` actor, a `:subjectController` participant, and two entity participants, `:subject` and `:chapter`. The process begins with the user sending a `createChapTopic(TopicNo, ChapNo, subjectCode, form)` message to the `:subjectController`. The controller then sends a `3:createChapTopic(chapNo, subjectCode, form)` message to the `:chapter` entity. In response, the `:chapter` entity sends a `3:setCreateDate()` message back to the `:subjectController`. Subsequently, the controller sends a `1:subj:=getSubject(subjectCode, form, name)` message to the `:subject` entity. Finally, the `:subject` entity sends a `2:chap:=getSubjChap(chapNo, subjectCode, form, name)` message to the `:chapter` entity.

(d) Collaboration Diagram for “selectSubChapter()” System Operation



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(e) Collaboration Diagram for “selectPastPaper()” System Operation

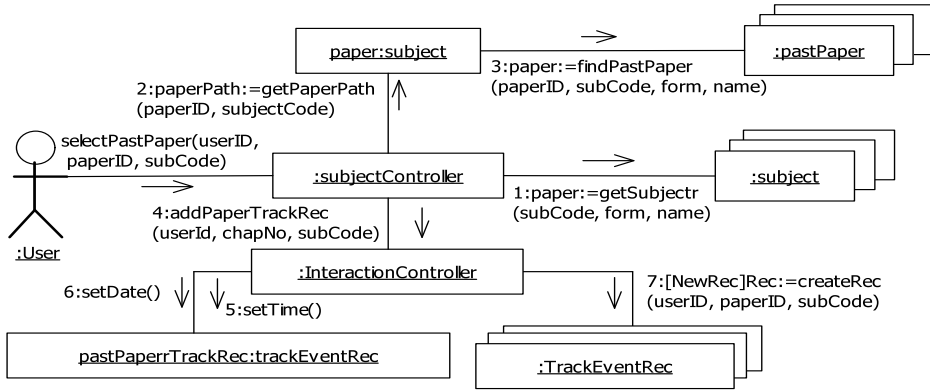


Fig. B.5: Collaboration Diagram for “selectPastPaper()” System Operation

(f) Collaboration Diagram for “selectSelfTestExerc()” System Operation

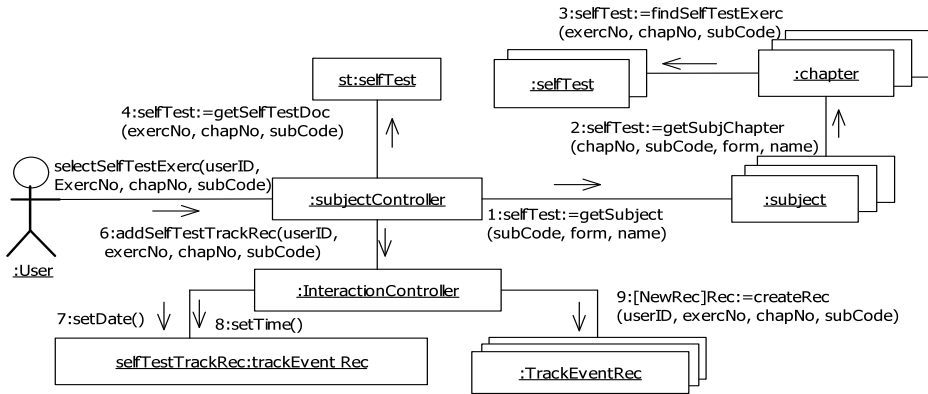


Fig. B.6: Collaboration Diagram for “selectSelfTestExerc()” System Operation

(g) Collaboration Diagram for “makeAnswers()” System Operation

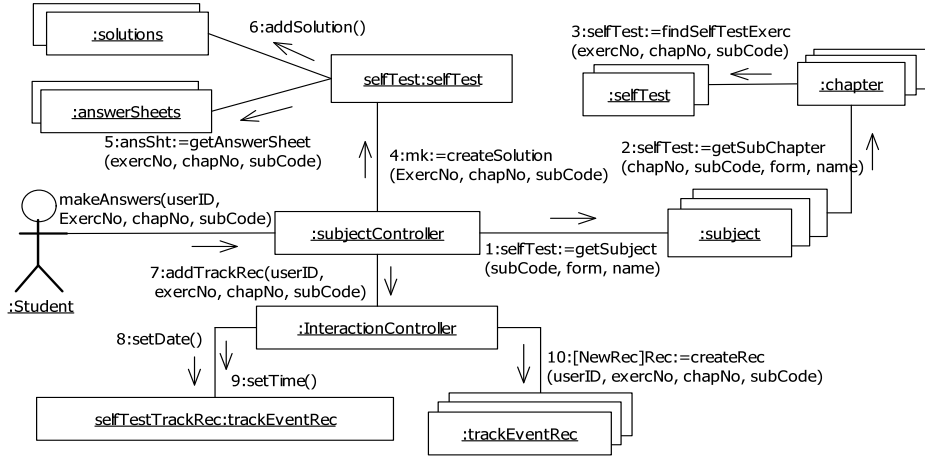


Fig. B.7: Collaboration Diagram for “makeAnswers()” System Operation

(h) Collaboration Diagram for “getUseList()” System Operation

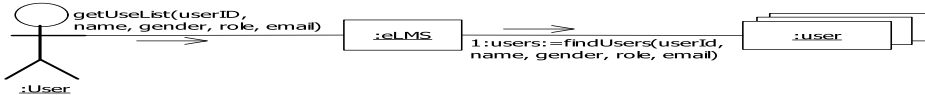


Fig. B.8: Collaboration Diagram for “getUseList()” System Operation

APPENDIX C: CONFERENCE AND JOURNAL PAPERS

Two papers were presented at international conferences and were included in International Journals as follows:-

Paper I: “An Interactive e-Learning Management System (e-LMS): A Solution to Tanzanian Secondary Schools’ Education”

Abstract— Information and Communications Technologies (ICT) has been integrated in education in many developing and developed countries alike, but the use of ICT in Tanzanian schools is dismal. Many Tanzanian secondary schools have no computers. The few schools with computers use them primarily for secretarial services and computer literacy training.

The Tanzanian education system at other levels like secondary school level has to undergo substantial transformation, underscored by the growing application of new information and communication technology. This paper presents the e-readiness survey result from secondary schools in Tanzania. The paper also suggests how Tanzania can make use of the few present ICT resources to support and improve teaching and learning functions to improve performance and acquisition of knowledge by using e-Learning Management System (e-LMS).

Keywords— e-Learning, ICT, Object-Oriented, Participatory design,

Presentations:

“An Interactive e-Learning Management System (e-LMS): A Solution to Tanzanian Secondary Schools’ Education” was presented on May 2007 and included in the conference proceedings of World Academy of Science, Engineering and Technology (WASET), 21st International Conference on Computer, Electrical, and Systems Science, and Engineering, CESSE, Volume 21, May 2007, Vienna, Austria, ISBN 978-975-01752-0-6.

“An Interactive e-Learning Management System (e-LMS): A Solution to Tanzanian Secondary Schools’ Education” paper was included in World Academy of Science, Engineering and Technology (WASET), International Journal of Social Sciences Volume 1 Number 4, Pages 250 – 253.

Paper II: “Strategies for Developing e-LMS for Tanzanian Secondary Schools”

Abstract— Tanzania secondary schools in rural areas are geographically and socially isolated, hence face a number of problems in getting learning materials resulting in poor performance in National examinations. E-learning as defined to be the use of information and communication technology (ICT) for supporting the educational processes has motivated Tanzania to apply ICT in its education system. There has been effort to improve secondary school education using ICT through several projects.

ICT for e-learning to Tanzania rural secondary school is one of the research projects conceived by the University of Dar-es-Salaam through its College of Engineering and Technology. The main objective of the project is to develop a tool to enable ICT support rural secondary school.

The project is comprehensive with a number of components, one being development of e-learning management system (e-LMS) for Tanzania secondary schools. This paper presents strategies of developing e-LMS. It shows the importance of integrating action research methodology with the modelling methods as presented by model driven architecture (MDA) and the usefulness of Unified Modelling Language (UML) on the issue of modelling. The benefit of MDA will go along with the development based on software development life cycle (SDLC) process, from analysis and requirement phase through design and implementation stages as employed by object oriented system analysis and design approach. The paper also explains the employment of open source code reuse from open source learning platforms for the context sensitive development of the e-LMS for Tanzania secondary schools.

Keywords—Action Research Methodology, OOSA&D, MDA, UML, Open Source LMS.

Presentations:

“Strategies for Developing e-LMS for Tanzanian Secondary Schools” was presented on October 2007 and included in the conference proceedings of World Academy of Science, Engineering and Technology (WASET), 26th International Conference on Computer, Electrical, and Systems Science, and Engineering, CESSE, Volume 24, October 2007, Nice, France, ISSN 1307 – 6884. This paper presents strategies of developing e-LMS.

“Strategies for Developing e-LMS for Tanzanian Secondary Schools” paper was included in World Academy of Science, Engineering and Technology (WASET), International Journal of Social Sciences, Volume 2, Number 3, Pages 145 – 150.

ABSTRACT

e-Learning, defined as the use of information and communications technology (ICT) for supporting the educational process, has motivated Tanzania to apply ICT in its education systems. Tanzanian secondary schools which are geographically and socially isolated face a number of problems, including a way to get learning materials. The impact of these problems is poor performance in National Examinations. This poor performance however is most noted in science and mathematics. The problem in getting learning materials can be reduced by employing ICT.

This research developed an interactive e-learning management system (e-LMS) to be used by Tanzanian secondary schools. Tanzania Secondary Schools e-Learning (TanSSe-L) system is the name adopted for an interactive e-LMS developed. The research is aimed at supporting teaching and learning functions by allowing for the creation and storage of learning materials, making them available, easily accessed and sharable by students from different secondary schools in Tanzania. It is a contextdriven research work of knowledge production in a specific context for application. Initially, the research work focused on two selected pilot schools; Kibaha Sec-

dary School and Wali-ul-Asr Girls' Seminary in Kibaha town, Pwani region. Features of the TanSSe-L system represent the standard form of any secondary school registered by the Ministry of Education and Vocational Training.

The development of the TanSSe-L system made use of software engineering discipline. The research used Unified Modelling Language (UML) and integrated Object-Oriented System Analysis and Design (OOSA&D) and Model Driven Architecture (MDA) to address the System Development Life Cycle (SLDC) in a systemic way. UML design class diagram (DCD) is a Platform Independent Model (PIM) that was transformed into a Platform Specific Model (PSM) in MDA for implementation. Implementation made use of open source LMS to help generate a timely solution to TanSSe-L system development. In this specific context, focus group discussion as inspired by action research methodology was used. The research evolved into a triple helix process in close cooperation with other stakeholders. Finally, it is considered that replication and mirroring will make learning materials highly available to end-users.

