Hybrid E-learning for Rural Secondary Schools in Uganda,

Co-evolution in Triple Helix Processes

Peter Okidi Lating

Blekinge Institute of Technology Doctoral Dissertion Series
No 2009:01
ISSN 1653-2090
ISBN 978-91-7295-158-7

Hybrid E-learning for Rural Secondary Schools in Uganda,
Co-evolution in Triple Helix Processes

Peter Okidi Lating

School of Technoculture, Humanities and Planning
Division of Technoscience Studies
Blekinge Institute of technology
Sweden

Blekinge Institute of Technology

Blekinge Institute of Technology, situated on the southeast coast of Sweden, started in 1989 and in 1999 gained the right to run Ph.D programmes in technology. Research programmes have been started in the following areas:

Applied signal processing
Computer science
Computer systems technology
Development of Digital Games
Human work science with a special focus on IT
Interaction Design
Mechanical engineering
Software engineering
Spatial planning
Technosicence studies
Telecommunication systems

Research studies are carried out in faculties and about a third of the annual budget is dedicated to research.

Blekinge Institue of Technology
S-371 79 Karlskrona, Sweden
www.bth.se

School of Technoculture, Humanities and Planning
Division of Technoscience Studies
Graphic Design and Typesetting: Bildbolaget i Kyrkhult
Publisher: Blekinge Institute of Technology
Printed by Printfabriken, Karlskrona, Sweden 2009
ISBN 978-91-7295-158-7
urn:nbn:se:bth-00424

This work is dedicated to my dear wife, Christine Alanyo, children,
Felix Langol, Atim Joan, Mwaka Stephen, Aredo Joy Goretti
and Okot Samuel, my mother, the late Antonietta Labogi, who succumbed to
pancreatic cancer in January, 2008.

Acknowledgements

I would like to acknowledge the generous financial support I received from Sida/SAREC for purposes of carrying out the PhD research in the remote, poor and insecure rural district of Arua in the West Nile Region of Uganda.

I am extremely grateful for the constant guidance and assistance I received from both supervisors: Dr. Samuel Baker Kucel of Makerere University, Uganda, and Professor Lena Trojer of Blekinge Institute of Technology, Sweden.

Special gratitude is extended to Arua District Local Council which unreservedly offered buildings for housing the ICT Research Center in Arua town. In this regard, Mr. Saibo Kamilo (the Vice Local Council V Chairman), Mr. Stanley Adrabo (formerly the Deputy Chief Administration Officer) and Mr. Dawin Dawa (the District Information Officer) deserve to be individually recognized for their close collaboration with me throughout the period of the study in the District.

It will not be fair if I do not recognize the leadership of the two advanced-level secondary schools for offering the female students who participated in the hybrid e-learning project. Special thanks go to the headmistresses of both schools: Sr. Susan Ndeezo of St. Mary's Ediofe Girls, and Mrs. Margaret Ayiseni of Muni Girls. They fully participated in the integration of e-learning in their schools.

I acknowledge the invaluable contribution made by SchoolNet Uganda and Makerere College School; an elite secondary school in Kampala. SchoolNet Uganda helped to develop ICT pedagogic skills of science teachers in the project schools. It also donated a server with pre-loaded science content for use by both the students and their teachers. The server was used for setting up the digital library for the participating students. Mr. Daniel Kakinda, the Executive Director, SchoolNet Uganda deserves special recognition for this support. Senior teachers of Makerere College School developed content for the hybrid e-learning project. Special thanks go to Mr. Kato Dennis, Head of Department of Physics, Mr. Sairo Sulaiman, a senior Mathematics teacher and Ms. Jennifer Nalule Bbosa, a Physics Laboratory Technician.

It is my pleasure to thank the following staff of Blekinge Institute of Technology for the various supports they rendered to me while in Sweden: Mr. Peter Giger, Dr. Pirjo Elovaara, Dr.Peter Ekdahl, Mr. Silvio Ocasic, Anita Carlsson and Ms Madeleine Persson. From the faculty of Technology, Makerere University, I would like to thank all the colleagues in the faculty for their useful academic interaction throughout the four years of the research activities.

Lastly, I am also indebted to my family especially my wife Ms Christine Alanyo and children (Felix Langol, Atim Joan, Mwaka Stephen, Aredo Joy Goretti and Okot Samuel) for tolerating my long absence from home during the study period.

Table of Contents

LIST OF TABLES

CHAPTER FIVE: PRESENTATION OF RESULTS

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

CHAPTER FIVE: PRESENTATION OF RESULTS

Foreign exchange rate used in this study was 1 USD to 1,575 UGX

Abbreviations/Acronyms used

ADB-African Development Bank
ANOCVA- Analysis of Covariance
ANOVA- Analysis of Variance
AR(1)- First-Order Auroregressive covariance structure
AU- African Union
BEE- Business Education Education certificate.
BTVET- Business, Technical and Vocational Training
CD-ROM- Compact Disk- Read Only Memory
CMS- Course Management System
DFID- Department for International Development (UK)
DRC- Democratic Republic of Congo
ESA- Education Standards Agency
ESC- Education Service Commission
FOT- Faculty of Technology
FSI – Female Scholarship Initiative
GDP – Gross Domestic Product
GIS- Geographical Information System
GOU- Government of Uganda
HIPC – Highly Indebted Poor Country.
HIPC- Highly Indebted Poor Country
HLM- Hierarchical Linear Models
ICC a- International Criminal Court
ICC- Intraclass Correlation Coefficient
ICT – Information and Communication Technologies
ID- Identification of the participants in the project
IDRC- International Development Research Center.
INSET- In-Service Teacher
INSSTEP- In-Service Secondary Teacher Education Project.
ISP- Internet Service Provider
IT – Information Technology
ITU- International Telecommunications Union.
JICA- Japanese International Development Agency.
LAN- Local Area Network
LL- Log Likelihood
LRA – Lord's Resistance Army.
MACOS- Makerere College School
MANOCVA- Multivariate Analysis of Covariance
MANOVA- Multivariate Analysis of Variance
MCT- Multimedia Community Telecenter.
MDG – Millennium Development Goal
MOES- Ministry of Education and Sports.
MOFPED- Ministry of Finance, Planning and Economic Development
MOICT- Ministry of ICT
MTN- Mobile Telecommunications Network
NCDC- National Curriculum Development Center
NCHE- National Council for Higher Education.
NEPAD – New Partnership for African Development
NGO- Non-Governmental Organisations

NTC – National Teachers College
NTC- National Training Coordinator
OAU- Organisation of African Unity
OLS- Ordinary Least Squares
PCM – Physics, Chemistry, Mathematics.
PGDE – Post Graduate Diploma in Education
PLE – Primary Leaving Examinations
POP- Internet point of presence
PRA- Participatory Rural Appraisal
PTA – Parents and Teachers Association
PTC- Primary Teachers College.
RCDF- Rural Communications Development Fund
RRA- Rapid Rural Appraisal
SAREC- The research arm of Sida.
SESEMAP- Secondary Science and Mathematics Project
Sida- Swedish International Development Agency
SSS- Senior Secondary School
SST- Social Studies, a subject in primary schools
STEPU- Science Technology Production Unit
TRC- Teacher Resource Centre
UACE – Uganda Advanced Certificate of Education.
UCC- Uganda Communications Commission
UCE – Uganda Certificate of Education
UGX- Uganda Shillings
UJTC- Uganda Junior Technical Certificate.
UK- United Kingdom
UN- United Nations
UNCST- Uganda National Council for Science and Technology
UNDP – United Nations Development Programme
UNEB – Uganda National Examinations Board.
UNESCO- United Nations Educational, Scientific and Cultural Organisation.
UNHCR – United Nations High Commission for Refugees
UNIDAS- A Spanish organisation
UNIDO- United Nations Industrial Development Organisation
UNRF- Uganda National Rescue Front
UPE – Universal Primary Education.
UPPET- Uganda Post-Primary Education and Training Project
UPTC- Uganda Posts and Telecommunications Corporation
USA- United States of America
USAID- United States Agency for International Development.
USD- United States Dollars
USE – Universal Secondary Education.
UTE- Uganda Technical Education certificate.
UTL- Uganda Telecom Limited
VCR- Video Cassette Recorder.
VSAT- Very Small Aperture Terminal.
WENRECo – West Nile Rural Electrification Company.
WNBF- West Nile Bank Front.
WSIS- World Summit on the Information Society

Abstract

For the last two decades, a number of policies aimed at increasing participation of female students in higher education have been implemented by Uganda Government. However, the participation of female students in the engineering courses in Makerere University, Uganda's biggest University, has remained between 17% to 20% only. Furthermore, over 90% of the female engineering students are from the 'elite' and advantaged urban schools located in the capital city, Kampala, and its surrounding Districts of Mukono and Wakiso. Rural secondary schools perform poorly in Physics and Mathematics; the key technology and engineering subjects. One rural District, which has failed to send female students to Makerere University for engineering training, is Arua- a remote, poor and insecure District in the West Nile Region of Uganda.

The main objective of the doctoral research was to improve the performance in Physics and Mathematics, at Advanced Level Examinations, of two rural girls' secondary schools in Arua (Muni and Ediofe) through application of e-learning. Both schools have no functional science laboratories and libraries. They also have no qualified and committed teachers who can competently teach at that level of education. The research included participatory action research methodology and the use of interactive multimedia CD-ROMs for Physics and Mathematics as the main course delivery platform. During the study, twenty nine female students from the two schools effectively used the hybrid e-learning tools and applications for six months in 2007 and they were independently examined four times. The repeated measures data that were collected were analysed using multilevel methods to establish the effects of the hybrid e-learning intervention and school contexts on the performance of the students in external examinations.

Results of the analysis showed that, 41% of the students passed and were eligible for university admission. Furthermore, it was found that within-student factors were chiefly responsible for the performance of students in Physics, while for Mathematics, the school contexts were more dominant. However, after extrapolation of the performance of the students over twelve months, up to 72% of the students would have passed and be eligible to join higher institutions of learning.

The study, which focused e-learning for two schools in the rural district of Arua, included co-evolving elements in Triple Helix Processes. The results were the setting up of the ICT/GIS Research Centre in Arua. The Centre is not only helping the community in the West Nile region of Uganda but also near by communities in Southern Sudan and Eastern Democratic Republic of Congo. The Centre has helped to establish an Information Society in the region.

Keywords: Secondary Schools, Hybrid E-Learning, Multilevel Analysis, Rural, Gender, Triple Helix, Physics and Mathematics, Mode 2, CD-ROMs, ICT/GIS Research Centre, Information Society, Uganda.

Introductory Remarks

This doctoral study was part of a research project seeking to investigate the effects of hybrid e-learning application in rural advanced-level secondary education on the performance of students in Physics and Mathematics. However, during the implementation of the project, the study co-evolved into triple helix processes and Mode 2 methods of knowledge production in the specific context of its application and implication (Nowotny, 2003).

The study was motivated and inspired by the requirements of the Uganda Vision 2025 (Government of Uganda- GOU, 1999), Poverty Eradication Action Plans (PEAP) of Uganda Government, Millennium Development Goals (MDGs), World Summit on the Information Society (WSIS, 2003), the New Partnership for Africa's Development (NEPAD) and the 1995 Constitution of the Republic of Uganda.

The Uganda Vision 2025

Following the introduction of a series of structural adjustment measures from 1987, the GOU formulated a new national development plan, Vision 2025. The plan provides an overview of long term goals and aspirations of the country by the year 2025. These aspirations are 'Prosperous people, Harmonious nation and a Beautiful country' (GOU, 1998). That is where Uganda is expected to be by the year 2025.

The Poverty Eradication Action Plans

In Uganda, the Vision 2025 is being actualised through the Poverty Eradication Action Plans, (PEAP). PEAP provides a national medium-term planning framework for eradicating poverty in Uganda by 2017. From 1995, with the awareness of poverty eradication as the fundamental goal of the Government, the process of formulating PEAP was initiated in a broad participatory manner. The first PEAP, (termed as PEAP 1), was finalized in 1997. It established the policy framework for eradication of poverty. PEAP 1 was revised in 2000 and the current PEAP 3 came as a revision of PEAP 2 in 2004. Detailed sector plans are developed within PEAP. The current PEAP has five pillars and they include (GOU, MOFPED, 2004):
Pillar 1: Economic Management
Pillar 2: Production, competitiveness and incomes
Pillar 3: Security, conflict-resolution and disaster management
Pillar 4: Good governance
Pillar 5: Human development

Millennium Development Goals

At the global scene, the Millennium Summit took place in September 2000 at the United Nations headquarters in New York. The 189 United Nations (UN) member countries and states adopted the so called Millennium Declaration, committing their nations to the achievement of the eight Millennium Development Goals (MDGs), by 2015. World leaders agreed to form a new partnership between developed and the developing countries in a bid to reduce extreme poverty, hunger and diseases. The eight MDGs are (UN, 2003):

Goal 1: Eradicate extreme hunger and poverty
Goal 2: Achieve Universal Primary Education
Goal 3: Promote gender equality and empower women
Goal 4: Reduce child mortality
Goal 5: Improve maternal health
Goal 6: Combat HIV/AIDS, malaria and other diseases
Goal 7: Ensure environmental sustainability
Goal 8: Develop a global partnership for development.
Uganda is an active member of the UN and is working towards the achievement of the MDGs within the PEAP framework.

A specific target to be achieved in Goal 3 is to eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015.

While the first 7 MDGs are to be achieved by the poor countries, Goal 8 calls for developed countries to support the efforts of the poor countries. The five targets to be met by the developed partners are:

1. Address the special needs of least developed countries, landlocked countries and small islands developing states.
2. Develop further and open, rule-based, predictable, non-discriminatory trading and financial system.
3. Deal comprehensively with developing countries' debt.
4. In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries.
5. In cooperation with the private sector, make available benefits of new technologies, especially information and communications.

Up to 147 UN member states and nations signed the Millennium Declaration, Uganda is one of them.

The World Summit on the Information Society

The first World Summit on the Information Society, (WSIS, 2003), took place in December 2003 in Geneva. The world leaders made the WSIS Declaration of Principles on the Information Society: 'Building the Information Society: a global challenge in the new Millennium'. The first Summit was to develop a clear statement of political will and take concrete steps to establish foundations for an Information Society which is described as:

'A people centred, inclusive and development oriented society where everyone can create, access, utilize, and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life'.

From the 2003 WSIS Declaration of Principles in Geneva, a Plan of Action was drawn. The plan specifies objectives, goals and targets for implementation by UN member states and governments by 2015.

The objectives of the WSIS Plan of Action (UN, 2003) are: 'to build an inclusive Information Society; to put the potential of knowledge and ICTs at the service of development; to promote the use of information and knowledge for achievement of internationally agreed goals, including those contained in the Millennium Declaration; and to address new challenges of the Information Society, at the national, regional and international levels. Opportunity shall be taken.....to evaluate and assess progress made towards bridging the digital divide'.

Specific targets to be achieved by 2015 are:

a. Connect villages with ICTs and establish community access points;
b. Connect universities, colleges, secondary and primary schools with ICTs
c. Connect scientific and research centres with ICTs;
d. Connect public libraries, cultural centres, museums, post offices and archives with ICTs;
e. Connect health centres and hospitals with ICTs;
f. Connect all Local and Central Government departments and establish websites and e-mail addresses;
g. Adapt all primary and secondary schools curricula to meet the challenges of the Information Society;
h. Ensure that all the World's population have access to television and radio services;
i. Encourage the development of content and facilitate use of all World languages on the Internet;
j. Ensure that more than half of the World's inhabitants have access to ICTs within their reach

It was recognised that ICT applications in society has benefits in all aspects of life. It was recommended that ICTs must be used in the accelerated achievement of the MDGs.

A second Summit took place in Tunis in November, 2005 where world leaders re-affirmed their commitment in the implementation of the WSIS Plan of Action.

The above national and international requirements helped in guiding this study. There is a need to look at the background to the study.

The New Partnership for Africa's Development

The New Partnership for Africa's Development (NEPAD) is a vision and strategic framework for Africa's Renewal. The Strategic Framework document was approved by the 37th Summit of the Organisation of African Union (OAU), now African Union (AU) in July 2001.

The primary objectives of NEPAD are (AU, 2005)

a. To eradicate poverty
b. To place African countries, both individually and collectively, on the path of sustainable growth and development
c. To halt the marginalization of Africa in the global process and enhance its full and beneficial integration into the global economy
d. To accelerate empowerment of women.

NEPAD e-Africa Commission is the NEPAD ICT Task Team that is responsible for developing NEPAD ICT programme and implementing related projects. The team has come up with the NEPAD e-Schools initiative which focuses on providing end-to-end ICT solutions in connecting schools across Africa to the NEPAD e-Schools Network and Internet. Solutions also include the provision of content, learning material and the establishment of health points at schools.

Uganda is one of the few African countries where this project is being piloted in six schools.

The 1995 Constitution of the Republic of Uganda

This study is supported by Articles 30, 32(1) and 33(5) of the 1995 Constitution of Uganda.

- *Article 30: Right to Education*

This Article states that 'All persons have a right to education'.

- *Article 32: Affirmative Action in favour of marginalized groups*

Section 32(1) reads: 'Notwithstanding anything in this Constitution, the State shall take affirmative action in favour of groups marginalized on the basis of gender, age, disability or any other reason created by history, tradition or custom, for the purpose of redressing imbalances which exist against them'.

- *Article 33: Rights of Women*

Furthermore, section 33(5) says: 'Without prejudice to Article 32 of this Constitution, women shall have the right to affirmative action for the purpose of redressing the imbalances created by history, tradition and custom'.

The thesis is organised in three parts.

Part I consists of six chapters. Chapter one gives the background to the study, the difficult context under which students of science and Mathematics learn, statements of the problems, research questions and research objectives. The scope of the research and ethical considerations are also included in this chapter. Chapter two focuses on the ICT situation in Uganda generally. While there has been a lot of improvement in the ICT sector, its introduction in education remains wanting. It is an affair which is largely left to NGOs. Chapter three is divided into two sections. The first section covers definitions of concepts that should be understood within the context of this study. The second section covers the theoretical frameworks for the study. Chapter four has methodological considerations where both qualitative and quantitative methods are used. Chapter five includes results of the study. These results are discussed in chapter six which also contains conclusions and recommendations.

Part II contains seven scientific papers that were presented and published during the period of the study.

Part III has the epilogue; an afterword by the author. Statements of scientific contributions, originality and future work to be done are presented in this part of the thesis.

PART I

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

1.1.1 Some Remarks about Uganda

Uganda was a British protectorate from 1894 until October 9th, 1962 when it attained independence from Britain. It is a poor developing country with a weak economy and is now categorized as a Highly Indebted Poor Country, HIPC. Such countries are unable to service their foreign debts and are characterized by poverty and its associated evils: illiteracy, diseases and low quality of life.

The population of Uganda is estimated to be 32 million (2007 estimates) with an annual growth rate of over 3.2 %; one of the highest in the world. The structure of the Ugandan population is also not suitable for increased productivity. The majority of the people are below 18 years, a non-working population. Furthermore, only a small percentage of the working group is formally employed either in the public or private sectors of the economy.

The uncontrolled population growth puts a lot of strain on the social services delivery particularly in education, health, infrastructure like roads, telecommunications, railways, housing, water and sanitation and security. Growth in the social services delivery is slower than that of the population.

Urbanization is low in Uganda with nearly 85% of the population living in rural areas where they practice traditional, non-mechanised, subsistence agriculture as a means of survival. This has led to very low quality of life especially of rural communities.

The economy is private –sector led after the government fully liberalised it. The market forces control the economy with minimum regulation by the State. However, despite the fact that the economy has been growing at the rate of 6 to 7 % annually, Uganda remains a poverty-stricken country, with up to 31% (by 2006) of the population living below the poverty line. This translates to nearly 9 million people who depend on less than one USD a day.

Administratively, by December 2007, Uganda was divided into eighty one Districts. Twenty six of the 81 districts were created recently (between 2005 and 2007). The Government intends to increase the number of Districts to 110 by 2009. All the Districts are decentralized from the Central Government. The thinking was that many Districts should be created as a means of taking crucial social services nearer to people. However, most of the Districts are rural, remote and poor and they lack financial and administrative autonomy from the Central Government. Many of them can only fund up to 2% of their budgets using their own internally generated funds. Most of them cannot generate incomes of more than 5,000,000 Uganda Shillings (3,174 USD) a year.

Uganda Government believes that education is crucial in its poverty reduction programmes. Education plays a vital role in promoting sustainable development through improving the population's various skills as well as on various issues of national importance including improving general standards of living.

1.1.2 Regulation of the Education Sector in Uganda

Education in Uganda falls under the mandate of the Ministry of Education and Sports (MOES). It is responsible for the overall supervision and regulation of the education and sports sector in Uganda. It sets national policies and monitors the standards of education in various institutions of learning in the country. This includes both private and public educational institutions.
`

The official language in Uganda is English. All teaching instructions and national examinations are in English.

The MOES is responsible, for among other things, registering and licensing of schools, colleges and universities (both private and public). It is also responsible for registering qualified teachers (who have completed teacher training in Primary Teachers Colleges (PTCs), National Teachers Colleges (NTCs) and graduate teachers from universities.

There are autonomous institutions under the MOES that have specific roles in the further regulation of the education sector. The main autonomous institutions are the Education Service Commission, the National Curriculum Development Centre, the National Council for Higher Education, the Education Standards Agency and the Uganda National Examinations Board. The main functions of these institutions are:

- The Education Service Commission (ESC) is responsible for appointing/recruiting and disciplining registered teachers in public schools. The commission is also responsible for reviewing the terms and conditions of service of teachers. It also has some limited mandate in the operation of private educational institutions.

- The mission of the National Curriculum Development Centre (NCDC) is to initiate, develop, monitor and evaluate existing and new curricula for primary, secondary, technical, vocational and tertiary levels of education. Under NCDC, there is the Science and Technology Equipment Production Unit (STEPU) which is responsible for the production and maintenance of science laboratory equipment and apparatus for schools. The unit was set up using British aid at the time of independence in 1962.

- The National Council for Higher Education (NCHE) is a statutory agency which is responsible for:

a. Regulating and guiding the establishment and management of institutions of higher learning, and;
b. Regulating the quality of higher education, equating of higher education qualifications and to advise Government on higher education issues.

The functions of the NCHE are to advise the Minister of Education on higher education issues, to establish an accreditation system (and do the accrediting) for higher education institutions, to investigate higher education complaints, to evaluate national manpower requirements, to set national admission standards, to ensure that institutions of higher learning have adequate physical structures (and education facilities), to publish information on higher education, to determine equivalences of academic and professional awards and credits between institutions as well as tertiary education policy formation.

- The traditional school Inspectorate department in the MOES has been reformed and restructured to create the Education Standards Agency (ESA). Its function is to inspect schools to assess the levels of the teaching and learning processes and activities. It is a Directorate which handles education quality control, especially in primary and secondary levels of education. However, there is no legal instrument yet that supports the creation of ESA.

- The Uganda National Examinations Board (UNEB) was set up as an independent professional examinations authority. It is semi-autonomous corporate body with its own board. The main function of UNEB is to conduct national examinations at various levels, where the following certificates are awarded to the successful candidates:

  a. Primary Leaving Examinations (PLE) Certificates.
  b. Uganda Certificate of Education (UCE) –Ordinary Level
  c. Uganda Advanced Certificate of Education (UACE)- Advanced Level
  d. Uganda Business Education Examinations Certificates and Diplomas (BEE).
  e. Uganda Technical Education Certificates, Diplomas and Higher Diplomas (UTE)
  f. Uganda Junior Technical Certificates (UJTC)

These examinations are conducted at the end of a given level of education by the candidates. They examination levels reflect the structure of the Ugandan education system.

Examinations are mostly done in the schools where the students are studying. UNEB is responsible for registering such schools if they meet its minimum requirements.

The formal system consists of seven years of primary education, four years of ordinary level secondary education, two years of advanced secondary education and three to five years of tertiary education. Progression from one level of education to another is based on national examinations which are set and administered by UNEB. Universities use the UNEB advanced secondary level results as a basis for admission of students for various academic programmes.

1.1.3 Enrolment by Gender for Engineering Courses in Makerere University

In 1970 Makerere University started the Faculty of Technology (FOT) as a means of supplying industries with skilled technical manpower. A total of twenty six students were admitted for the traditional engineering programs of civil, electrical and mechanical engineering (Turyagyenda, Lugujjo, & Mugisa, 2005). However, after liberalizing the telecommunications sector in Uganda, the FOT started admitting students for telecommunication engineering programme from the 2004/2005 academic year. The faculty is making attempts to introduce computer engineering programme in the 2009/2010 academic year.

There were no female engineering students admitted into the Faculty of Technology until 1993 when only one was enrolled. Records of admissions of students for engineering training into the Faculty from 2000/2001 to 2006/2007 academic years were analysed. Table 1.1 gives a summary of the enrolment by gender for each of the engineering disciplines over the seven academic year period. The number includes students who were admitted on both government and private sponsorship through the various avenues for admission: direct and indirect entry.

Table 1.1

Enrolment by Gender into the Faculty of Technology, Makerere University

Item	Civil	Electrical	Mechanical	Telecommunication	Total
Total number of students	586	461	353	230	1,630
Number of female students	96	112	37	35	280
% of female students	**16.4%**	**24.3%**	**10.5%**	**15.2%**	**17.2%**

Source: Senior Academic Registrar's Office, Faculty of Technology.

It can be seen that female engineering students constitute only 17.2% of the total enrolment for engineering training in Makerere University. Out of 1,630 students admitted for engineering training over the seven year period, only 280 were female students. Further analysis revealed that the majority of these female students were from educationally elite schools in the country.

The 280 female engineering students who were admitted during the seven academic years were from different A-level secondary schools.

Two students were admitted through the mature entry scheme while twelve others joined through the diploma entry scheme. A student was transferred from another course to do engineering and her former school could not be traced by the time this thesis was being written. One other student came from an unknown A-level school. This gives a total of 16 female students whose former A-Level schools could not be traced. Records are available for the remaining 264 students.

The few female students were found to be from 45 A-level schools in Uganda. During the 2004/2005 academic year, there were 1, 961 secondary schools in Uganda of which 809 were Government-aided, 903 private and 249 community schools. While 1,148 secondary schools were only O-level schools, 770 were both O- and A-Levels, 7 were only for A-Level without O-Level section and 36 schools were not categorized whether O- or A-Level or both. Therefore, by 2007 Uganda had nearly 777 A-Level secondary schools. Unfortunately, for a period of seven years, only 45 such schools could produce female students for engineering education.

The number of students sent to the Faculty of Technology also varied from school to school. Of the 45 schools that managed to send students for engineering training, 20 sent only one student each for the entire period, 10 sent two each. Ten dominant schools sent 209 students out of a total of 264. Top on the list are educationally elite secondary schools like Mt. St. Mary's , Namagunga which sent 76 students (28.79% of admissions), Gayaza High School 42 (15.91%), Nabisunsa Girls 28 (10.61%), see table 1.2.

Table 1.2

Distribution of Female Engineering Students by Advanced-Level Schools of Origin

No	School	Number Sent	% of total
1	Mt. St Mary's, Namagunga	76	28.8%
2	Gayaza High School	42	15.9%
3	Nabisunsa Girls School	28	10.6%
4	Uganda Matyrs' Namugongo	15	5.7%
5	Makerere College School	13	4.9%
6	King's College, Budo	13	4.9%
7	Trinity College, Nabbingo	7	2.7%
8	Kibuli SS	6	2.3%
9	Mary Hill	5	1.9%
10	Bweranyangi Girls SS	4	1.5%

The 264 directly admitted students were from only twelve Districts in Uganda (see table 1.3). Yet the country is administratively divided into 81 districts.

Kampala (capital city) and its surrounding Districts of Wakiso and Mukono contributed 238 out of the 264 female students, a 90.15% contribution. Yet Uganda has 81 Districts; most of them rural and poor.

Table 1.3
Distribution of Female Engineering Students by Districts where the Advanced_Level School is Located

No	District	No of students	% of total
1	Wakiso	91	34.5%
2	Mukono	80	30.3%
3	Kampala	67	25.4%
4	Bushenyi	6	2.3%
5	Mbarara	5	1.9%
6	Mpigi	4	1.5%
7	Luwero	3	1.1%
8	Iganga	2	0.8%
9	Kayunga	2	0.8%
10	Masaka	2	0.8%
11	Mbale	1	0.4%
12	Rukungiri	1	0.4%

1.1.4 Policy Interventions for Improvement of Female Students Participation in Makerere University

In 1990/91, 1.5 bonus marks were awarded to every female student joining a public tertiary institution.

Makerere started admitting private students for undergraduate programmes in 1992/3 and now 80% of students are private in the university.

The number of students on Government sponsorship was doubled from the 2001 academic year from 2000 to 4000 students. More female students joined universities through that avenue.

In 2005, after realising that rural schools were not sending students for higher education, Government came up with a formula for sharing the 4000 places sponsored by the State:

- 3000 places were given on academic merit with 75% going to science-based courses and the remaining 25% is shared by Arts and Humanities.
- The other 1000 places to be given to Districts (11 places per District). With 81 Districts, this totals to 891 places. The balance is given to special interest groups like sportsmen and people with disabilities.

In 2001/2, Makerere University, with support from Carnegie Corporation of New York, established a Female Scholarship Scheme, FSI, with the sole purpose of enhancing enrolment, retaining and improving academic performance of female undergraduate students at Makerere University. The Scheme targeted female students who were admitted to mainly science disciplines and those from financially disadvantaged backgrounds. 70% of the fund went to Science Disciplines and 30% to Humanities. The scheme was operated up to 2006/7 academic year.

The above policies have helped to increase female students' enrolment in Makerere University for 24% in 1989 to the current 45.8% by 2008.

However, the increase in enrolment is not uniform in all the Departments and Units of Makerere University. For example, enrolment of female students in Faculty of Technology has remained low at an average of 17.2 %. The majority of the female students are from advantaged, elite, urban schools. Over 90% of the female students in the Faculty of Technology come from schools located in only three Districts in Uganda: Kampala (the capital city) and its surrounding educationally elite Districts of Wakiso and Mukono. Uganda has 81 Districts, most of them rural and poor.

It means that all the policy interventions have not improved enrolment of female students into the Faculty of Technology. It can be concluded that rural A-Level schools do not perform well enough in the two essential engineering subjects –Physics and Mathematics. That is why they do not gain admission into universities for engineering courses because they do not meet the minimum requirements to join the university.

Arua is one such District which has never sent a female student on merit for engineering training for the last couple of years.

1.1.5 Research Area Location

1.1.5.1 Arua District

Arua is a poor, remote and insecure rural District located in the West Nile region of Uganda. It is 500 kilometres from Kampala, the capital city of Uganda (see Fig.1.1). According to the results of the 2002 National Population and Housing Census, the district has a total of 855,055 people with 445,852 females against 409,203 males. However, the population is poor with a low socio-economic status.

Poverty manifests itself in the form of illiteracy, diseases and hunger. Epidemics of cholera and meningitis are frequent in the District.

The District shares a common border with the Democratic Republic of Congo (DRC). Its northern part is near the border with Sudan. Armed conflicts in both countries frequently spill over to Arua District. The District is also home to a large group of South Sudanese rebels who were resettled there in refugee camps.

Historically, Arua citizens themselves rebelled against successive Ugandan governments.

The Uganda National Rescue Front (UNRF) refers to two former rebel groups UNRFI (1980-1985) under General Moses Ali, and UNRF II (1996-2002) led by Major General Ali Bamwoze. The West Nile Bank Front (WNBF) under the late Colonel Juma Oris (1995-1998)

These rebel groups finally signed peace agreements with the Ugandan Government. However, some of the former rebels appear not to have handed over all their guns to the Government. They hid them. Such illegal guns cause a lot of insecurity in the area. Influx of small arms into the area is also being blamed on armed conflicts in DRC and Southern Sudan.

The Lord's Resistance Army (LRA) under the command of the self styled General Joseph Kony has been fighting with Ugandan Government troops since 1987. LRA operates mainly in the Acholi sub-region, on the way to the West Nile District of Arua. It is Africa's longest running conflict at the moment. The International Criminal Court (ICC a) has indicted five leaders of LRA and issued arrest warrants for them. They were charged in 2005 with crimes against humanity and war crimes, including murder, rape, sexual slavery, and enlisting of children as combatants. Since 2006 the LRA has been holding peace talks with Uganda Government in Juba and there is some fragile peace holding in the region. Ceasefire agreements were signed and hostilities have stopped. But the security situation remains volatile.

Arua District has 47 secondary schools of which 25 are Government-aided and the remaining 22 are private. There are only six Government grant-aided secondary schools that have both O- and A-Levels of which only two are girls' secondary schools: Muni Girls' Secondary School and St. Mary's Ediofe Girls (hereafter referred to as Muni and Ediofe respectively).

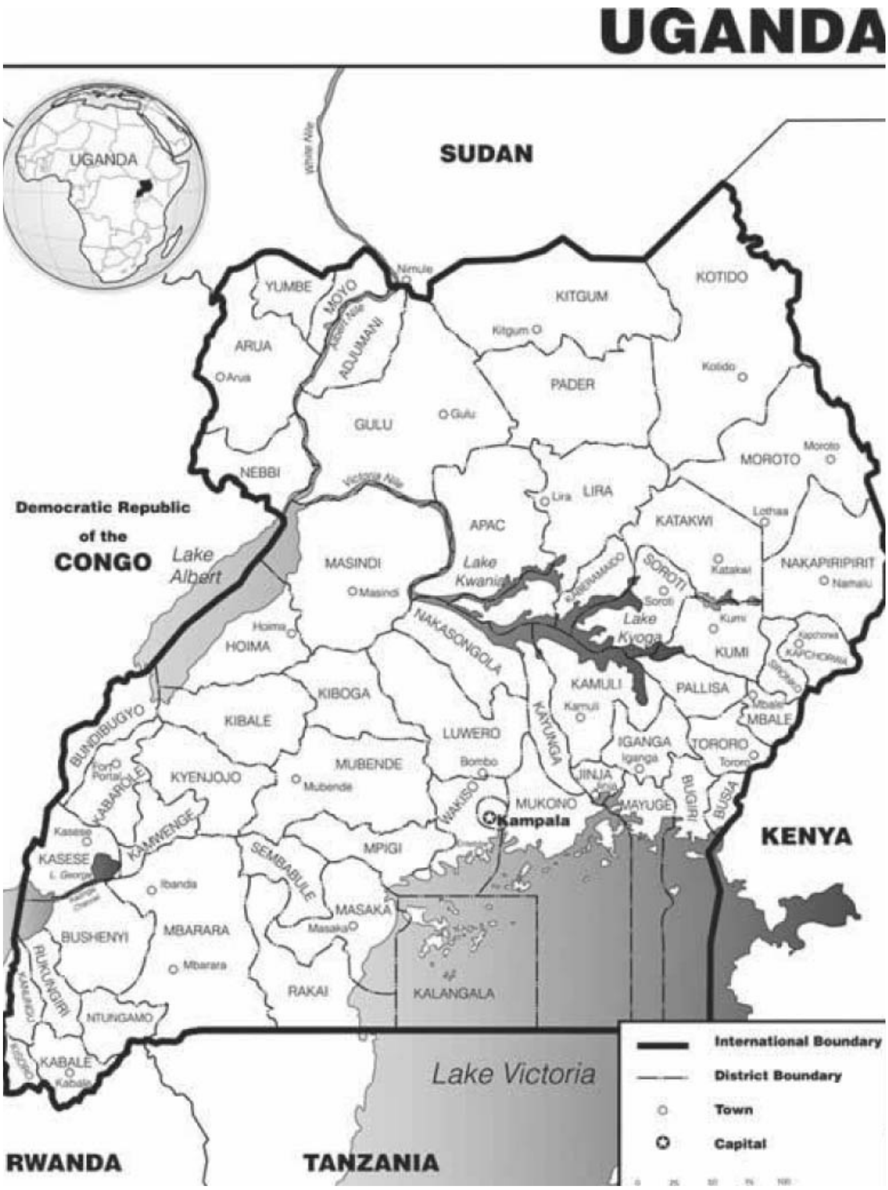

Figure 1.1 Map of Uganda showing the location of Arua District

1.1.5.2 Situational Analysis of Muni and Ediofe

Both schools (Muni and Ediofe) are categorized as rural boarding schools. The students are residential and the female students stay on campus. This gives the students more learning time than when they are non-residential.

The school foundation body for Muni is the protestant church, while Ediofe is of catholic foundation. Foundation bodies in Uganda are stakeholders in running of the schools.

Both schools were established in 1983 by Government of Uganda. They were established originally in primary schools that were in the areas where the schools are but later structures for secondary level were constructed.

In 2005, Ediofe had a total enrolment of 580 girls, of which 107 were in advanced secondary level (S5 and S6). In 2007, Ediofe had increased enrolment to 710 students. Shortage of classrooms and dormitories limit admission of female students to Ediofe. The enrolment in Muni was about 800 students at the beginning of 2008.

Students are admitted into advanced secondary level based on the total aggregate on best done eight subjects at O-Level. Muni and Ediofe admit averagely performing students. Cut-off points for both schools are low.

In 2006 when the schools were visited, both schools did not have current curriculum, examination syllabus, teaching syllabus and schemes of work for Physics and Mathematics subjects. Teachers were found without teaching guides for A-Level Physics and Mathematics. UNEB publishes examination syllabi for schools to purchase. Both schools did not have the current UNEB examination syllabus (UNEB, 2003). The schools consider them expansive to buy, yet a copy for A-Level subjects was being sold at 7,000 UGX (4.5 USD).

The financial status of both schools was not good. According to Government free and universal secondary education policy, every secondary school gets a variable grant of 29, 420 Uganda shillings, UGX, per student per term. The variable grant enables the school to meet its operational expenditures and not charge the students any extra fees. Furthermore, the same school gets 7,000,000 UGX per term as capitation grant for purposes of meeting its fixed costs. In a year, there are three terms. Consequently, a school like Ediofe which had 710 students would receive 83,664,600 UGX (or 53, 120 USD). For comparison, Muni's actual expenditures were 168,423 USD in 2004, 234,190 USD in 2005 and 301,380 USD in 2006. The biggest contributions towards the school budget were revenues collected by charging various fees to be paid by the parents and guardians of the students. Under the USE, the money provided by the Government would not even be enough to feed the students. Both Muni and Ediofe opted out of the USE programme. They preferred to continue charging fees which must be paid by the parents and guardians of the students. But the parents are generally very poor.

Both schools have no advanced level science laboratories where experiments can be done. According to UNEB, 40.8% of secondary schools in Uganda have no functional science laboratories. However, both schools have junior, non-functional O-Level laboratories with enough furniture but with poor fittings, broken water systems and no gas facilities. For example, the laboratories in Muni were found to have no running water. Laboratory technicians in both schools were not qualified. The junior O-Level laboratory block of Ediofe was built and partially equipped using funds from the United Nations High Commission for Refugees, UNHCR. 98 million UGX was used (62,200 USD). However, the funds were not enough to install facilities like electricity in the laboratory block. Ediofe paid for the UNHCR debt by admitting every year Sudanese refugees for free study in the school. It drastically affected the cash flow situation of the school for many years. Both schools use their science laboratories as ordinary classrooms since they hardly conduct any practical lessons. STEPU, a unit under the NCDC, is responsible for the production of laboratory equipment, apparatus and educational materials for distribution in Government schools through the MOES. Unfortunately, the Unit does not have capacity to do so. Many schools do not feel the impact of STEPU and are not aware about its existence. The unit has been silent for many years and was presumed dead. As part of the Government plan to support science education in the country, it is being revived with funding from ADB. However, even after reviving it, the unit will not have capacity to cheaply supply science materials for schools. It cannot produce science chemicals. All chemicals will have to be imported expensively from abroad. It produces only test tubes, flasks, stoppers, lenses, beakers, funnels and wooden materials like meter rules, slates, and set squares only. Items like measuring instruments will have to be imported. Under the liberalized economy, the MOES calls for bids for supply of scholastic and training materials. STEPU is not competitive always. Furthermore, the MOES also has a financial constraint and cannot buy enough quantities of scholastic materials and science equipment for schools.

Rural schools are in a similar situation. They perceive that science equipment and chemicals are expensive. Very few practical lessons are arranged for the students since the schools are reluctant to purchase the required materials. Examination syllabus requires that every week a student must do one practical lesson in each of the core science subjects: Physics, Biology and Chemistry. Muni in 2006 organised only three practical lessons for the female students in S5. The schools either borrow or share such equipment from other schools. However, for UNEB examinations at the end of the year, the schools purchase the required chemicals and equipment. But in most cases, the students see some apparatus, equipment and chemicals for the first time in final examinations. They do not have the opportunity to practice the use of some equipment and instruments early during normal lessons.

The laboratories have enough equipment for O-Level practical work. However, the equipment lack adequate maintenance and repair. Some measuring instruments like vernier callipers, micrometer screw gauges, voltmeters and ammeters were found to be out of calibration, some did not work, others were broken down. They were also poorly kept or stored.

Both schools did not have laboratory manuals for science subjects. Yet manuals help teachers, laboratory technicians and students to define goals and procedures for laboratory activities.

Both schools had acquired used computers without multimedia capabilities from the National Curriculum Development Center, NCDC. There were ten such computers in Muni while Ediofe had 15. Muni has a computer laboratory but Ediofe does not. The computers of Ediofe were installed in the small store in the library. However, both schools had no laboratory computer technicians. There was no Internet in the school. Almost all teachers and their students were found to be computer illiterate.

There are libraries with enough furniture but few relevant text books. The library in Muni was built with assistance by the Blue Caravan, a Swedish students' association. UNIDAS, a Spanish organization, helped Ediofe and financed the building of their library. Neither the schools nor the students can afford to purchase the recommended text books in enough quantities. Both libraries have no qualified librarians. In Muni, an O-Level teacher has taken over the role of a librarian. Ediofe assigned one of the support staff to act as a librarian.

The schools have reliable electricity supply from a local power generation and distribution company, the West Nile Rural Electrification Company, WENRECo. It supplies thermal electricity using black oil for 18 hours a day, from 6:00 am to 24:00 pm. However, thermal electricity is three times more expensive than hydro electricity. WENRECo is a monopoly in West Nile. Their public relations are poor and the level of service needs improvement.

Muni has enough classrooms after completing their three-storied classroom block with the help of parents' association. Ediofe has shortage of classrooms. The A-Level science students use the O-Level laboratories as classrooms. To build a five-classroom block requires 140 million Uganda shillings (approximately 88,900 USD). The schools cannot afford such a capital expenditure and Government financial situation is also no helpful.

Dormitories are congested because of increasing student numbers. The dormitories in Ediofe were found to be in appalling state. They were dilapidated with walls cracked to the foundation and roofs leaking. When it was raining, there was a lot of fear the buildings might collapse on the students. With the help of Japanese Government, a new dormitory block was constructed and handed over to the school in July 2008.

Both schools have water supplied by the National Water and Sewerage Corporation, a Government parastatal body. The level of sanitation is good.

Edife has a newly constructed main hall built with support from friends of the Headmistress from the United States of America. It is where the students hold their assemblies. Ediofe does not have a dining hall; the building is not roofed yet. Muni has no main hall but it is constructing a multi-purpose building which will have a dining hall, assembly hall and an examination hall. The construction of this complex is being funded by the Government under the Northern Uganda Action Fund, NUSAF. The fund was set up to rehabilitate war-ravaged Districts of Uganda. For now, the Students get food from the kitchen and go to eat from their dormitories.

There is an acute shortage of residential houses for teachers. Muni has 41 teachers and the school has only 8 staff houses. Ediofe has only 9 of the 48 teachers housed in the school. Teachers who are not housed in the school are paid rent allowance to enable them rent houses in town. This limits the availability of teachers on the campus. They are not readily available for the students to consult.

Both schools have no perimeter wall fence round them. They have a short and temporary perimeter fence made of chain links.

There is no more land for expansion in both schools. For Muni, land is already a big problem. The neighbouring communities do not like Government institutions like schools near them. They feel Government institutions will expand and grab their land. So they do not like schools in their communities. Ediofe has no more land for the construction of the teachers' houses. The land belongs to the church which may not be willing to give any more piece to the Government.

There is only one qualified and experienced teacher of Physics in Ediofe. He possesses a B.Sc (Physics) plus a Post Graduate Diploma in Education, PGDE. The same teacher is recognized by UNEB as an examiner for Physics Paper 2. The rest of the teachers for Physics and Mathematics are not qualified to teach at A-Level. The qualified and experienced Physics teacher is, unfortunately, the Deputy Headteacher of the school. This deployment limits his classroom time. But it was found necessary to deal with him during the project. The schools were found to be teaching without the current edition of the curriculum, examination syllabus, teaching syllabus and schemes of work. Yet examinations are set based on the syllabus. No science teachers in Muni were computer literate but Ediofe had three who were computer literate. While both schools had many teachers, science teachers were few. In the organization of science teaching in the schools, it was common to get that the head of science in the school, head of science subject and the science subject teacher being the same unqualified teacher. The few science teachers are overstretched. They were given many periods to teach. The MOES recommends that a teacher should teach 22 periods a week. In Muni and Ediofe science teachers take 32 periods. Salaries of teachers are extremely low. A university graduate qualified teacher is paid a gross salary of between 423,000 – 540,000 UGX (269 – 343 USD) per month. Qualified teachers who hold diplomas in education are paid a gross of 370,000 UGX (235 USD) per month. The meagre salaries create a powerful incentive for teachers to teach in more schools so that they can get more income. To rely on one salary will not make ends meet. Lack of promotion in the teaching profession is also another de-motivating factor. Teachers have limited prospects for promotion in Uganda. It is common to get newly recruited teachers who get the same salary with other teachers having vast experience in the field. The MOES has not created a structure where teachers can be promoted. Many class room teachers retire from public service after 40 years of service without promotion. Generally, teachers in Uganda are not motivated to teach. The teaching profession is considered a demeaning job. Most people go into teacher training as a last resort for fear of dropping out of the school system. These institutions admit students who have failed to progress in the field of academics. They did not like teaching as a profession in the first place. They eventually become teachers of subjects that they did not score well in, at A-Level. Coverage of the content by teachers was found to be shallow, a reflection that the teachers are not qualified. The subject matter is not covered to the depth and breadth required by the syllabus. The teachers do not teach some of the topics they are not competent in. This led to a low level of syllabus coverage in both schools. In Muni, sometimes only one third of the syllabus was covered.

Muni and Ediofe do not have strong Parents and Teachers Associations (PTAs). These are associations between teachers and parents who are poor. The main essence of creating PTAs in Ugandan schools was to try and bridge the funding gap between what the school needs and what the Government provides. Parents, who are interested in the education of their children, formed the PTAs. The parents agree to pay additional money to the schools to improve the welfare of teachers and students, build laboratories, libraries and classrooms, improve water and sanitation situation of the schools. PTAs are only effective in the elite schools in urban areas where there are many rich parents. That is why fees in such schools are two or three times higher than in rural schools. Rural schools imitated advantaged schools and formed PTAs that are not effective. For comparison, Ediofe student pays 185,000 UGX (117.5 USD) per term while a similar student in Namagunga (Government aided) pays 533,000 UGX (338.4 USD) and Seeta High (private school) pays 600,000 UGX (381 USD). Parents of Ediofe, just like those of Muni, have difficulties in paying the fees. In some cases the students complete one cycle of education without completing payment of fees for the previous level. It is common to find students of A-Level with fees balances of O-Level. Teachers in schools where PTAs are strong are paid well and are more committed to their jobs. Feeding is excellent in such schools. Laboratories and libraries are functional.

Schools are governed by the Board of Governors. For every school, this is the policy making body. The board has a chairman, and the school head teacher is the secretary to the board. The Government has a representative on that board. Schools like Ediofe and Muni that are founded on religious principles, key positions on the board are offered to practicing Christians. The church normally takes the position of the chairperson of the board and he/she takes part in the appointment of the headmistress. That is why Ediofe is led by a catholic nun and Muni's headmistress is a born-again Christian. Both schools are used by their respective foundation bodies for training students in Christian values and morals. Christian evangelization is done through the schools. The school leadership of Muni is based on fear and lack of trust among teachers, students and the administration. Corporal punishment is practiced in the school despite the Government ban of the practice. Students are caned and beaten. This lowers their self esteem. It is regarded as violence against children. Indefinite suspensions of the students are frequent. Students of Muni regard themselves as being under constant environment of fear. Some teachers, especially in Muni, openly abuse alcohol while others have very poor attendance record. This is because some of them teach in many schools. Such teachers are not effective in any of the schools. On the contrary, the leadership of Ediofe is participatory; teamwork spirit is exhibited at all levels.

Feeding and nutrition in both schools was found to be fairly satisfactory despite the rising costs of maintaining students in the school. Like in most rural schools, beans and maize meal remains the most dominant menu in Muni and Ediofe. However, fruits and vegetables are not served in adequate quantities to the students. It is generally believed that good feeding of a student can facilitate better performance in school.

Both schools did not have associations of old girls. Most former old girls do not progress to pursue higher qualifications and get good and respectable jobs in public and private sectors. The schools were unable to get role models from their own former students. Advantaged Government grant-aided schools that are mainly concentrated in the Central Region of Uganda have very strong associations of old students. Such associations of old students form very strong lobby and advocacy groups for their former schools. They have a stabilizing effect on the schools by checking administrative incompetence while at the same time inspire the continuing students. They also arrange additional fundraising for their former schools for projects that their former schools may be undertaking.

All the students were found to be from very poor backgrounds. Many of the students were found to be orphans, and a few of them were total orphans (both parents have died). The parents have difficulties in providing enough personal effects for their daughters. Just like the schools, the parents are unable to purchase personal textbooks and other scholastic materials for their children. In a number of cases, the students admit that their parents cannot provide personal effects for them. The situation is made worse because some parents think the girls are big enough to get married and stop bothering them. In a number of cases the students enter into love relationships with businessmen and employed men who provide personal requirements for them. In the process, some female students get pregnant and drop out of school. It is common to find that a number of students report two weeks late after the official opening of the school term. Parents look for some little money to make the girls pay part of the 185,000 UGX required for the term. Those who have not fully paid are sent back home in the middle of the term, thus losing more time for learning. While at home, the parents cannot quickly raise the money so that the daughter returns to school immediately. They start looking at the student as a burden and should be married off. In many cases, the term ends without the total amount of money being paid. There are a number of students who sit for UNEB examinations while the school fees for previous terms have not been paid. The schools hold their results, in an attempt to recover their debt. The extremely difficult contexts under which the female students study affect their performances at national examinations. The school climate in both schools is not conducive for learning, especially in Muni.

As a consequence of very difficult situations under which the two rural schools operate, their performance at national examinations was extremely poor, especially in science and Mathematics. At one stage, Muni stopped admitting students for science from 1998/1999 until 2002/2003. Both schools admit very few science students. Mathematics and Physics are the most 'hated' subjects in the two rural schools. Students resent combinations having both Physics and Mathematics, the Essential subjects for engineering. Table 1.4 shows a comparison between Muni and Ediofe with Makerere College School and Namagunga at UNEB examinations for three years, 2004 to 2006. It can be seen that while Makerere College registers very many students for Physics and Mathematics, Ediofe and Muni do the opposite: very few take those subjects. There is also disparity in performance. While Makerere College and Namagunga students get grades **A** and **B**, Muni and Ediofe has the majority of their students passing with subsidiary passes **O** and failures **F**.

Table 1.4

Comparison of Performances of Muni, Ediofe, Makerere College and Namagunga at UNEB

Examinations

School	Year	Subject	A	B	C	D	E	O	F	X	Total
Muni	2006	Mathematics	0	0	0	0	0	□	2	0	3
Ediofe		Mathematics	0	0	0	3	1	3	1	0	8
Makerere College		Mathematics	28	26	28	21	11	14	1	0	130
Mt. St.Mary's Namagunga	2006	Mathematics	18	24	16	7	1	3	1	0	70
Muni	2005	Mathematics	0	0	1	2	1	3	0	0	7
Ediofe											
Makerere College		Mathematics	34	18	24	4	1	5	0	0	86
Mt. St.Mary's Namagunga	2005	Mathematics	32	17	6	3	0	1	0	0	59
Muni	2004	Mathematics	0	0	0	0	1	1	0	0	2
Ediofe											
Makerere College		Mathematics	15	21	20	14	2	0	0	1	73
Muni	2006	Physics	0	0	0	0	1	2	0	0	3
Ediofe			0	0	0	0	1	5	5	0	11
Makerere College		Physics	11	31	34	36	10	22	1	3	148
Mt. St.Mary's Namagunga	2006	Physics	3	14	24	6	2	1	0	0	50
Muni	2005	Physics	0	0	0	0	1	3	4	0	8
Ediofe											
Makerere College		Physics	12	18	26	17	3	8	1	3	85
Mt. St.Mary's Namagunga		Physics	8	15	13	1	0	2	0	0	39
Muni	2004	Physics	0	0	0	0	0	2	0	0	2
Ediofe											
Makerere College		Physics	6	22	32	20	6	4	0	1	91

Source: Data were collected from the respective schools

Performance of students at A- and O-Levels differ. At O-Level, the performance in UCE examinations are better than at UACE examinations in S6. This may be due to the fact that most teachers in Muni and Ediofe are qualified registered O-Level teachers. Both schools do not add value at A-Level. The majority of students who passed O-Level fail at A-Level. Students who intend to study at A-Level 'migrate' from rural schools to advantaged schools in Central Uganda, especially in the districts of Kampala, Wakiso, Mukono and Mpigi.

1.1.6 Attempts by Ministry of Education to Improve Science and Mathematics Education in Uganda

1.1.6.1 In-Service Secondary Teacher Education Project (INSSTEP)

The 1992 Uganda Government White Paper on Education recommended that in-service training programmes for teachers provide the most important avenue through which teachers in the field can be exposed to the rapid changes in technology and science and to innovations in curricula and teaching methods.

With that background, Government started implementing the In-Service Secondary Teacher Education Project, INSSTEP. The project was co-funded by DFID and GOU. It was valued at 4.45 million USD.

The Project aimed to establish a sustainable system for In-Service Teachers, INSET, in English, Mathematics and Science by developing:

a. Ministry of Education and Sports, MOES, capacity for policy-making, planning and monitoring of National Teacher College, NTC, and Teacher Resource Centre, TRC, based In-Service Teacher, INSET, initiatives.
b. A cadre of NTC-based Trainer of Trainers.
c. A cadre of TRC-based District Subject Teacher Trainers capable of programme design, delivery and monitoring at district level.
d. In-School capacity to plan, manage and monitor teacher development programmes.
e. Subject Teacher Association at National, Regional and District levels.

The project was implemented in three phases each covering 13 Districts. Note that in 1996, there were only 39 Districts in Uganda. The first phase ran from August 1996 to July 1997. The second phase started in August 1997 to July 1998. The last phase did not take off since the funding was exhausted.

Arua was one of the Districts that benefited from the INSSTEP Project. It was in the first phase of the project implementation programme.

Under this project, the following was done:

a. Training materials for O-Level English, Mathematics and Core Science subjects like Physics, Chemistry and Biology were developed.

b. NTC tutors were trained as Trainers of Trainers. In Arua, Muni NTC tutors were trained.
c. District subject teachers of English, Mathematics, Physics, Chemistry and Biology were trained.
d. The District Subject Teachers Association was formed. Again, the subjects covered were O-Level English, Mathematics, Physics, Chemistry and Biology.
e. Teacher Resource Centres (TRCs) were constructed, furnished and equipped in the participating Districts. Pedagogic resources in the form of teacher reference materials, sets of subject specific texts, reading books and science and mathematics equipment for loan to schools were provided. Administratively, each TRC is headed by a Coordinator.

1.1.6.2 Support to the Education Strategic Investment Plan Project

This project, which was valued at approximately 33.27 million USD, was 90% funded by the African Development Bank (ADB). It was implemented over four years from 2001. The project was largely meant to support the UPE programme and its main objectives were:

a. Improve access to primary education and reduce the existing gender disparities in secondary education by 2004. Government hoped that more girls would enrol for science and technical subjects in secondary schools.
b. Assure quality improvement in the provision of primary education, mainstreaming Integrated Production Skills in primary and secondary education. It was hoped that by 2004, 5,400 girls would be taking science courses in normal conditions of study.
c. Improve the quality of science education in rural schools by construction, furnishing and equipping 45 science laboratories and 45 libraries.

The following tasks were accomplished under this project:

a. Construction of 1,576 new classrooms and 762 unfinished ones were completed.
b. Construction of 312 teachers houses
c. Construction of one 5-stance latrine per classroom built under the project. This means, 2,338 latrines were built.
d. Provision of eighteen 3-seater desks per classroom constructed or completed. Up to 42,084 such desks were provided.
e. Provision of one set of teacher's table and chair per classroom constructed or completed. This also means that 2,338 tables and chairs were provided.
f. Assisted in mainstreaming of teaching of Agriculture in primary schools.
g. Reorganize the Integrated Production Skills at both the primary and secondary levels.
h. Provide science laboratories, libraries as well as related Information, Education and Communication in girls' secondary schools.

Construction of the few physical facilities like classrooms, laboratories, libraries and pit-latrines appear to have been done. However, constructing 45 laboratories and 45 libraries in girls' secondary schools and expect that the intervention would result in the equalizing the number of female and male students appears to be not realistic. There is still gender disparity in secondary schools with female students fewer than the male ones. Introducing Agriculture and Integrated Production Skills in primary 1 to 4 was a total failure.

1.1.6.3 Uganda Post-Primary Education and Training Project (UPPET)

In 2005, the transition rate from primary to secondary level of education was only 40%. The Government intends to increase the rate to 52% by the year 2010.

The Government also realized that there were 25 rural sub-counties in Uganda that did not have any secondary school, whether Government-aided or private. Government decided that 'seed' secondary schools should be built in each of those sub-counties. Such schools were to be built complete with standard science laboratory blocks and classrooms fitted with solar units since most rural areas in Uganda have no access to grid electricity.

Equally disappointing was the failure rate in Mathematics by students at national examinations set and administered by UNEB. Government wanted to reduce this rate from 60% in 2005 to 40% by 2010.

To address the above problems in particular and other problems in the education system in general, Government approved the implementation of the Uganda Post-Primary Education and Training Project (UPPET) beginning from 2006. It is a five-year project. The project was worth approximately 32.38 million USD is funded largely by the African Development (ADB) Band. ADB provided 80.1% of the funds.

The UPPET project had the following components:

a. Increased access to secondary education and improvement of science education.
b. Support to Business, Technical and Vocational Training (BTVET).
c. Project coordination and management.

Under the project, the following was done in support of secondary education:

a. Construction and equipping of 24 new seed schools and one special seed school. A total of 104 classrooms providing 4,960 student places were constructed.
b. Science laboratories in each of the schools were built and equipped and stocked with science materials. The laboratories are in standard 3-blocks, each for Physics, Chemistry and Biology with a seating capacity of 40 students.
c. Upgrading of six existing seed schools and rehabilitation of six grant-aided schools.
d. Provision of reference books, pupils' text books and teachers guides. Up to 11,840 pupils text books, 2,800 teachers guides for Mathematics and science were provided.
e. 480 I teachers and 30 heat teachers were trained under the in-servicing of teachers.

f. Curriculum review for Mathematics and science was done. Up to 40 newly designed multipurpose workshops were built and equipped at 6 secondary seed schools and 236 solar power units were fitted.

In 2004/2005, there were 1,961 secondary schools in Uganda most of them are rural and poor. These are schools with non-functional laboratories and libraries and structures that are collapsing. The UPPET introduced more of such schools that are not sustainable after the useful life of the project.

Standard classrooms and laboratories are not suitable for the current schools in Uganda now. Students are over-admitted and cannot fit in a standard class of 40. Typically, there are between 60 and 100 students in a class. This is because there are few facilities at secondary level to absorb all the students in primary. It is common to find students occupying Physics, Chemistry and Biology laboratories but carrying out a Physics experiment. The situation would have required a complete re-design of physical structures in schools.

1.1.6.4 Repairs of Formerly Top Schools

The MOES has received a grant of 70 million USD from the African Development Bank (ADB) to renovate 42 Government grant-aided secondary schools. These are schools that were never maintained for the last 30 years. Under this programme, classrooms and dormitories will be renovated, while laboratories will be equipped and libraries stocked. The bank also approved the expansion of 15 seed secondary schools and the construction of 12 more. Arua District will get a new seed school. The MOES hopes that the project would help to facilitate schools in the country side to compete favourably with other schools in the central and urban areas.

1.1.6.5 Government to Build Teachers Houses

In the Peace, Recovery and Development Plan, GOU intends to construct 2,705 teachers' houses in the war-ravaged northern part of Uganda at a cost of 126.45 billion UGX (over 80 million USD). Furthermore, 1,510 existing houses will be rehabilitated at 40.56 billion UGX (nearly 26 million USD). The plan is to be implemented in the next five years beginning from 2008. Arua is one of the 40 Districts in the north of Uganda that will benefit from the funding.

1.1.6.6 Strategic Investment in Education

The project led to the construction of 54 science laboratories and 13 libraries in 56 girls' secondary schools at a total cost of 28.8 billion UGX.

1.1.6.7 Secondary Science and Mathematics Training Project (SESEMAT).

The project is on-going. It was started in the 2005/06 financial year and is being funded by the Government of Japan through the Japanese International Development Agency

(JICA). The project aims at addressing the poor performance of students in science and Mathematics at O-Level through enhancing the quality of teaching and learning of the subjects. Secondary school teachers are being trained through In-Service Education Training (INSET). Arua district is participating in the second cycle of the programme in 2008.

1.1.6.8 Minimum Requirements of Examination Centres by UNEB

UNEB has joined the MOES and the Government to support science and Mathematics education in the country. The examination body has realized that 40% of schools in the country do not have science laboratories. Now UNEB demands that for a school to have a Center Number, it must, among other things, have a laboratory block (or laboratories) for carrying out the science practical examinations with sufficient chemicals and science apparatus and equipment. The laboratory must be able to seat at least 20 candidates under examination conditions. Enough single desks and chairs that can seat the candidates. Each candidate should have a desk and a chair.

UNEB examinations in all primary and secondary schools in Uganda usually take place in the third term from October to December. When GOU made core science subjects compulsory at O-Level, the first candidates were examined in 2006. The sudden increase in the number of students to be examined in practical subjects offered some difficulty for UNEB. The examination body used mobile laboratories in most schools for science practical O-Level examinations.

1.1.6.9 UNEB O-level Syllabus Amended

The introduction of Computer Studies into ordinary secondary school curriculum is a big improvement in the Ugandan education system (UNEB, 2005). This course is one of the optional subjects that students may take at UCE examinations. Schools are now getting computers for preparing their students to be examined in S4. UNEB sets two papers: paper 1 is a Theory paper that lasts two and a half hours; paper 2 is a Practical paper of two and quarter hours duration.

1.1.6.10 Some Concluding Remarks

Most of the projects under the MOES like INSSTEP and SESEMAT focus only on ordinary-level secondary schools. There are no projects that specifically address problems of Science and Mathematics education at advanced secondary school level.

The large numbers of students in secondary schools has caused a lot of shortage in physical structures. The reaction of MOES is to construct more of such structures: laboratories, libraries, classrooms, seed schools, repair old schools that have never been maintained for 30 years and provide furniture like desks and tables. The problem is that the number of students grows faster than the growth in the numbers of the physical structures. In 2005 there were 1,961 secondary schools in Uganda. If 54 laboratories, 13 libraries and build

24 new seed schools, when will we have enough physical structures for the rapidly growing population? The future of the closed educational system is no longer tenable. Innovative ways of delivering the curriculum must be explored. E-learning can be a viable option. There is need to develop an e-learning policy for schools. Introducing Internet in schools is not e-learning.

1.2 Research Problem Statements and the Research Questions

1.2.1 Problem Statements

Rural secondary schools in Uganda perform poorly in Physics and Mathematics subjects due to a number of reasons, the most critical ones being:

- Lack of functional senior laboratories where experiments and demonstrations can be done (the rural schools cannot afford the construction of laboratories). A typical advanced level standard secondary school laboratory block for Physics, Chemistry and Biology costs approximately one billion Uganda shillings (634,920 USD) to build and equip. Standard laboratories are designed for a maximum of 40 students per class. In rural schools where sciences have been dropped due to persistently poor performance in the science subjects, it is not cost effective to build laboratories for a few students. There should be another approach for teaching sciences in such schools.

- Many rural schools have non-functional libraries. Yet a library is a useful resource for learning and teaching. Those schools that have physical libraries cannot afford to purchase text books and other reference materials. Purchasing text books is considered expensive. In situations where text books are available, they are of old editions and usually the content in them are no longer recommended by the examination body, UNEB. Building and stocking a school library with the relevant books would require 150,000 USD in an average college in the USA. In Uganda, a conservative estimate would be within the vicinity of 75,000 USD. This is extremely expensive for a rural school.

- Rural schools do not attract good, committed and qualified Physics and Mathematics teachers. Good teachers remain in urban or sub-urban schools where they are motivated by high salaries and other generous fringe benefits. Teachers who remain in rural schools are sometimes not qualified to teach A-level subjects. Furthermore, teachers who teach in urban and peri-urban schools constantly upgrade their qualifications unlike their counterparts in rural areas who do not have such opportunities.

1.2.2 The Research Questions

No rural school can afford to build and equip or stock its science laboratories and libraries. They cannot attract good, qualified teachers due to budget constraints. The Internet could be used to support rural secondary education for the benefit of the disadvantaged female students. When Internet is used for learning purposes it is termed as e-learning. In the context of Uganda's rural schools, hybrid e-learning can be introduced. It is an asynchronous e-learning mixed with traditional face to face teaching methods and use of stand-alone CD-ROMs as the main course delivery platform.

The above scenario presents a research question that needs to be addressed as regards rural A-level secondary Physics and Mathematics education in Uganda:

> **What effects will application of hybrid e-learning in rural Advanced-level secondary education in Uganda have on the performance of female students in Mathematics and Physics?**

More specifically, the study will focus on the following effects on the performance of students in Physics and Mathematics subjects at independent, external examinations:

1. How much of the variation in performance of rural students lies within-students or between-students?
2. What percentage of the within-student variation is explained by the duration of the hybrid e-learning intervention?
3. What is the predicted performance of the students after 12 months of using the hybrid e-learning tools?
4. What percentage of the between-student variation in performance is explained by the difficult school contexts?

1.3 Objectives of the Research

1.3.1 Main Research Objective

The main research objective of this study is to improve performance of disadvantaged Ugandan advanced-level rural secondary school female students in Mathematics and Physics so that they can pass national examinations and get admitted for engineering training in universities and other tertiary institutions.

To achieve the main objective, the study is divided into two parts. The objective of the first part of the study is to develop and implement hybrid e-learning tools in typical rural advanced level secondary schools for the benefit of female students. This forms the licentiate study.

The objective of the second part is to study the individual change in achievement scores of the participants in the study using multilevel analysis methods. These are the repeated measures scores in the essential engineering subjects- Physics and Mathematics. This objective provides the purpose of the Doctoral study.

1.3.2 Specific Research Objectives

The specific research objective of the whole research project is to find out the effects of hybrid e-learning application in rural advanced-level secondary education in Uganda on the performance of female students in Physics and Mathematics. Five specific objectives are to be achieved:

1. To develop an online local content courseware material according to the current national examination syllabus for Physics and Mathematics.
2. To source and apply an online course platform for the delivery of the courseware.
3. To develop the relevant Tools and Applications for managing the platform and the course material.
4. To create an offline digital library for use by the advanced -level secondary school students as a source of reference materials.
5. To develop a Hierarchical Linear Model (HLM) for the longitudinal data.
6. To use the HLM model to analyze the performance of students in Mathematics and Physics after application of hybrid e-learning in rural A-level secondary education.

1.4 Scope of the Study

This study is specifically done in the two government-aided rural girls' A-level secondary schools in Arua District: Muni and Ediofe. Arua is the eighth poorest district in Uganda. The other poorer Districts are either situated in rebel infested areas where research cannot be done or they have no advanced level girls' schools.

However, the study does not include analyzing gender-specific constraints that are related to female students like absence of women role models to encourage female students to pursue science subjects, unfriendly environments like sexual harassment of female students, etc.

It must be mentioned here that sometimes it is possible that in a longitudinal study, observed evolutions (changes) may be highly influenced by many covariates which may or may not be recorded in the study. For the avoidance of doubt, only the following covariates will be considered:

a. Duration of use of hybrid e-learning intervention is assumed as the only Level-1 predictor variable. No more predictors will be added at Level-1.
b. The school context will be the only Level-2 predictor. No more predictors will be added at Level-2.

The research is restricted only to the effects of hybrid e-learning application on performance in Physics and Mathematics. These are the essential engineering subjects for those pursuing engineering education. The study does not include other science subjects like Biology and Chemistry.

1.5 Ethical Considerations

The names of all the participants were arranged in alphabetical order depending on the school beginning with Ediofe. Then, each student was uniquely identified with a number ranging from ID = 1 (a student of Ediofe) and ID = 30 (a participant from Muni). This was found necessary for ethical reasons. Results were considered confidential and could not be published with the real student's identity.

Before e-learning was implemented in Muni and Ediofe, there was need to know what was the ICT status in Uganda, what the MOES was doing to improve science and Mathematics education in secondary schools in Uganda. In the next chapter the reader can see that the implementation of ICTs in schools is left to NGOs, with minimum involvement of the line ministry.

CHAPTER TWO: CONTEXTUAL ANALYSIS OF ICTs IN SECONDARY EDUCATION IN UGANDA

2.1 Status of ICTs in Uganda

From 1996 Uganda Government substantially liberalised the telecommunications industry by implementing a number of reforms in the sector.

2.1.1 Telecommunications Policy

Uganda approved the Telecommunications Policy in 1996. The Policy aimed at:

- Improving access by consumers to competitive range of services in Uganda.
- Facilitating the private sector participation in the telecommunications sector substantially so that they feature prominently in the overall national development. As a consequence, competition was introduced in the sector which was a monopoly of the Uganda Posts and Telecommunications Corporation (UPTC). The thinking was that private businesses would add new services in the sector and improve quality. It was also anticipated that the private businesses would also meet the un-served customer demands.
- Separating the roles of policy, regulation and operation in the telecommunications sector. An independent regulatory body needed to be created.
- Increasing penetration (geographical coverage) of telecommunication services to set targets. A specific goal was to increase teledensity from 0.26 lines to 2 lines per 100 persons over a 5-year timeline.

The telecommunications policy led to the enactment of the Uganda Communications Act cap. 106 by parliament in 1997 and the Telecommunications Act, 1996.

The Uganda Communications Act led to the creation of an independent regulator of the sector, the Uganda Communications Commission (UCC) in 1998.

UPTC, a government parastatal body that was extremely inefficient, was split into three companies (Uganda Post, Uganda Telecom and Post Bank Uganda). Almost immediately, the Uganda Telecom Limited (UTL) was privatised. Earlier in 1995, Celtel, a mobile phone company was licensed to operate in Uganda. It was the first mobile phone company in the country. Later Mobile Telecommunications Network (MTN) was licensed in 1998 as a second national operator to compete with Uganda Telecom Ltd. in the provision of fixed and mobile phones, and other telecommunications services.

2.1.2 Uganda Communications Commission

Uganda Communications Commission (UCC) is the Government of Uganda's regulator of the Communications industry. UCC regulates and promotes development in the communications sector. Its mission is to facilitate sustainable development of communication services that are universally accessible through effective regulation.
Key functions of UCC are to:

- Ensure orderly development of communications sector (telecommunications and postal) through licensing;
- Regulate the sector through legal, economic and technical means;
- Manage the spectrum;
- Ensure universal access to communication enablement
- Development of human resources in the sector

2.1.3 Rural Communications Development Policy

UCC adopted a Rural Development Communications Policy in July 2001. The mission of the Policy is
'To support the development of communications infrastructure in rural Uganda while ensuring reasonable and affordable access....'

The Policy established the Rural Communications Development Fund (RCDF). RCDF has two sources of funding: the mandatory 1% tax on gross revenue of telecommunications operators in the country and contributions from multilateral and bilateral agencies like World Bank. The Fund gives subsidies to successful private business for purposes of rolling out telecommunications services to rural areas. The subsidies go towards provision of Internet Points of Presence (POPs), ICT training centres, Internet cafes, Telecentres, Public payphones, and Development of IT content for District websites. Funds disbursed to private companies on 'least subsidy' competitive bidding basis.

2.1.4 National ICT Policy

The Uganda National Council of Science and Technology (UNCST) was mandated by Government to formulate a National ICT Policy in 1999. The final policy that emerged after numerous multistakeholder consultations was approved by cabinet in October 2003 and it became a Government White Paper. The Uganda's ICT Policy defines ICT as

'Technologies that provide an enabling environment for physical, infrastructural and services development for generation, transmission, processing, storing and disseminating information in all forms including voice, text, data, graphics and video'.

In the policy, the GOU declares its total support to the development of ICT in the country by stating categorically that 'The Government of Uganda recognises the important role information and ICT play in the national development. The Government consequently unreservedly commits itself to champion the development and use of ICT in Uganda'.

One of the positive aspects of the policy is that it recognises the role of gender in national development

2.1.5 Ministry of ICT Established

To show that there was political will to support ICT, Government of Uganda established the Ministry for ICT (MOICT) in 2006 with the mandate to handle Information Technology and Telecommunications sectors in Uganda. However, the Ministry of Broadcasting and Information is under the Presidents' Office.

Vision of the MOICT: 'A knowledge-based Uganda where national development and good governance are sustainably enhanced and accelerated by timely and secure access to information and efficient application of ICT'

The mission of the ministry is to promote the development of ICT infrastructure and services throughout the country.

2.1.6 Growth of ICTs in Uganda

Uganda has one of the most deregulated telecommunication markets in Africa, leading to a robust communications infrastructure. Government created an enabling environment that has resulted in the following improvements in the ICT sector:

- Government waived taxes on computers and their accessories imported into the country. This stimulated growth in the ICT sector.
- In 2008, Phase I of the National Data Transmission Backbone and E-Government Infrastructure Project was completed. The project entailed:
  a. Laying of 183.3 kms of optical fibre connecting Kampala, Entebbe, Bombo and Jinja.
  b. Installation of e-Government infrastructure connecting 27 Ministries with voice, data and video services.
- A computer refurbishment centre was established in Kampala in collaboration with the United Nations Industrial Development Organisation (UNIDO) and Microsoft Corporation with the local private sector as directed by the Presidential Round Table Investment Council.

- Telephone penetration increased to 20.6 lines per 100 inhabitants by March 2008. There were 5,704,506 mobile and 166,552 fixed line telephone subscribers. In 1996, the penetration was 0.26 lines per 100 inhabitants.
- Telephone coverage in Uganda is 80% by the beginning of 2008.
- The National Switching Capacity reached 9 million in 2008.
- In 2008 there were 34,172 payphones resulting in 1.2 payphones per 1000 inhabitants.
- International bandwidth was 383.1 mbps of which 91.1 was uplink and 291.2 was downlink in 2008. In 2002 the bandwidth was 9.5 downlink and 6.125 uplink.
- Mobile wireless internet accounts were 170,000 in 2008.
- Laws that were passed in the ICT sector
  a. The Electronic Media Statute, Cap 104, 1996.
  b. The Telecommunications Act, 1996.
  c. The Press and Journalist Statute, 1995, Cap.105.
  d. The Uganda Communications Act, Cap. 106, 1997.
  e. The Copyright Act, Cap.215.
  f. The Trademarks Act, Cap.217.
  g. The Patents Act, Cap. 216.

2.2 ICTs in Secondary Education in Uganda

2.2.1 SchoolNet Uganda Projects

SchoolNet Uganda has implemented a number of projects in Ugandan secondary schools.

a. The Uganda School-Based Telecentre Project.

A school based telecentre is a combination of a computer laboratory and an Internet cafe. This project was launched in 2001 and ended in 2003. It was funded by World Links Organisation, World Bank Institute, Schools Online, Bill and Melinda Gates Foundation and the Ministry of Education and Sports. The project had two aims. First, it was to introduce ICTs and help in the delivery of content to rural secondary schools. The second aim was to provide access to communication facilities and ICT training to communities in the after-school hours, evenings, weekends and public holidays when the students did not need the computer laboratories. The project was implemented in 14 secondary schools and one National Teacher's Training College. Eleven schools were connected via C-band VSAT (Very Small Aperture Terminal) satellite technology to link them to Internet. Each of the schools was equipped with at least eight computers on a Local Area Network (LAN). The remaining four schools were connected via spread spectrum technology off the VSAT hub from Busoga College, Mwiri, in Jinja. Each of the schools was paying a monthly charge of 200 USD for access to a bandwidth of 256 kbps downlink and only 32 kbps uplink. This was a subsidised price because World Links was paying the remaining half of the cost of access to VSAT. The schools were raising the funds through charging students 18 USD on top of their tuition fees a year. The school was also charging some fees for community access. This project was later extended in 2004 by connecting eight more schools. Some schools requested for Internet connectivity. Eventually, SchoolNet connected 42 secondary schools and institutions to Internet. The eleven schools connected to VSAT were Ndeje SS, Iganga SS, Duhaga SS, Teso College Aloet, Lango College, Moroto High, Mbale SS, Kitovu, Muni NTC, Kigezi High, Mwiri. The schools connected to Mwiri by using spread spectrum microwave links were PMM, Wanyange Girls, Kira College Butiki and Jinja SS.

b. Curriculum and Technology Integration – E-Learning Pilot Project

In 2003, World Links conducted a blended e-learning training for secondary school teachers from Uganda, Ghana, Gambia, Zimbabwe, South Africa, Botswana and India. The course was on 'Curriculum and Technology Integration'. The course was done between February and May, 2003 and it lasted for twelve weeks. In Uganda, the training was conducted by SchoolNet. The purpose of the course was to help teachers develop skills and depen their understanding of how to collaborate with peers to create, incorporate and facilitate classroom practices that integrate networked technology and curricula. In Uganda, SchoolNet coordinated the training; five mentors were trained online for three weeks first. Then, each of the mentors was given twenty secondary school teachers. Altogether there were one hundred participants from the following schools: Gayaza High, Budo, Nabisunsa, Kibuli, Mengo SS, Bishop's SS Mukono, St. Peter's Nsambya, St. Joseph's Girls School Nsambya, Ntare, Makerere College and Kitovu. The online course was set up on the Blackboard Learning Management System and most of the activity tasks had to be submitted to the course discussion. The recommendation made at the end of the course was that a blended e-learning needs at least two face-to-face meetings; one at the start (to attach names to faces) and another in the middle of the course.

c. Inspiring Science Education for Girls using ICTs

This project started in 2006 and is still ongoing. It is supported by Digital Links (supply of used computers from UK), Barclays Bank Uganda (pays for the transportation of the computers from UK to Uganda), MOES (policy guidance, Project schools (releasing students and teachers for training) and SchoolNet Uganda (the implementing agency). The project addresses the low female students participation in science in Uganda. It aims to inspire them to like science subjects and perform well in them. Under the project headteachers, science teachers and students from the 15 participating schools are gathered in workshops aimed at imparting ICT skills, Internet use and working with e-mails. An online repository for learning resources called the Uganda Digital Education Resource Bank has been set up at *http://www.uderb.org*. Science students can get learning materials from that website. The participating schools are: Muni Girls, Ediofe Girls, Gayaza

High, Bweranyangi Girls, Kyeizooba Girls, Dabani Girls, Bukomero SS, Mutuyera High, Aggrey Memorial, Aiden College, Ngora High, Ngora Girls, Bukolo College, Tororo Girls and Lwantale Girls.

2.2.2 Uconnect Project

Uconnect was registered in Uganda as an NGO in 1996. It is based in the Ministry of Education and Sports. The project supports ICTs introduction in schools buy supplying used, refurbished old computers from Europe and America to schools that can afford to pay for them. Uconnect also helps their client schools to network the computers using their Education Axxess server and train teachers and students of the schools in the basic maintenance of the networks. In some cases, Uconnect helps the schools to get Internet connectivity at reduced costs, but it is rare that rural schools request for Internet connectivity. Uconnect had presence in over 300 primary and secondary schools in Uganda by the end of 2008.

2.2.3 Connect-ED Project

The Connectivity for Educator Development, Connect-ED, was initiated in May 2000 with financial support from the United States Agency for International Development, USAID. The project aimed at using technology to enable and enhance learning and teaching for primary educators (teachers) through the creation of multifaceted approaches to integrating media and computers in Primary Teacher Colleges (PTCs) classrooms. Connect-ED accomplished this by setting up Education Technology Centres thereby increasing access, availability, and provision of relevant and quality learning materials and support for teacher professional development. Connect-ED provided Internet connectivity to eight core PTCs, namely Shimoni (a non-existent school now), Mukuju, Gulu, Bushenyi, Ndegeya, Kibuli, Soroti and Boroboro. The project developed interactive multimedia CD-ROMs for use in primary teacher training. The project outputs were:

a. Content for six subjects was developed in CD-ROM format.
b. A digital resource library for PTCs was created.
c. Professional Development Training of teachers was done. They were proficient in the use of online resources.
d. Multimedia PTC curriculum was developed.

The use of CD-ROMs for delivery of content to schools was found to be interesting, given that most schools recognized that Internet connectivity would not be sustainable in the long run.

2.2.4 CurriculumNet Project

The National Curriculum Development Center, NCDC, with financial support from International Development Research Centre (IDRC), implemented the CurriculumNet project with the aim of developing, testing and implementing a mechanism for curriculum integration and delivery for primary and secondary schools via communication networks using computer related tools. The Project developed interactive multimedia training CD-ROMs for Primary four Mathematics and Social Studies (SST) and Senior two Mathematics and Geography subjects using local content materials in the online format. The project was implemented between 2001 and 2005.

2.2.5 Community Multipurpose Telecenters

With financial support from the Canadian International Development and Research (IDRC), United Nations Educational, Scientific and Cultural Organisation (UNESCO), International Telecommunications Union (ITU) and Government of Uganda Nakaseke Multipurpose Community Telecenter (MCT) was set up in Uganda in May 1999. In May 1999, Nabweru MCT in Central Uganda was set up by the Uganda National Council for Science and Technology (UNCST). Shortly after that, in July 1999 again UNCST set up the Buwamba MCT located in the South-Eastof the country. Kachwekano MCT in Kabale, Western Uganda, was started in the Agricultural Research Development Centre as a result of cooperation between IRDC, Acacia project and the African Highlands Initiative. In Apac District a telecenter was started by an NGO. The rural District of Kibale got their first MCT set up in Kagadi by the Uganda Rural Development and Training Programme in 2003. Additional subsidy from UCC helped to establish twenty more telecenters in Uganda. Each telecenter has ICT equipped like computers, Internet facilities, televisions, Video Cassette Recorders (VCRs), printers, scanners, fax machines, photocopying machines and radio transmitters. Teachers, students, health workers, business people, farmers, women, children and the community at large use these MTCs.

2.2.6 EasyLearning Project

In 2005, the MOES adopted e-learning referred to as EasyLearning as one of the methodologies for delivering education in Uganda. EasyLearning belongs to Serebra Learning Corporation of Canada. The company has over 500 courses that are accessible online. The courses are mainly for skills training for the working class. The aim of the training is to improve the working class qualifications of Ugandans. The trainees study and qualify for certifications in Desktop practical skills, IT and Professional Development courses for the job market. Access to content is through pre-paid Scratch Card or Pin Code mechanism to grant access to the website training courses (http://camous.easylearning.org/uganda). A card unlocks a course for a student for three months of unlimited access.

2.2.7 New Partnership for African Development e-Schools Project

The New Partnership for African Development (NEPAD) e-Schools initiative is to ensure that the majority of the people in Africa should have the skills required to function in the information society and the knowledge based economy. The objectives of the project are:

a. To provide ICT skills and knowledge to primary and secondary school students that will enable them to function in the emerging information society and knowledge economy.
b. To make every learner health literate.
c. To provide teachers with ICT skills to enable them to use ICT as tools to enable the teaching and learning.
d. To provide school managers with ICT skills so as to facilitate the efficient management and administration of schools.

The first NEPAD e-school in Africa was launched in Uganda by the President of Uganda on 18th July, 2005 in Bugulumbya Secondary School, Busobya Village in the rural District of Kamuli. ICT equipment was supplied and Internet connected to the school. The headquarter of the project is in Kyambogo College School, one of the best schools in Kampala. The other four schools in this pilot project are: Masaka Senior Secondary School, Bukoyo Senior Secondary School, St. Andrew Kagwa Senior Secondary School and Kabale Senior Secondary School.

2.2.8 Cyber Schools Project

In 2005 the Government of Uganda contracted Cyber Schools Technology Ltd (www.cyberschooltech.com) to equip and train science and mathematics teachers in 100 schools in Uganda. During the 2006/7 financial year, up to 1,325 teachers were trained by CyberSchools. They also deliver training materials to schools in CD-ROM formats. Muni in Arua is one of the beneficiary schools where demonstration of the products has been done. The school is unable to enter into contract with CyberSchools for supply of learning equipment and connectivity to Internet.

2.3 Some Concluding Comments

Although the telecommunications sector has been liberalised substantially from 1996 and the Uganda Communications Communication was established in 1998 as a regulator of the sector, less than 2% of Uganda's population has access to Internet by 2008. Furthermore, up to 20.6% of the population has access to mobile telephone services which covers 80% of the country. The impact of these sector reforms is low in the education sector. In 2001, there were 13,219 primary and 2,400 secondary schools in Uganda and by 2003 only 106 schools had ICTs and some connection to Internet through support from NGOs like SchoolNet Uganda, Uconnect and Connect-ED. Few schools in Uganda can afford the high costs of Internet connectivity and bandwidth. Low electricity coverage in the country (6% only) and the high costs of setting up a computer laboratory are additional challenges to schools. Dial up telephone connectivity has a monthly operational cost in telephone charges ranging from 200 to 300 USD for usage of Internet for one hour a day. For 30 hours of Internet dial up some schools have negotiated a 146 USD payment. A minute of telephone call in Uganda costs 36 US Cents. This is on top of the fixed installation cost for equipment, survey and other expenses. Broadband VSAT connectivity is extremely expensive. The VSAT disk costs 2,500 USD. The minimum monthly operational charge is 450 USD. Schools that were connected via VSAT in the SchoolNet projects failed to sustain them and they were disconnected. Only a few of those schools have Internet now. The slow growth in Internet use is because Uganda does not have its own Internet backbone infrastructure. The country depends on very expensive satellite technologies.

Most of the projects that introduced Internet in schools did so as projects with definite end points. Very few schools were connected. SchoolNet introduced Internet in 42 secondary schools. Connect-ED project assisted eight PTCs. NEPAD e-Schools is operating in six schools in Uganda. These are too few schools connected to Internet when considering the thousands of educational institutions in the country.

The Connect-ED and CurriculumNet projects emphasized on the delivery of the curriculum through multimedia CD-ROMs. Both projects rightly fore-saw that Internet presence in schools was not sustainable. This project made the right assumption that secondary schools cannot afford internet connectivity and bandwidth for educational purposes. Similar thinking was evident in the implementation of the ConnectED project where content was developed in CD-ROMs format for delivery to student teachers in PTCs.

SchoolNet used the Blackboard, a very expensive proprietary platform, for delivering an online course where secondary school teachers were trained in integrating technology in the curriculum. Later, SchoolNet wanted schools to use the Blackboard. No secondary school can afford proprietary software like the Blackboard because of its high costs of acquisition, and equally high cost of ownership. However, the repository of resources for science subjects based on open access principles that SchoolNet established was found to be good for rural schools. The National ICT Policy, which has remained a White Paper from 2003, need to be amended to force Uganda to preferentially use open source software platforms. Most projects fail because of using very expensive commercial platforms.

The connection SchoolNet made linking four schools to a VSAT hub using spread spectrum microwave links deserve some mention. This type of connectivity proved troublesome in the final analysis. The problem was that if one of the schools had a problem, all the other schools would not receive Internet. Also, the link was based on line of sight. If trees were overgrown, the line of sight would be blocked and no signals would be received. A lot of time was spent clearing trees from the line of sight. Eventually they dropped the idea of having Internet in those schools.

Uconnect is basically for supply of refurbished computers to schools and networking them. It helps to link some schools to connect them to Internet. However, some critics are concerned that the disposal of used, old computers from the developed countries to developing countries is leading to an increased level of e-waste in Africa.

There are some concepts that should be understood within the context of this study. In the next chapter, descriptions of such concepts are given and the theories that were used for guiding the study are mentioned.

CHAPTER THREE: CONCEPT DISCUSSIONS AND THEORETICAL FRAMEWORKS

3.1 Concept Discussions

3.1.1 E-Learning

This is generally taken to be computer supported learning with no in-person or face-to- face interaction taking place. Many people understand e-learning as learning by anyone, any time and in any place. Sometimes, e-learning is taken to mean learning over the Internet. It is a completely virtual learning environment. This study adopts a broader definition by Govindasamy (2002) that considers e-learning as 'instruction delivered via all electronic media including the Internet, intranets, extranets, satellite broadcasts, audio/video tapes, interactive TV and CD-ROM'.

In literature, there are many other different names of e-learning depending on which delivery platform is considered appropriate within a given context. The naming depends on the mixture of the delivery platforms used. Blended e-learning serves as a good example in this case

3.1.2 Blended E-Learning

Voci and Young (2001) refer to blended e-learning as a balance between classroom learning and learning online through the Internet. The concept appears to have been developed by multinational corporations like IBM. These are companies that had invested extensively in training their employees using the classroom, face-to-face, method. But when Internet technologies became widely available for public use, such companies had difficulties moving automatically to pure Internet-based or online training. The move was slow, with small steps being taken at a time. Therefore, blended learning allows an organisation to move learners from the traditional classrooms to online learning in small steps making the change easier to accept. Four directions of blending are common in practice:

1. To combine or mix modes of web-based technology (like live virtual classroom, self-paced instruction, collaborative learning, streaming video) to accomplish educational goal.
2. To combine pedagogical approaches (like constructivism, behaviourism, cognitivism) to produce an optimal learning outcome with or without instructional technology.
3. To combine any form of instructional technology (like Video, CD-ROM, Web-based training) with face-to-face, instructor-led training.
4. To mix or combine instructional technology with actual job tasks in order to create a harmonious effect of learning and working.

Blended e-learning should not be regarded as hybrid e-learning, a concept which reflects the main idea of this study.

3.1.3 Hybrid E-Learning

There has been an ongoing debate among the educationalists on how much virtual space a learner should be given. Many experts believe that the traditional face-to-face instructions are equally important. Roger Shank, as quoted by Skill and Young (2002), argue that a learner should spend one third of the time on the computer, another one third talking to each other (collaboration) and the last one third doing something. The authors call this a mixed model of learning.

Hybrid e-learning, in the context of this study, means e-learning where the main course delivery platform is the interactive multimedia CD-ROM. It is e-learning for learners who have no computing capability at home or in the community where they live. The computing means for them are only available on campus or in their respective schools. Therefore, in hybrid e-learning, the face-to-face traditional classrooms remain a permanent feature for such learners. Details about this are discussed in the Licentiate Dissertation of Lating (2006). The author uses the concept when referring to a type of e-learning that is designed for use by rural, disadvantaged students in Ugandan secondary schools.

3.1.4 Rural

The word 'rural' has many meanings depending on the context where it is used. Thesaurus refers to it as countryside, pastoral, bucolic, rustic or country and urban as its antonym. In the UK the definition of rural as adopted in 2004 means that it is a settlement type (morphology) with a population of less than 10,000 people in a settlement grid or it is a sparsely populated place. Developed economies are very careful in their use of the word 'rural' because it has cost implications for education policies and practices. According to Arnold, Biscoe, Farmer, Robertson and Sharpley (2007), the US Government has six different definitions of the word 'rural'; each of the definitions is applied in a particular context. One such definition is that word 'rural' means 'all territory, population and housing units located outside urbanised areas and cluster areas'. Clearly, different societies have different working definitions of the word rural. In the developed economies, the meaning of rural has no connection to poverty. In the context of this study, the word 'rural' means 'poor'. Therefore, a rural secondary school may be understood to be a poor secondary school.

3.1.5 Digital Divide

Integrating ICT in every sector of life in the developed countries has resulted in faster growth of the economies in those countries. Poor countries that are reluctant to embrace ICTs have their economies becoming weaker and weaker. The consequence is that the gap between the developed and developing countries is widening, not narrowing. Poor nations are becoming poorer and poorer, while the richer ones are becoming richer and richer. Poor countries are less likely to have access to computers or Internet in all sectors of their lives in the near future. This has created a technology gap between countries that have applied those technologies and those that have not. This technology gap is called the digital divide.

Attewell (2003) distinguishes two types of digital divide: the first and second digital divides. The first digital divide is the lack of access to computers and Internet in families and schools. The second digital divide occurs when those with access fail to use the technologies for gainful purposes. According to the author students who have access to computers and Internet most of the time play games and have fun; they do not use the technologies to improve their academic achievement.

3.1.6 Gender

Gender definitions are also many and many of the definitions come from different theoretical perspectives, belief systems and cultural contexts. In this study, the working definition of gender which was adopted by Verma and Ivens (2008) in their project presentation was found suitable for the context of this study. The authors define gender as 'the socio-culturally and politically constructed roles and responsibilities ascribed to women and men that change over time, context specific and are inseparable from power relations. It also refers to a domain of characteristics that determine the value and status of women and men within society'.

3.1.7 Triple Helix

In the product-based economy (p-economy), development was driven by the industry. This is not possible under the current knowledge-based economy (k-economy). Future development in the knowledge economy is driven by incremental innovation within industry. Innovation only can be achieved as a result of an alliance between government, industry and the industry. This is a triple helix alliance. The purpose of the triple helix is for stimulating knowledge-based economic development, drawing resources from all the three members of the helix. Etzkowitz and Leydesdorff (2000) are the originators of the Triple Helix concept.

3.1.8 'Mode 2' Knowledge Production

Mode 2 is a concept that is used to describe a way of scientific knowledge production or co-production of scientific knowledge. According to Gibbons, Limonges, Nowotny, Schwartzman and Trow (1994) this form of knowledge production is context driven, problem focussed and transdisciplinary. Mode 1 knowledge production is strictly disciplinary; it is research within a given discipline. The concept of transdisciplinary research needs further clarification.

3.1.9 Transdisciplinary Research

Makerere University is one of the recent universities that have adopted the goal of rendering social services to communities in addition to its traditional mandate of teaching and research. This shift calls for rethinking the role of research from a strong transdisciplinary perspective. Transdisciplinarity is a new form of learning and problem solving involving co-operation among different parts of the society and academia in order to meet complex challenges of society. In transdisciplinary research, researchers work jointly to develop a shared conceptual framework and methodological approach that integrates and transcends their respective disciplinary perspectives to address a common problem. Therefore, the research goes across, between and beyond disciplines. The reader is referred to Gibbons et al (1994) and Nowotny, Scott and Gibbons (2001) for more insights about mode 2 and transdisciplinary research. However, it should be noted that in this study many stakeholders were involved in the research in the context of application and implication of the results making it a transdisciplinary research. The research was done in the social context of the problem. This is a mode 2 knowledge production as opposed to the mode 1 traditional type.

3.2 Theoretical Frameworks

The concept of e-learning, and more specifically the concept of hybrid e-learning, do not have any particular, singular scientific theory that guide the understanding. Therefore, in this transdisciplinary study, mainly three theories are used: situated learning theory, participatory rural appraisal theory and multilevel theory.

3.2.1 Situated Learning Theory

Generally, learning is a process that brings together cognitive, emotional, environmental/contextual influence and experiences for acquiring, enhancing or making changes in one's knowledge, skills, values and world views. A learning theory is an attempt to describe how people and other animals learn. There are three main categories or philosophical frameworks under which learning theories fall: behaviourism (focuses only on objectively observable aspects of learning), cognitivism (looks beyond behaviourism to explain brain-based learning) and constructivism (which views learning as a process by which a learner looks for solutions to practical problems).

According to the book reviews by Strauss (1990) Lave in 1988 proposed the concept of situated learning theory. Later in another book review by Matusov, Bell and Rogoff (1994), Lave and Wenger in 1990 gave more details about situated learning theory. The theory believes that learning is unintentional and situated within authentic activity, context and culture. Therefore, learning is embedded within activity, context and culture and it is usually unintentional rather than deliberate. Lave and Wenger call this a process of 'legitimate peripheral participation'. Knowledge needs to be presented in authentic contexts- settings and situations that would normally involve that knowledge. Social interaction and collaboration are essential components of situated learning. Learners become involved in a 'community of practice' which embodies certain beliefs and behaviours to be acquired.

The concept of situated knowledges is emphasized especially by Haraway (1997). The fact that knowledge is situated within the context of application and implication is in line with the thinking of Dewey (1931). In his book the philosopher writes that '.....I should venture to assert that the most pervasive fallacy of philosophical thinking goes back to neglect of context'. With such a strong philosophical backing for contexts to be considered in any thinking, additional emphasis of the fact is not required.

Other researchers have since further developed the situated learning theory. Brown, Collins and Duguid (1989) emphasize the idea of cognitive apprenticeship: 'cognitive apprenticeship supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity'. The authors argue rightly that learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge.

In Uganda, the national examination body, UNEB, tests higher-order cognitive skills of students by asking generally open ended questions in examinations. The situated learning theory that supports this is related to the Lev Vygotsky's (1896-1934) notion of learning through social development. Vygotsky's work did not appear in the Western literatures early enough because it needed to be translated from Russian to English. The translation was later done by Alex Kozulin and the work was reviewed by Dewsbury (1992). Vygotsky emphasises higher-order cognitive functions through signs, symbols and languages.

3.2.2 Participatory Rural Appraisal Theory

This research was done not for the sake of doing it. It was not a basic research. It was an applied research aimed at making disadvantaged female students and their subject teachers to take action and improve their situation. Therefore, it was an action-oriented research. In the works of Small (1995), four models of action-research are identified: action research, participatory research, empowerment research and feminist research. In the study, a hybrid e-learning intervention was made with the aim of causing an improvement in the performance of disadvantaged female students at external national examinations so that they could qualify for higher education. Participatory research based on postpositivist epistemological assumptions was used in this study. More concretely, Robert Chamber's Participatory Rural Appraisal theory was applied in the research. Rydhagen (2002), in her doctoral study, used participatory methods in the development of ecological sanitation technologies in South Africa and Sweden.

Participatory Action Research is a means of putting research capabilities in the hands of the deprived and disenfranchised people so that they can transform their lives for themselves. Paulo Friere, the reknown scholar and liberation theologist, believed that the poor and exploited people can and should be enabled to analyse their own reality. Using his liberation theory, Paulo Freire, provided a combination of mobilisation effort with that of conscientisation. This, Freire, effectively applied to change the mindsets of the poor slum dwellers of Brazil where he demystified the elusive development logic and deconstructed the barrier to development effort: an unliberated mind. An unliberated mind is an expectant one in that it thinks someone else has to provide services for it to consume.

Deconstructing the mind is critical because the state of the mind influences how information is processed. Consequently, deconstructing community is equally important because it enables the entire community internalise government policies and programmes which then prepare them to embrace and participate in the implementation of such programmes.

In 1983 Robert Chambers used the term Rapid Rural Appraisal (RRA) to describe a qualitative survey methodology that uses a multidiscipline team to formulate problems for agricultural and research development in rural areas. The technique had emerged in the 1970s when 'development tourists' would go to see farmers in rural areas during dry seasons with structured questionnaires and surveys. They would interview local 'key informants' who were representing the poor. Qualitative data collected were misleading and difficult to use for development purposes. The multidiscipline teams were going to farmers as experts in their fields of study. They did not recognize the local knowledge of the indigenous people. The technique was widely used in the developing countries in the 1980s.

The main weakness of the RRA was its sole purpose of formulating the problems for the poor. It was not aimed at helping the poor get solutions to their problems. Robert Chambers believed that:

- Poor people are creative and capable enough to manage their own change
- The outsiders' role is in facilitator
- The poor and exploited should be empowered.

In 1985, Robert Chambers coined the term Participatory Action Research (PRA), a Research and Development method that involves rural people in examining their own problems, setting their own goals and monitoring their own achievement. The concept of PRA is based on three pillars (Rollin, 1999):

a. Outsiders facilitate, not dominate;

b. Methods are open, group-oriented and visual;
c. Information, food, training, etc. are shared between insiders and outsiders.

3.2.3 Multilevel Theory

Educational data, just like medical, organizational, geographic, social behavioural and growth data are hierarchically structured. Such data are not independent since they are nested, grouped or clustered. Therefore, traditional Ordinary Leased Squares (OLS) methods cannot be used to analyse them. Raudenbush and Bryk (1986) recommend Hierarchical Linear Models (HLMs) as a basis for the analysis of nested, correlated data.

Different authors call HLMs using different names. Liard and Ware (1982) call such models Random Effects Models while de Leeuw and Kreft (1986) call them Random Coefficient Models.

There are very many studies that are truly multilevel or hierarchical. These are studies that result in the collection of nested, clustered or correlated data. This correlation must be taken into account when analyzing such data if the correct inferences are to be made. The Ordinary Least Squares (OLS) method cannot be used for the analysis of nested data because of its restrictive assumptions that:

a. its model is linear in parameters,
b. The data are a random sample of the population. This implies that the random errors are statistically independent of one another,
c. The expected values of the random errors is always zero,
d. There is no correlation between the independent variables. The implication in this case is that covariance is zero,
e. The residual errors have a constant variance hence homoskedasticity.

These assumptions make the traditional OLS method unsuitable for the analysis of correlated data. Many strategies have been used over the last decades in the analysis of such data.

3.2.3.1 Strategies for Analyzing Correlated Data

Traditional approaches that have been used for the analysis of nested data also have restrictive assumptions. For univariate analysis, traditional Analysis of Variance (ANOVA) and later Analysis of Covariance (ANCOVA) methods have been used. Extensions of these analyses can be made for purposes of doing multivariate analyses into MANOVA or MANCOVA. However, the assumptions required for the use of these traditional methods remain even more restrictive. The assumptions are that:

a. Normality of the sampling distributions of the outcome variable and explanatory variable
b. Independence of residual errors

c. Homoskedasticity (equal variance)
d. Linear relationship between the dependent variable and the explanatory variables
e. Homogeneity of regression (equal slopes or rates of change)
f. Absence of multicollinearity or no correlation between variables. If correlation nears 1, a condition known as singularity exists and therefore one of the variables must be removed from the model.
g. The covariate is not affected by environmental factors. There should be no correlation among covariates.
h. In the case or repeated measures study, additional assumptions are
   – data must be balanced, no missing data and
   – Measurement intervals for the data must be the same

ANOVA methods have been widely used in repeated measures designs. For repeated measures designs with no control groups, One-Way Repeated Measures ANOVA (RM-ANOVA) has been used. Studies with both control an experimental groups use the Two-Way RM-ANOVA. Shaw and Mitchell-Olds (1993) mention how ANOVA methods handle unbalanced data. According to the authors, balance is imposed on unbalanced data by either eliminating the values which leads to loss of information or the missing values are filled leading to bias. All these manipulations render ANOVA with its cousins ANCOVA and MANOVA methods not suitable for the analysis of nested data.

Multilevel data need to be analysed using multilevel models. More insights about multilevel modelling are decribed in the works of Gorard (2003) and Steenbergen and Jones (2002). Snijders and Bosker, as quoted in the lecture notes of Anderson (2008), give the working definition of multilevel analysis as '….a methodology for the analysis of data with complex patterns of variability, with a focus on nested sources of variability'.

3.2.3.2 Longitudinal Data Analysis

The simplest multilevel data are longitudinal ones with only two levels of nested data. Longitudinal data are a special type of multilevel data structure with two levels of nesting. The lowest level, Level-1, is the measurement occasion level. The higher level is the Level-2 which includes the students.

In longitudinal studies, repeated measurements are made on the same experimental unit (or subject) over time. The measurement occasions (lower level or Level-1) are said to be nested within the subjects (higher level or Level-2). Liang and Zeger (1986) first proposed the use of Generalized Linear Models for the analysis of longitudinal data. Later Zeger, Liang and Albert (1988) proposed the use of Generalized Estimation Equation (GEE) approach for the analysis of GLMs for both continuous and discrete responses. However, GEEs are most appropriate for the analysis of the fixed or structural component of multilevel models. Such models are frequently referred to as Marginal Models or Population Average models.

In this study, individual growth models recommended by Singer and Willet (2003) were used for the analysis of the repeated measures scores of the Arua female students.

There are two levels of modelling longitudinal data. Level-1 is within-person models while Level-2 is taken to be between-persons models.

In terms of HLM, Level-1 is measurement occasions while Level-2 are individual persons or units that are being observed.

3.2.3.3 Multilevel Model Assumptions

When modelling multilevel outcomes, it is important to make assumptions regarding the probability distribution of the error structures of the data, the measurement metrics and the variance-covariance matrix structure (Bryk and Raudenbush, 1987).

- *Distribution of the errors assumption*: The probability distribution of the response variables is assumed to belong to the exponential family, and more specifically the multivariate normal distribution.
- *Measurement metrics assumptions*: All the response variables should have the same measurement metrics. In this study, the results of the measurements of cognitive abilities of participants based on the standardized scale acceptable by the national examination board, UNEB was done.
- *Variance-covariance matrix structure assumptions*: Littell, Pendergast and Natarajan (2000) identify the following common covariance structures: simple (independent) structure, compound symmetry structure, first order autoregressive structure, unstructured structure and Toeplitz structure.

Simple, independence variance-covariance structure assumes that the observations are independent and have homogeneous variances (equal variances along main diagonal of the matrix). Correlation is zero, and as a consequence, covariances along the off diagonals of the matrix are all zero. The implication is that variances are constant and residuals are independent across time. This structure is not suitable for repeated measures data since it assumes that measurements on the same person are independent. It is good for ANOVA. The structure is simple because a single parameter is estimated: the pooled variance.

Exchangeable, spherical or compound variance-covariance structure has all measurements on the same unit are equally correlated. Variances (in the main diagonal) and covariances (in the off diagonal of the matrix) are constant. This structure requires estimation of two parameters only.

First-order autoregressive, AR(1), variance-covariance structure AR(1) assumes that autocorrelation between adjacent time points are higher than between other time points. This means that correlation decreases with increasing lag. Variances (in the main diagonal) are constant hence homoscedasticity assumption. Covariance increases as measurement occasions increase. It means that covariances between observations on the same person are not equal, but decreases towards zero with increasing lag. The implication is that observations on the same person at far apart measurement occasions would be essentially independent, which may not be realistic. This structure is good for repeated measures where correlation is known to decline over time. However, the measurement occasions must be equally ordered and equally spaced. This structure also estimates two parameters only.

Unstructured variance-covariance structure has no particular pattern. The variances (in the main diagonal) and the covariances (in the off diagonals) are not constant. They increase as measurement occasions increase. The advantage of this structure is that no assumptions are made about the correlations. However, its main disadvantage is that a lot of parameters will have to be estimated since there are separate variances on the main diagonal and separate covariances on the off diagonal. The structure is good for MANOVA. This is the most complex structure since it requires up to 10 parameters to be estimated. Variance is estimated for each time, covariance for each pair of times. The structure leads to less precise parameter estimation since it has the degrees of freedom problem.

Toeplitz variance-covariance structure specifies that the covariance depends only on lag, but not as a mathematical function with a smaller number of parameters. In this structure, the number of parameters to be estimated is the same as the number of measurement occasions.

3.2.3.4 Specification and Fitting of the Longitudinal Models

Using the individual growth modelling procedures recommended by Singer and Willet (2003) and Lating, Kucel and Trojer (2007 a), the resulting composite or integrated model appears in the form:

$$Y_{ij} = [\gamma_{00} + \gamma_{01} SCHOOL_i + \gamma_{10} DURATION_{ij} + \gamma_{11} SCHOOL_i \times DURATION_{ij}] + [\zeta_{0i} + \zeta_{1i} DURATION_{ij} + \varepsilon_{ij}] \quad (3.1)$$

Where Y_{ij} denotes the score of student i at measurement occasion j .

ε_{ij} are residual errors of student i during measurement occasion j . It is the proportion of student i 's score that is unexplained on measurement occasion j . According to (de Leeuw & Kreft, 1995) ε_{ij} are 'disturbances' which 'vary according to specific probability distributions'. For continuous, normally distributed data, it is prudent to assume that $\varepsilon_{ij} \sim iidN(0, \sigma_e^2)$.

π_{0i} is the student i 's true initial average standardized score (at baseline when $DURATION_{ij}$ =0). It is the intercept.

π_{1i} is the monthly rate of change of the student i 's score in a particular subject. This is the slope or gradient. It shows the monthly rate of change in performance of a student participating in the project as the duration of the hybrid e-learning intervention increases.

γ_{00} and γ_{10} are Level-2 intercepts while γ_{01} and γ_{11} are Level-2 average rates of change or slopes. The slopes are of great interest because they show the effect of predictors on the individual growth trajectories.

The variation in individual change parameters (π_{0i} and π_{1i}) is to be taken as a function of the differences between individuals in the Level-2 predictor variable $SCHOOL_i$ and the coefficients γ_{01} and γ_{11} stand for the average effect of variable $SCHOOL_i$ on the individual development parameters (Hernandez-Lloreda, Colmenares, & Arias, 2003).

Level-2 residuals ζ_{0i} and ζ_{1i} are also assumed to be independent and identically (multivariate normally) distributed with zero expected mean values and variances σ_0^2 , σ_1^2 and covariance $\sigma_{10} = \sigma_{01}$. These residuals are deviations of individual change trajectories around the population averages, where $\begin{bmatrix} \zeta_{0i} \\ \zeta_{1i} \end{bmatrix} \sim iidMVN\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_0^2 & \sigma_{01} \\ \sigma_{10} & \sigma_1^2 \end{bmatrix}\right)$. It is further assumed that Level-2 residuals ζ_{0i} and ζ_{1i} are independent of Level-1 errors ε_{ij} for all *i* and *j*. Since there are two Level-2 residuals, *multivariate* normality is assumed. To be specific, this is a *bivariate* normality assumption.

There are eight parameters to be determined from the models above: γ_{00} , γ_{10} , γ_{01} and γ_{11} are called *fixed effects* while random error variances σ_e^2 , σ_0^2 and σ_1^2 and covariance $\sigma_{10} = \sigma_{01}$ are called *random effects* parameters.

Composite model (3.1) has two components:

$\gamma_{00} + \gamma_{01} SCHOOL_i + \gamma_{10} DURATION_{ij} + \gamma_{11} SCHOOL_i DURATION_{ij}$

and the random error or stochastic part or variance components part is

$\zeta_{0i} + \zeta_{1i} DURATION_{ij} + \varepsilon_{ij}$. The stochastic part is regarded as the composite residual.

Equation (3.1) shows that the average standardized score of a student *simultaneously* depends on:

a. the Level-1 predictor, DURATION of the hybrid e-learning intervention in months
b. the Level-2 predictor, SCHOOL characteristics or school contexts
c. the cross-level interaction, DURATION by SCHOOL.

The deterministic part of the composite model strongly resembles the usual regression model with predictors, DURATION and SCHOOL, as the *main effects* (associated with γ_{10} and γ_{01} respectively) and in a *cross-level or interaction effects* (associated with γ_{11}). The cross-level interaction means the outcome variables are dependent. That is why traditional regression methods which assume independence of outcomes cannot be used for the analysis of such data.

The cross-level or interaction between the school contexts and the duration the participants used the hybrid e-learning tools should be looked at from a higher philosophical perspective. It confirms that this study is partly a social research. Social research involves problems that investigate the relationships between individuals and society (Maas & Hox, 2004). It means that individuals interact with their social contexts. The individual participants are influenced by the social groups or contexts. Then in turn, the properties and characteristics of these social groups and contexts influence the individuals.

By school contexts of Ediofe and Muni that affect performance of students include status of laboratories and libraries, qualification and commitment of teachers and the leadership styles in each of the schools.

The error term ζ_{1i} is connected to the level-1 variable in the product $\zeta_{1i} DURATION_{ij}$. Therefore, the residuals are larger for large values of $DURATION_{ij}$ implying *heteroscedasticity*. This is another reason why traditional methods cannot be used for the analysis of correlated data because they assume constant variance or homoscedasticity. Again, note that Level-2 residuals ζ_{0i} and ζ_{1i} are independent of Level-1 errors ε_{ij} for all *i* and *j*.

The random component is not of any scientific interest but their error variances are.

The composite model shows why in scientific publications multilevel models have many names. When interest is only on the fixed part of the model, they are referred to as the *fixed components models*. Researchers interested in only analyzing the random parts of the composite model talk of *random components models* or *random effects models* (Laird & Ware, 1982). *Mixed effects models* are used in the naming of composite models that contain both the fixed and random components. In yet some cases, researchers are interested in modelling only the variances of the random effects. Such models are referred to as *variance components models*.

To provide answers to the research questions, the composite model (3.1) should be fitted to the data collected using a three-step process recommended by Lee, (2000); Singer & Willet, (2003) and Lating, Kucel and Trojer, (2007 a). The three models to be fitted are:

> The *fully unconditional means model* (Model A) is the simplest multilevel model and it is used for estimating the variance components. It is a fully unconditional model with no predictors at either level of the hierarchy. Such a model is called a *null model*. Quene & van der Berg (2004) refer to it as the *basic multilevel model*. Because it contains no predictors, some authors call it the *empty model*. The model contains only the intercepts and the corresponding error terms. That is the reason for referring to it as the *intercept only* model since it has no predictors.

With no predictors at each level, the composite equation (3.1) becomes

$$Y_{ij} = \gamma_{00} + \varepsilon_{ij} + \zeta_{0i} \qquad (3.2)$$

Where γ_{00} is the grand mean across all individuals and measurement occasions; ε_{ij} is the deviation of individual score of a student from her own mean and ζ_{0i} is the deviation of individual score of a student from the grand mean. Both ε_{ij} and ζ_{0i} are not of any statistical significance. Interest is put on their respective variances: within-person variance σ_e^2 and between-person variance σ_0^2

This baseline model is fitted first for purpose of partitioning variances in outcomes into the within-students and between-students parts. The variance partitioning is done by determining the Intra Class Correlation (ICC) using the relationship

$$ICC = \rho = \frac{\sigma_0^2}{\sigma_0^2 + \sigma_e^2} = \frac{Intercept\ Variance}{Intercept\ Variance + Residual\ Variance}$$

$$= \frac{Between\ Variance}{Between\ Variance + Within\ Variance} \qquad (3.3)$$

> The *unconditional growth model* (Model B) has predictors at level-1. In this study we are concerned with only one level-1 predictor- the *DURATION* of the hybrid e-learning intervention. In this instance, the composite equation (3.1) reduces to

$$Y_{ij} = \gamma_{00} + \gamma_{10} DURATION_{ij} + [\varepsilon_{ij} + \zeta_{1i} DURATION_{ij} + \zeta_{0i}] \qquad (3.4)$$

The unconditional growth model differs from the null model by the inclusion of the level-1 predictor. So, the model can be used to test the effects of the level-1 predictor that was added. The model can also be used to compare the magnitude of the reduction in variance components by determining the R^2 statistics

$$R^2 = \frac{\sigma^2_{previous\,model} - \sigma^2_{current\,model}}{\sigma^2_{previous\,model}} = 1 - \frac{unexplained\ \ variation}{Total\ \ variation}$$

……………………………………………………………………………(3.5)

The R^2 statistic helps to quantify the proportion of outcome variation as a result of a variable added to the fitted model.

The *conditional growth model* (Model C) is the composite model depicted in (3.1). The model is fitted with the categorical dummy variables *SCHOOLi =0* for Muni and *SCHOOLi* = 1 for Ediofe. Therefore, two models are fitted: for Muni

$$Y = [\gamma_{00} \square \gamma_{10} \square DURATION_{ij}] \square [\zeta_{0i} \square \zeta_{1i} \square DURATION_{ij} \square \varepsilon_{ij}]$$

…………………….(3.6)

And for Ediofe when *SCHOOLi* = 1,

$$Y = [\gamma_{00} \square \gamma_{01}] \square [\gamma_{10} \square \gamma_{11}] \square DURATION_{ij} \square [\zeta_{0i} \square \zeta_{1i} \square DURATION_{ij} \square \varepsilon_{ij}]$$

……………………………………………(3.7)

3.2.3.5 Hypothesis Testing and Deviance Statistics

Hypothesis testing is done by comparing deviances of any two nested models (Models A and B, and then models B and C). The differences between deviances have a Chi-squared distribution. The degrees of freedom are taken to be the number of independent constraints between the models. Deviances also show the goodness-of-fit of models. The smaller the deviance, the better the fit. For normally distributed errors, the deviance, D, is the residual sum of squared errors.

Deviance based hypothesis testing method is suitable for testing fitness of models since it permits joint tests on several parameters simultaneously. Single parameter tests are suitable for tests on variance components only. Deviance tests are based on the log likelihood (LL) statistic that is maximized under the Full Maximum Likelihood Estimation of model parameters.

Deviance statistics can be used to compare two models if two criteria are satisfied

a. Both models are fit to the same exact data.
b. One model is nested within the other.

If these two conditions hold, then:

a. The difference in the two deviance statistics is asymptotically distributed as chi-square, χ^2 . This difference is called the *deviance residuals*.
b. The degree of freedom is the number of independent constraints.

Models with smaller deviance are better. Such models are better supported by the data. For normally distributed data, deviance is the Residual Sum of Squares given by the expression

$D = \sum_{i=1}^{n}(y_{ij-}\bar{y}_{ij})^2$ ………………………………………………(3.14)

where D is the deviance, y_{ij} is the actual score of student *i* on measurement occasion *j* and $\bar{y}_{ij}$ is the estimated score of student *i* on measurement occasion *j*.

Note that modelling change requires a two-tail test, it is not a one-tail test of the hypothesis.

Comparing models A and B: Model A can be obtained from model B by invoking three constraints. This gives us the three null hypotheses to be tested:

$H_{0:}\ \gamma_{10} - 0;\ \sigma_1^2 - 0; and\ \sigma_{01} - 0$ (3.15)

The null hypothesis being tested here is that if the unconditional growth model (B) fits better than the unconditional means model (A) then the null hypothesis must be rejected.

Comparing Models B and C: Model B can be obtained from model C by invoking two independent constraints (now only on the fixed effects). This gives us the two null hypotheses to be tested:

$H_{0:}\ \gamma_{01} = 0;\ and\ \gamma_{11} = 0$ ……………………………………(3.16)

The null hypothesis being tested here is that if the conditional growth model (C) fits better than the unconditional growth model (B) then the null hypothesis must be rejected.

The degree of freedom is the difference in the number of parameters in the two models being compared.

3.3 Some Concluding Remarks

E-learning in general and hybrid e-learning in particular are new concepts that do not have any theories that guide their understanding. In this study, a number of theories are used to help guide the research in rural school contexts. The main theories that are found more relevant are the two qualitative theories, the situated learning theory and the participatory rural appraisal theories and the HLM theory for the analysis of nested data. Chapter four shows how these theories were used in the study.

CHAPTER FOUR: METHODOLOGICAL CONSIDERATIONS

4.1 Philosophical Underpinnings of the Research

The main aim of research is to expand knowledge in a given area. In this study, knowledge was produced in the specific context of its application and implication where the problem was being addressed. The research context was in Muni and Ediofe; the two rural girls' schools in Arua. Therefore, the scientific knowledge generated was situated in the given social context of the two schools. The knowledge was constructed socially in a collaborative effort involving a number of co-actors: students, subject teachers, school administrations, District Local Council of Arua, Non-Governmental organisations like SchoolNet Uganda, donors like Sida/SAREC, research institutions like Makerere University and Blekinge Institute of Technology in Sweden, Makerere College School, UNEB, National Curriculum Development Centre (NCDC), Advanced-Level secondary schools in Arua, Koboko and Nyadri Districts. This made the study a transdisciplinary research. The transdisciplinary alliance in the collaboration for purposes of distributed knowledge generation by the 'communities of practice' resulted in the development of the following e-learning tools and applications: Internet, project website, e-mail communication, Mambo- the Course Management System and portable devices like training CD-ROMs and memory sticks. This arrangement led to the creation of a dialectical unity between knowledge production, technology and 'communities of practice.' Therefore, Mode 2 research methodology was used in the knowledge production.

4.2 Research Approaches Used

To understand the difficult school context under which the participants study, qualitative research methods were used. However, the research data collected were quantitative. Consequently, this study adopted both research approaches hence the use of qualitative and quantitative methods.

4.3 Population in the Study

During field visit to Arua in March 2005, a list of all the secondary schools in the District was compiled. The list included both private and Government grant-aided schools. There were 45 secondary schools in Arua of which only six were Government grant-aided schools with both O- and A-Levels. From the six schools, only two were girls' only schools: Muni and Ediofe. The hybrid e-learning project was implemented in the two girls' schools. The others were either mixed, co-educational schools like Vurra Senior Secondary School (SS), Arua Public and Mvara SS or boys, single-sex schools like St. Joseph's College, Ombachi.

4.4 Sampling Method

Multi-stage sampling was done to identify the participants in the project. Participating schools were identified first, followed by selection of classes in the schools before identifying the project students who were taking subject combinations containing either Mathematics or Physics or both.

4.5 Participants in the Study

In March, 2006 the participants were identified during a field visit to the schools. The female students who were admitted into A-Level in 2006 and were taking combinations containing either Mathematics, or Physics or both were selected. From Ediofe, 17 students were identified, 12 were taking Physics, 11 were offering Mathematics and 6 were taking both Physics and Mathematics. Muni had 12 students who were admitted that year into A-Level; 7 were offering Physics while 10 were doing Mathematics and 5 girls were doing both subjects. The total number of participants was 29 out of which only one girl of Muni was taking the PCM combination as the main principal subjects that are acceptable for engineering and technology combination of subjects.

In multilevel analysis language, the 19 Physics students and 21 Mathematics students from both schools participating in the study are referred to as Level-1 participants. The Level-2 participants refer to the grouping of the students within their respective schools: for Ediofe there were 12 Physics students and 11 for Mathematics. Muni had 7 students for Physics and 10 for Mathematics.

4.6 Procedure

4.6.1 Local Content Development

In September, 2005 a Local Content Creation Workshop was organized in Arua town. The purpose of the Workshop was to let teachers develop interactive multimedia digital local content based on the national examination syllabus for A-Level Mathematics and Physics. The Workshop was facilitated by curriculum experts and programmers from the NCDC. It took place from 5th to 10th September, 2005.

Fifty one A-Level subject teachers of Mathematics and Physics from 14 schools were invited for the Workshop. They were from A-Level schools located in the current Districts of Arua, Koboko and Nyadri. Only 33 teachers reported at the Workshop venue in Mvara SSS in Arua town. Two teachers were female, the rest were male. Eighteen of the 33 teachers had taught for more than five years. This was taken as a sign of enough experience in the subject area. Unfortunately, only three of the teachers were recognized by UNEB as examiners. One of the examiners was from Ediofe Girls (for Physics Paper 2) and the other two examiners were from Arua Public SSS (one for Physics Paper 2 and another for Mathematics Paper 2). Twelve of the teachers admitted that they were teaching in more than one school. It is common for secondary school teachers in Uganda to teach in many schools for purposes of getting more pay or remuneration. Nine of the teachers were not formally employed as teachers by the Government. They were being paid by the schools where they were teaching using PTA funds. None of the teachers admitted that he or she had wanted to be a teacher as a first choice. Teaching in Uganda is a profession that most people go for as a last resort for fear of dropping out of the education system completely. All the 33 teachers did not have the curriculum from NCDC and none had the current UNEB examination syllabus. Finally, only 4 of the 33 teachers were able to do basic Microsoft word-processing. Basic computer skills training of the teachers needed to be done. All the teachers had no access to Internet in their schools and were unable to use e-mails.

The objective of the Local Content Creation Workshop was not achieved. The teachers were unable to create digital content of their notes because of low computer skills. More time was spent on teaching them basic ICT skills since they were more motivated to learn how to use computers. The written/manual local content that the teachers created was taken to Makerere College School (MACOS) for review by senior subject teachers and UNEB examiners. Makerere College is one of the elite secondary schools in Uganda and it shares the same campus with Makerere University in Kampala. Many MACOS students pass well at A-level examinations and join Faculty of Technology for engineering training. After review of the local content created by the rural A-Level teachers, it was found that the content was shallow and lacked the necessary depth required by the examination syllabus. It was unsuitable for use for the hybrid e-learning project.

4.6.2 Collaboration with Makerere College School in Local Content Development

Faculty of Technology, Makerere University contacted the leadership of MCOS to provide senior A-Level Mathematics and Physics teachers to join the project. The school accepted and attached three experienced teachers to assist the hybrid e-learning project. The Head of Physics Department, a Senior Mathematics teacher and a Physics Laboratory Technician joined the project from March 2007. Later in the project, MACOS also attached one senior Chemistry teacher and a Biology Laboratory Technician to the project. The MACOS teachers developed all the relevant local content in the digital format for Physics Papers 1, 2 and 3 and Mathematics Papers 1 and 2.

4.6.3 Collaborative Development of Relevant Tools and Applications for the Hybrid E-Learning Environment

The following hybrid e-learning tools and applications were collaboratively developed by various 'communities of practice':

- The digital content materials that were developed by MACOS were used to produce interactive multimedia CD-ROMs for A-Level Physics and Mathematics.

- A website for the project was designed and commissioned; its URL is http://www.aruaeduc.com. The website is hosted by a web hosting provider, b-one.net.
- An open source Course Management System (CMS), the Mambo, was used for managing the hybrid e-learning environment.

- All the participating students and teachers in the project were given e-mail accounts to ease communication among researchers and co-researchers (students, teachers and collaborators in the project). Some content were sent as e-mail attachments to students and teachers. Mobile phones and SMS text messages were also used as appropriate tools for communication during the project.

- All the teachers and student class leaders were given flash disks/ memory sticks for purposes of transferring content retrieved from the Internet to their computers in the schools.

- An ICT Research Centre was set up in Arua town in a collaborative effort between the Faculty of Technology, Makerere University and Arua District Local Council. The Local Chamber of Commerce later joined to support the Research Centre so as to make it sustainable. The District Council provided buildings for housing the Centre. The Faculty of Technology equipped the Centre with financial support from Sida/SAREC. The Centre was connected to broadband VSAT Internet in December 2005. A Network Administrator, a Secretary/Receptionist and two guards (one works during the day and the other at night) were recruited in May 2006. The participating schools provide part-time instructors at the Centre and they form part of the staff at the Centre. Equipment at the Centre include 57 computers, 2 servers, 2 printers (one of them is colours), one office telephone line, 1 canon photocopier and one spiral binding machine. The Centre was opened for public use in June 2006. Ten Faculty of Technology, second year telecommunications students were used. They did massive training of all the students and their teachers in Basic ICT skills, Internet use and working with e-mails. Muni and Ediofe offered subject teachers of the project students as coordinators between the Research Centre and their schools. They were later trained as ICT part time Instructors by the Research Centre. Subject teachers and the students were allowed free access to resources from the Internet and project website. The Centre was opened for public use to support local businesses and communities. It is being jointly managed by the triple helix partners: Academia (Makerere University, Faculty of Technology), Arua District Local Government and the local District Chamber of Commerce and Trade. The following services are offered by the Centre to the community: Internet surfing, e-mail services, CD-ROM services, Word processing, printing, technical and technology support to clients, basic computer skills training (including Internet use and working wilt e-mails), advanced computer skills training(computer hardware maintenance and repair; networking and troubleshooting), digital library services for science students and teachers. The users of the Centre include Local Government officials, civil servants, secondary school students and their teachers, NGOs, local businesses and other state institutions like the army, police and prisons.

- One of the classrooms at the ICT Research Centre was converted into an offline digital library. SchoolNet Uganda collaborated with the project in the establishment of the library. It donated a content server with pre-loaded science materials from 'elite' urban schools in Uganda. The server also contained science materials that SchoolNet received from other African countries. Nine computers were networked for purposes of retrieving relevant content from the server. Students and teachers were allowed free access to the digital library. The library was made offline as part of the sustainability effort of the Research Centre. The ISP was charging 450 USD per month for access to VSAT and 350 USD as annual maintenance fees. The Centre was having difficulty in raising that amount of money. The local community and businesses cannot afford Internet at market price. It was anticipated that Internet would be disconnected because of non-payment. In case such interruption occurred, the students and their teachers would still access content offline.

- SchoolNet Uganda helped in the training of some participating students and their teachers. An ICT in Education Workshop for science teachers from 13 secondary schools in Uganda was held in Gayaza High School in Kampala. Muni and Ediofe participated in that workshop. Five teachers from each school were invited. The Workshop was aimed at the pedagogic development of the teachers; to help them integrate ICT in their teaching and learning. It took place from 23rd to 25th April, 2007. There was a follow-up workshop organized by SchoolNet in Mukono District Farm Institute, on the outskirts of Kampala. The ten teachers from Ediofe and Muni again joined their colleagues from the 11 other schools in Uganda. The objectives of the follow up workshop were to:
  a. have a general review of the earlier workshop organized in Gayaza High School;
  b. reactivate the alternative teaching and learning methods through the use of ICT;
  c. review the ICT progress in the schools from which the members were drawn;
  d. equip the participants with advocacy skills to amass reasonable support for ICT in their respective schools.

SchoolNet again invited one female science teacher and three science students of A-Level for an ICT in Science Camp hosted again in Gayaza High School from 7th to 11thn April, 2007. Ediofe was invited and the three students were participants in the project. It was aimed at deepening the understanding of students in locating resources from the Internet and promoting their self-confidence in science subjects.

The headteachers of the schools being supported by SchoolNet were invited for a Workshop in Mukono District Farm Institute from 2nd to 4th September, 2007. Both headteachers of Muni and Ediofe participated. They were trained in the benefits of ICT in education.

- To supplement the efforts of the schools with acquisition of learning materials, the following materials were purchased and distributed to Muni and Ediofe to support both the project students and their teachers:

a. UNEB physics and Mathematics examination syllabi.
b. Stationery and other scholastic materials including dissection kits for Biology students
c. MACOS local content notes for Physics Papers 1 and 2 and Mathematics Papers 1 and 2.
d. Advanced Level Physics Practicals Manual by Professor E.Banda. Students used the manual for carrying out actual experiments.
e. Arua Joint A-Level Teaching Syllabi for Mathematics, Biology, Physics and Chemistry.
f. UNEB past papers for Mathematics Paper 1 and 2 (1988-2005), Physics Papers 1 and 2 (1992-2005). Some past papers for Biology and Chemistry were also given to every student. These past papers were used as typical examination questions for students to practice and get solutions to them.

- All the inferior computers of Muni and Ediofe were replaced with those having multimedia capabilities by the project. The computers were upgraded to higher multimedia capacities: hard disk drives (40 MB), memory (256 MB), and processing speed of 512 MHz. They were fitted with CD drives and had sound capabilities. Digital content developed by Makerere College were uploaded onto the computers in the schools and those at the ICT Research Centre. Some were uploaded on the project website http://www.aruaeduc.com.

4.7 Rolling Out of the Hybrid E-learning Tools to Students in Muni and Ediofe

After developing all the hybrid e-learning tools, they were put at the disposal of the participating students and their teachers.

The teachers were given free Internet access on working days from mid-day (noon) to

14:00 hours. They would use the time to identify relevant websites for their students, download relevant materials from websites and transfer them to computers in the schools for students to access. All Saturdays were free for students accompanied by their teachers to access resources from the ICT Research Centre. While at the Centre, a student would access content from the Internet, project website, other recommended websites by their teachers and the offline digital library.

The participating students were scheduled to have their lessons in their computer laboratories. Their subject teachers would act as facilitators and provide the necessary support to those in need of assistance

MACOS teachers were released by their school to periodically go to Arua and explain the content given to the schools which they developed. Workshops were arranged and each of the schools was hosting the exercise alternately. The following workshops were facilitated by MACOS:

a. Practical Physics workshop was held in Ediofe from 25th to 31st March, 2007.
b. Mathematics and Practical Physics workshop held again in Ediofe from 25th to 30th June, 2007.
c. Practical Physics and Practical Biology held in Muni from 5th to 11th September, 2007.
d. Mathematics and Physics theory workshop was held in Muni between 21st September to 3rd October, 2007.

The participants interacted with the hybrid e-learning tools effectively from May 2007 to November 2007 when they were examined by UNEB

4.8 Research Design

This study was both quantitative and qualitative depending on the theories that were used.

4.8.1 Research Design for the Longitudinal Study

During the period of the intervention, the students were subjected to the following independent external examinations:

a. MACOS examinations in May, June and September, 2007.
b. Arua Joint District Mock Examinations in July, 2007.
c. UNEB Examinations in November, 2007. The UNEB results were released in March 2008.

All the examinations were set, administered and marked by MACOS and Arua District Mock Examination body and UNEB using the same guidelines UNEB usually uses. Note that the measurement occasions were of unequal intervals. The examinations were done at unequal intervals. Four waves of repeated data for Physics students and three waves for Mathematics students were collected for analysis. Some of the students missed some examinations due to sickness and some cases of indiscipline (especially for Muni students). Therefore, there were missing or incomplete results in the data collected for analysis. Repeated measurements taken from the same student in time with some students having missing results on some occasions made the study an unbalanced, longitudinal one with four waves of data for Physics and three waves for Mathematics. In such research designs, measurement occasions are nested within individuals or experimental units.

4.8.2 Research Design for the Qualitative Study

At the beginning of the research, there was very little knowledge about the context in Arua generally, and Muni and Ediofe specifically. Numerous field visits were made to Arua. There was need, in the Action Research, to describe, understand, explain, and cause change simultaneously. Circumstances surrounding the poor performance in Physics and Mathematics by rural female students were explored to ensure that more information about the problem was gathered. Therefore, the research design was Descriptive (because there was need to describe the context), Exploratory (because there was need to do a lot of literature search and gathering experience of the participants) and causal (the results of the longitudinal analysis). During field visit to Arua, the spiral nature of PRA was used to generate small improvements in the project. A problem would be identified, then a plan of action was developed, the plan was implemented, the effects of the action were monitored and finally, reflection and reappraisal of the situation would be done at the next field visit to determine the next plan of action.

4.9 Variables Measured in the Longitudinal Study

In this longitudinal study, two levels of variables were measured.

4.9.1 Independent Variables

The independent or predictor or explanatory variables measured were qualitative and quantitative:

- Within-student or level-1 variables. The time-varying covariates measured at the level-1or measurement occasion level was the $DURATION_{ij}$ of the hybrid e-learning intervention by student i at measurement occasion j. This was a quantitative variable.

- Between-student or level-2 variables measured was the time-invariant covariates, $SCHOOL_i$ of student i and was represented as a dummy variable coded as 1 for Ediofe and 0 for Muni. This means that the level-2 variables were categorical, qualitative variables. SCHOOL characteristics of student i that affected performance of the female student were: leadership style of the school (fear or trust), qualification and commitment of the subject teachers and the presence of functional A-level science laboratories and libraries. The qualitative variables SCHOOL were coded as SCHOOL = 1 for Ediofe and SCHOOL = 0 for Muni.

4.9.2 Dependent Variables

The dependent variables measured (or the predictands) were the results of the performance of the participants at independent examinations administered by MACOS, Arua Joint Mock Examination body and UNEB. The average standardized results of the performance of each student in Physics and Mathematics at every independent external examination administered to them were taken as the required cognitive outcome variables. For Physics, four waves of outcomes were recorded while Mathematics students were measured three times. For each examination, there were three papers for Physics and two papers for Mathematics. Scores in each of these papers were added up and divided by the numbers of papers. This produced the final average standardized score for each of the subjects that needed to be analysed.

4.10 Data Collection

In the study both quantitative and qualitative data were collected.

4.10.1 Quantitative Data Collection

All the results of the performance of the participating students in Mathematics and Physics were obtained from the respective schools. For each student, the final average standardised score in Physics or Mathematics was determined by getting averaging the total scores in all the papers and dividing it by the number of papers in a subject. For Physics, there are three papers and Mathematics consists of two papers. Tables 4.1 and 4.2 show the final average standardized scores for Physics and Mathematics respectively.

Table 4.1

Person-Level (Multivariate) Data Structure for Physics Students

ID	School	May-07	Jun-07	Jul-07	Nov-07
1	1	8.67	8.33	6.67	7
2	1	7.33	8	6	5.67
3	1	8.33	8.33	8.67	5.67
4	1	7.67	7.67	7.67	6.33
5	1	9	9	8.67	7
8	1	9	6.33	6	5
11	1	9	9	7	5.33
12	1	9	9	5.67	4.67
14	1	8	7.33	5.67	7
15	1	9	8	5.67	5
16	1	7	7.33	6	5.33
17	1	7.67	8	7.33	7
18	0	7.33	6.33	6	5
19	0	8	9	8.33	6.67
21	0	9	6.67		9
23	0	7	7	7	6.67
25	0	6.33	6.67	9	8.33
26	0	9	7.33	9	8.33
27	0		7.67	9	7

A student in Muni (ID=27) did not sit for the first external examinations of MACOS in May 2007 because she was involved in a disciplinary case with the school administration of Muni. Another student of Muni (ID = 21) did not sit for the Arua District Joint Mock Examinations in July 2007 because she was sick.

In Physics, students of both schools registered some improvement from the initial status except two students (ID 21 and 25) from Muni showed decline in performance.

Table 4.2
Person-Level (Multivariate) Data Structure for Mathematics Students

ID	School	Jun-07	Jul-07	Nov-07
1	1	9	9	7.5
6	1	8	9	8
7	1	9	9	8.5
8	1	5.5	8.5	5
9	1	8	8.5	5.5
10	1	5	8.5	6
12	1	4	8	6.5
13	1	9	9	8
14	1	7	9	6
15	1	8	9	6.5
17	1	9	9	7
18	0	9	6	6.5
19	0	9	9	6.5
20	0	9	9	9
22	0	9	9	7
23	0	9	9	8.5
24	0	9	9	9
26	0	9	9	9
27	0	9	9	8
28	0	9		6.5
29	0	9	9	7.5
30	0			4

Muni student (ID = 28) also did not sit for the Arua District Joint Mock Examinations in July 2007 due to sickness.

Student (ID = 30) sat for her final UNEB examinations in Muni. She was not part of the students who were participating in the hybrid e-learning project. She studied in one of the educationally elite secondary schools in Wakiso District, Uganda Martyrs', Namugongo. She only registered to do her UNEB examinations in Arua so that she could benefit for Government sponsorship in the university on the District Quota scheme. Her results were considered as outliers and were removed from subsequent analysis.

Three students from Muni failed Mathematics at all measurement occasions (ID = 20, 24 and 26). They did not improve, despite the intervention.

4.10.1 Qualitative Data Collection

Qualitative data collected were recorded as field notes by the author. These were results on interviews of stakeholders and observations made as the research progressed. Some relevant documents were collected from schools and the MOES. Some of the documents/ records collected were:

- performances of the schools in previous national UNEB examinations
- expenditures and incomes of the schools
- Schemes of work for A-level Physics and Mathematics classes from MACOs
- Timetables for the Physics and Mathematics students in the schools
- Examination syllabus
- Arua Joint Teaching syllabi for A-level science and Mathematics subjects
- Advanced level curriculum
- Interactive CD-ROMs for A-level Physics and Mathematics
- Text books for A-Level Physics and Mathematics were purchased for the schools
- Practical Physics Manuals/Workbooks were distributed to the participating students
- UNEB past papers for Physics and Mathematics for 1991 to 2006 were photocopied and distributed to each of the participants. They were to assist the students in practising solutions to UNEB-type questions.
- Opinions of stakeholders about the poor performance of rural schools in Physics and Mathematics were recorded during various interviews and discussions with them.
- Interview transcripts
- Field notes
- Video and audio recordings of practical sessions facilitated by MACOS senior teachers
- Photographs taken using digital cameras
- Audio recordings using MP3 recorders
- Documents like reports of field visits, minutes of meetings, e-mails and SMS messages.

4.11 Data Analysis

Both quantitative and qualitative data analysis methods were used for analysing the data collected.

The repeated measures data that were collected were analysed using multilevel methods that were found suitable for the analysis of nested, correlated data. The analysis aimed at establishing the effects of the hybrid e-learning intervention and school contexts on the performance of rural students in Physics and Mathematics. Three individual growth models for each subject were fitted to aid the analysis. Details of the analysis are depicted in the next chapter.

Action Research methodology which simultaneously combined both 'action' and 'research' was used in the qualitative data analysis. In this type of participatory research, the researchers continuously repeated the process of performing action, reflecting on what happened and using the information to plan the next action. Therefore, the process of action research had the self-refining effect on action and the researchers gained understanding of what was going on. The action research was regarded as a three-step spiral process of data analysis: planning, taking action and fact finding about the results.

CHAPTER FIVE: PRESENTATION OF RESULTS

5.1 Presentation of Longitudinal Analysis Results

5.1.1 Variance-Covariance Matrix Structure

The correlation and variance-covariance matrices from the longitudinal data collected in the study were calculated and are depicted in Tables 5.1 and 5.2 for Physics and Mathematics respectively.

Table 5.1

Correlation and Variance-Covariance Matrices for Repeated Measures in Physics

	Measurement Occasion 1	Measurement Occasion 2	Measurement Occasion 3	Measurement Occasion 4
Measurement Occasion 1	**0.7315**	0.29915	-0.06445	-0.08077
Measurement Occasion.2	0.388829	**0.767202**	0.156505	-0.24418
Measurement Occasion 3	-0.062068	0.14378	**1.594257**	0.966608
Measurement Occasion 4	-0.07570	-0.22809	0.70237	**1.493715**

Table 5.2
Correlation and Variance-Covariance Matrices for Repeated Measures in Mathematics

	Measurement Occasion 1	Measurement Occasion 2	Measurement Occasion 3
Measurement Occasion 1	**2.174603**	0.221875	0.984127
Measurement Occasion.2	0.217799	**0.461875**	0.28812
Measurement Occasion 3	0.57484	0.359998	**1.348073**

Between- student variances in the diagonal, covariances above diagonal, correlations below diagonal

From tables (5.1) and (5.2) it can be seen that:
• the between-student variances in the main diagonals of the matrices were variable, not constant. Therefore, the assumption of heteroskedasticity appeared justifiable.
• there was no clear observable trends in the behaviour of correlations (or covariances) with increasing lag. These correlations between outcomes had to be factored in the analysis otherwise wrong inferences would be made. Traditional regression methods of data analysis were disqualified as possible options to be used. Multilevel methods were found to be more convenient.

The variance-covariance matrices showed no particular trend. It was found prudent to assume that the variance-covariance matrices were unstructured.

5.1. 2 Analysis of Trends in the Longitudinal Data

To determine the broad trends in the data, smooth splines of individual performance trajectories with increasing duration of the hybrid e-learning intervention in months were drawn. These trajectories are shown in figures 5.1 and 5.2 for Physics and Mathematics respectively. Note that a standard score of 9 represents a failure while 1 represents the best score.

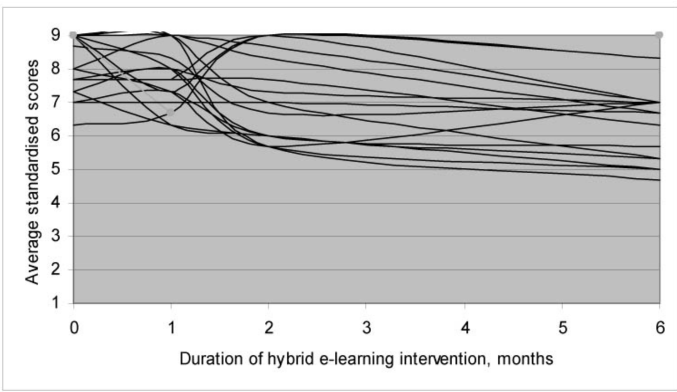

Figure 5.1 Individual smooth splines for performance in Physics

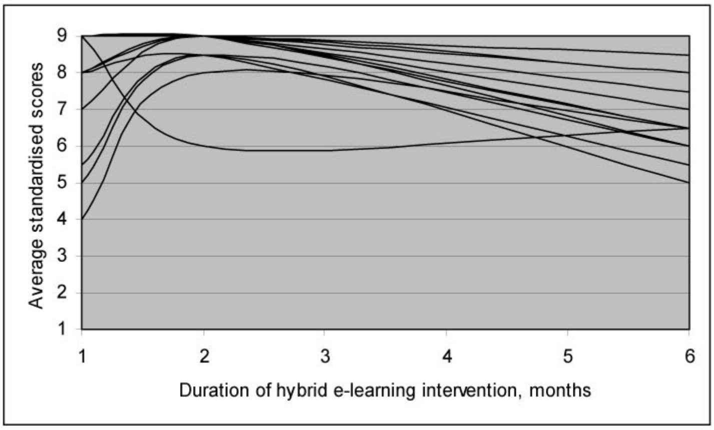

Figure 5.2 Individual smooth splines for performance in Mathematics

From the smooth splines in figures 5.1 and 5.2, it was observed that generally there was generally a linear relationship between individual performance scores and duration of hybrid e-learning intervention. The implication was that the data could be modelled as linear relationship between the outcomes and predictors.

The trajectories also showed that there was a general improvement in performance with increasing duration of the intervention. It could also be seen that variability in individual performance was increasing with time.

5.1. 3 Results of Model Fitting

The composite model (3.1) was fitted to data collected. The results of fitting the three individual growth models are shown in Figures 5.3 to 5.6.

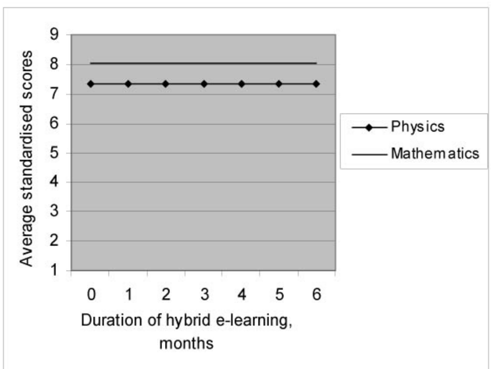

Figure 5.3 The unconditional means models (Models A)

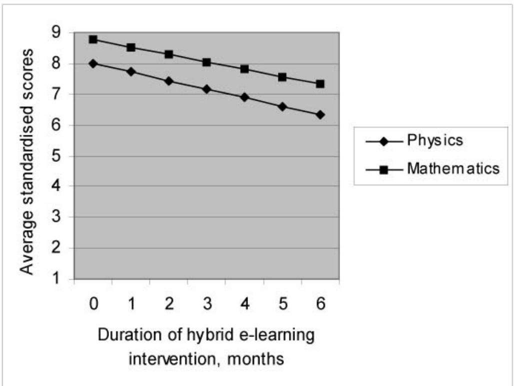

Figure 5.4 The unconditional growth models (Models B)

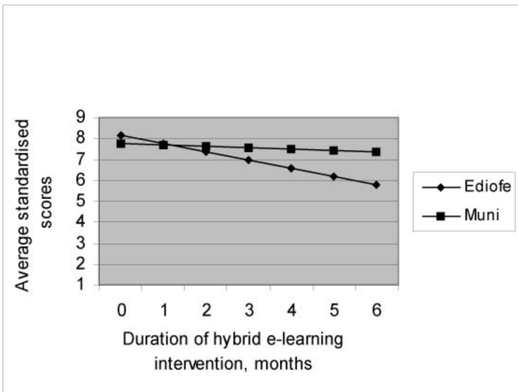

Figure 5.5 The conditional growth models for performance in Physics (Models C)

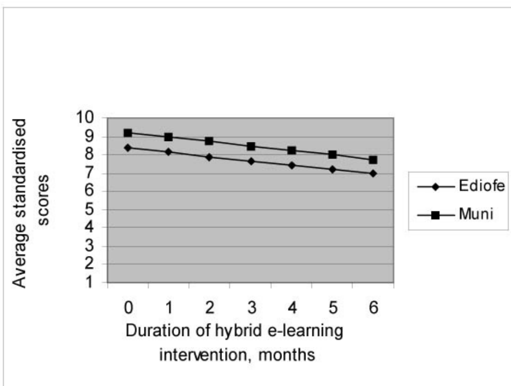

Figure 5.6 The conditional growth models for performance in Mathematics (Models C)

The results of fitting these models and deviance calculations are shown in Tables 5.3 and 5.4 for Physics and Mathematics respectively.

Table 5.3
Results of Fitting Individual Models for Change in Average Standardized Scores in

Physics

Fixed Effects		**Parameter**	**Model A**	**Model B**	**Model C**
Initial status, π_{0i}	Intercept	γ_{00}	7.3604 (0.1462)	7.9841 (0.2131)	8.1417 (1.1503)
	Difference in intercepts between the schools	γ_{01}			0.4185
Rate of change, π_{1i}	Intercept	γ_{10}		-0.2737 (0.0468)	-0.3962 (0.3074)
	Differences in rates of change between the two schools	γ_{11}			-0.3366
Variance Components					
Level-1	Within-student	σ_e^2	1.1623 (0.1859)	0.3893 (0.1076)	0.3893 (0.1076)
Level-2	In initial status	σ_0^2	0.7742 (0.2015)	0.5567 (0.1746)	0.4961 (0.2033)
	In rate of change	σ_1^2		0.0709 ((0.0611)	0.0418 (0.0590)
	Covariance	σ_{01}		-0.0979 (0.1508)	-0.0782 (0.2217)
R^2 statistics	Proportional reduction in Level-1 variance components	R_e^2		0.6651 (0.2017)	0.6651 (0.2017)
	Proportional reduction in Level-2 intercept variance	R_0^2		0.2809 (0.1070)	0.1090 (0.2657)
	Proportional reduction in Level-2 slope variance	R_1^2			0.4104 (0.0849)
Goodness of Fit Statistics	Deviance	D	115.46	86.46	41.74

Standard errors are in parentheses

Table 5.4
Results of Fitting Individual Models for Change in Average Standardized Scores in

Mathematics

Fixed Effects		**Parameter**	**Model A**	**Model B**	**Model C**
Initial status, π_{0i}	Intercept	γ_{00}	8.0323 (0.1678)	8.7598 (0.1317)	8.3528 (0.3834)
	Difference in intercepts between the schools	γ_{01}			-0.8516
Rate of change, π_{1i}	Intercept	γ_{10}		-0.2389 (0.0352)	-0.2338 (0.1025)
	Differences in rates of change between the two schools	γ_{11}			0.0103
Variance Components					
Level-1	Within-student	σ_e^2	0.9501 (0.1923)	0.5433 (0.1454)	0.5433 (0.1454)
Level-2	In initial status	σ_0^2	2.2833 (0.3297)	1.1351 (0.2325)	1.8137 (0.4061)
	In rate of change	σ_1^2		0.0460 (0.0468)	0.0524 (0.0690)
	Covariance	σ_{01}		-0.1194 (0.2118)	-0.2011 (0.4414)
R^2 statistics	Proportional reduction in Level-1 variance components	R_e^2		0.4282 (0.1392)	0.4282 (0.1392)
	Proportional reduction in Level-2 intercept variance	R_0^2		0.5029 (0.2338)	-0.5978 (0.5178)
	Proportional reduction in Level-2 slope variance	R_1^2			-0.1391 (0.0946)
Goodness of Fit Statistics	Deviance	D	106.44	89.94	60.83

Standard errors are in parentheses

5.1.4 Hypothesis Testing using Deviance Residuals

The difference in the deviances of models A and B for Physics was 115.46 - 86.46 = 29.0 (3 df) and for Mathematics it was 106.44 - 89.94 = 16.5 (3df). Note that the degrees of freedom were taken to be the difference in the number of parameters in the two models being compared. From the Chi squared table, both deviance for Physics was highly significant at $p < 0.0005$ while for Mathematics it was significant at $p < 0.001$(3df) . Therefore, the null hypotheses were rejected.

The difference in the deviances of models C and D for Physics was 86.46 – 41.74 = 44.72 (2 degrees of freedom) and for Mathematics it was found to be 89.94 – 60.83= 29.11 (two degrees of freedom. From the Chi squared table, both deviance differences for Physics and Mathematics are significant at $p < 0.0005$ (2 df). Therefore, the null hypotheses are rejected.

5.1.5 Predicting Performance after Twelve Months of the Hybrid E-Learning Intervention

After six months of the hybrid e-learning intervention 11 students from Ediofe and 1 from Muni qualified to join the university. This was 41.4% of the participants.

If the trend was extrapolated to 12 months, 14 Ediofe and 7 Muni girls would be eligible to join universities, 72.4% of the total number of participants. The results of the extrapolation are shown in Table 5.5 and figures 5.7 to 5.10 depict the individual regression lines for all the students in the study.

Table 5.5

Results of Predicting Performance Scores after Twelve Months of Hybrid E-learning Intervention

Physics				Mathematics		
ID	Predicted Score	UNEB final grade		ID	Predicted Score	UNEB final grade
1	5.160	D		1	5.61	E
2	3.39	B		6	7.69	F
3	3.02	B		7	7.87	F
4	4.97	D		8	3.44	B
5	4.93	D		9	2.19	A
8	1.4	A		10	6.18	E
11	1.35	A		12	8.42	F
12	-0.15	A		13	6.74	O
14	5.9	E		14	4.12	C
15	0.85	A		15	4.30	C
16	3.40	B		17	4.48	C
17	6.17	E		18	4.27	C
18	2.80	B		19	3.35	B
19	5.03	D		20	9	F
21	9.68	F		22	4.48	C
23	6.34	E		23	7.87	F
25	10.59	F		24	9	F
26	8.21	F		26	9	F
27	5.74	E		27	6.52	E
				28	3	B
				29	5.29	D

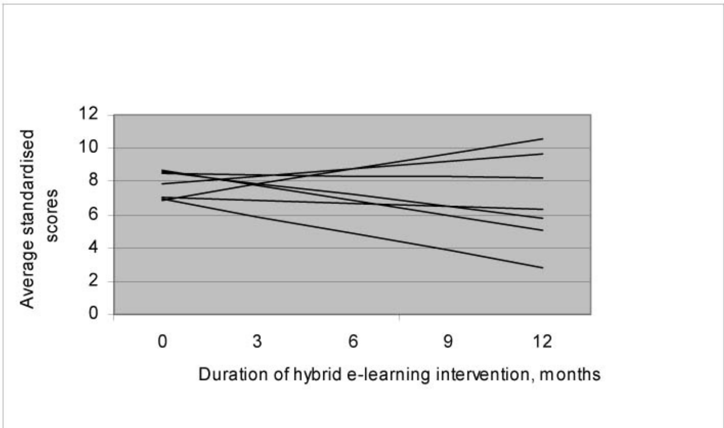

Figure 5.7 Extrapolated individual performances of Ediofe students in Physics

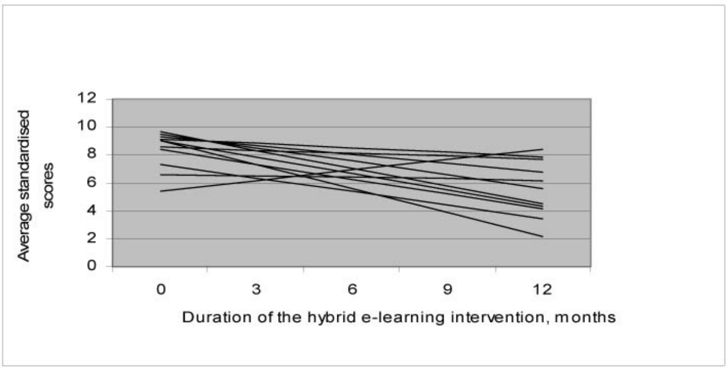

Figure 5.8 Extrapolated individual performances of Muni students in Physics

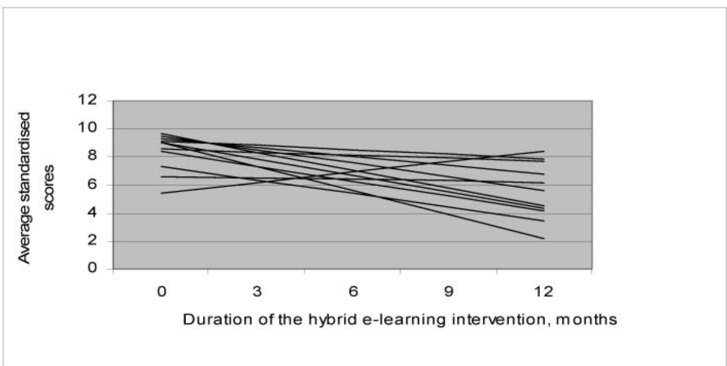

Figure 5.9 Extrapolated individual performances of Ediofe students in Mathematics

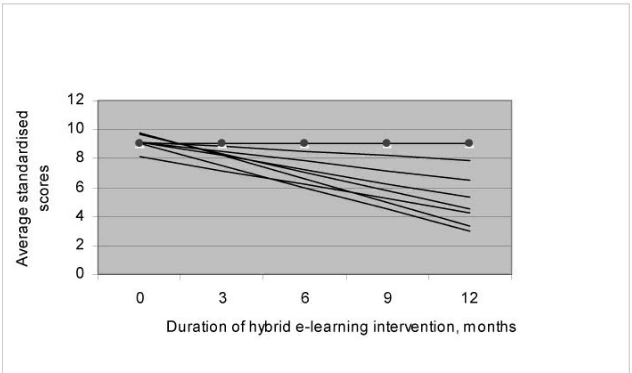

Figure 5.10 Extrapolated individual performances of Muni students in Mathematics

5.2 Social and Economic Impacts of the Hybrid E-Learning Intervention Project

When the ICT Research Centre was opened for public use in June 2006, within three months up to 1253 female students and their teachers were trained in Basic ICT skills, Internet use and working with e-mails. These were students and teachers from Muni, Ediofe, Logiri and Mvara. The training was done free and ten Makerere University telecommunication engineering students were used as instructors. Free training was extended the following three months to all district leaders and heads of departments in Arua. Thereafter, the Research Centre started applying some fee for training to meet some operational costs. The training and broadband Internet access was done at half the market price in Arua. 270 members of the public are trained every year in Basic ICT skills, Internet use and working with e-mails. For the advanced ICT skills training 21 people are trained annually. The curriculum includes hardware maintenance and repair, networking and troubleshooting. Trainees include public civil servants, students, political leaders, members of the state agencies like police, army and prisons, out-of –school youth, secretaries and employees of local businesses in Arua. The Internet cafe has 7 workstations for public use. The Centre offers technical and technology services to businesses and individuals in Arua. The Centre employs eight people from the community: a systems administrator, two guards, one secretary/receptionist, a resident administrator and three part-time instructors who are teachers from the neighbouring secondary schools (Muni, Ediofe and Mvara). The Centre is deeply rooted in the community and they have taken ownership of the Centre. It trains not only Ugandans from the West Nile region, but some students come from South Sudan and the Eastern Democratic Republic of Congo. The Centre has an International status.

The 29 students and ten science teachers who were directly involved in the e-learning project benefitted more from the project. There awareness of the usefulness of ICT was extremely increased. Their expertise and knowledge in ICT drastically increased. They achieved additional skills and competencies that can help them in their private lives. The 11 Ediofe students and one Muni project students who qualified for further education were direct beneficiaries from the study. If their parents and guardians can support them for further education, they will be empowered more. The ten science teachers were retrained in learner-centred pedagogy by SchoolNet. The teachers, students and headteachers of both schools were linked to their colleagues in 13 other secondary schools in Uganda to form a knowledge network of teachers and students and headteachers. A good social capital emerged out of the collaboration with SchoolNet.

In addition to the setting of the Arua ICT/GIS Research Centre with VSAT Internet connectivity using the triple helix framework, further collaborative efforts produced other tangible results. Through collaboration with Makerere College School, local content for Advanced-level Physics and Mathematics was developed in a local context. The local content developed was digitized and through collaboration with programmers, interactive multimedia CD-ROMs were produced. The CDs were used by the students in the study and they are available for use by other schools.

A website was commissioned for the project, www.aruaeduc.com.

Collaboration with SchoolNet, an offline digital library was established in the ICT/GIS Research Centre for use by students of A-Level Physics and Mathematics.

SchoolNet helped in the capacity building of the 10 science teachers, the two headteachers and some students in the project from Muni and Ediofe. A number of Workshops were arranged in Kampala for each group of participants.

The *Mambo*, an open source Course Management System platform was used for managing the e-learning environment.

Stakeholders in the study were given e-mail accounts, most of them for the first time, for purposes of easy communication in the project. E-mails were the only viable communication media among the communities of practice.

These results are discussed in the next chapter.

CHAPTER SIX: CONCLUDING DISCUSSIONS

6.1 Summary of Major Findings

This study found out that:

- After using hybrid e-learning tools and applications for six months, 41% of the Physics and Mathematics students were able to pass national examinations. Consequently, they were eligible for higher education. By predicting the performance after twelve months of using the hybrid e-learning tools and applications, it was found that up to 72% of the students would have passed national examinations, thus qualifying for admission into higher education institutions.
- The Intraclass Correlation Coefficients (ICCs) were found to be 0.4 for Physics and 0.71 for Mathematics.
- The R-squared statistics showed that within the period of the hybrid e-learning intervention, the within-person variability reduced by a factor of 0.67 and the between-person variance reduced by only 0.28 for Physics. Mathematics variations reduced by 0.43 in the case of within-person variance and between-person variance reduced by 0.50.
- The R-squared statistics showed that for Mathematics, the school contexts led to the increase of the variability in intercepts by 0.59 and of slopes by 0.14. For Physics, variability in intercepts reduced by 0.11 and for slopes, it was a 0.41 reduction.
- Triple helix interaction among the academia, local governments and the business community/industry can be useful in looking for solutions to social problems of rural communities.
- Solutions to rural community problems can only be found in collaboration with a number of stakeholders with the target people taking ownership of the process. Participatory methods in creating the 'communities of practice' or alliances for purposes of solving social problems were found to be very helpful in the study.

6.2 Meaning of the Findings

6.2.1 Improvement in Performance

By using mainly interactive multimedia CD-ROMs as a platform for delivering local content course materials for Physics and Mathematics, the rural students were able to perform well at national examinations. Therefore, poor secondary schools can embrace hybrid e-learning and save resources required for constructing and maintaining physical Science laboratories and libraries, Internet connectivity and maintenance of Local Area Networks (LANs). It is much cheaper to introduce hybrid e-learning tools and applications for the benefit of students in rural schools. This finding is in line with that of Evoh (2007) who found that ICTs were the most feasible and economically sound means of expanding access to and improving the quality of secondary education in Africa.

With this level of improvement after one year of using hybrid e-learning tools, should A-Level duration be reduced from 2 two to one year? This should form part of a policy debate. However, there were students in the project who would never improve, despite the intervention.

Mathematics students from Muni like ID 20, 24 and 26 never improved throughout the duration of the intervention. They constantly failed all the external examinations. These students were admitted into A-Level with very poor background experience, low marks at O-Level. To complicate the problem, student ID 26 had eye problems that needed proper spectacles. But throughout the period the parents refused to take her for proper medical examination by an eye specialist to determine the right strength of the lenses needed. Instead, cheap spectacles were being purchased and each time the student would suffer using them. It was a big problem for her when doing practical experiments in light. She would shed tears after failing to see the right images and the head would start aching. This girl would never have improved. The same case applies to student ID 20. She was constantly falling sick. She missed the Arua District Mock Examinations in Physics in July 2007 because she was sick. Muni student ID 27 would never improve also. She was constantly having disciplinary cases to answer with the administration. She missed the first MACOS examinations in May 2007 because she was sorting out cases of indiscipline with the administration. In fact, hatred and mistrust between the administration and Muni students caused all the students to be suspended in August 2007. A lot of learning time was lost because of suspensions, either of individual students of the whole group. Another constantly sick student of Muni was candidate number ID 28. She also missed Mathematics examinations of Arua District in July 2007.

6.2.2 Intraclass Correlation Coefficient

The Intraclass Correlation Coefficient (ICC) shows how much variation in the performance scores lies between-students (at level-2). Therefore, an ICC of 0.40 for Physics means that most of the variation in performance in Physics 0.60 or 60% lies within the students. The implication is that for any attempts to improve performance of the students in Physics, the student should be the point of focus, not the school-level characteristics. An analysis of the performance of the same students in the Physics Practical paper by Lating, Kucel and Trojer (2007 a) shows that the between-person variance was only 32%. This further illuminates the fact that for Physics, within-person variances should be the point of focus in any interventions to improve performance. In the case of Mathematics, most of the variation in performance was between students (ICC of 71%). Therefore, any attempts to improve performance in Mathematics, the school contexts must be at the central focal point.

ICC determines where subsequent modelling effort must be made. An ICC of 0.4 as in Physics means that adding a level-1 predictor will be more viable in reducing the within-person variations. For Mathematics, it is the other way round. With an ICC of 0.71 means that a level-2 predictor will help to reduce the between-person variability in performance. In this study, DURATION of hybrid e-learning and SCHOOL contexts were used as level-1 and level-2 predictors respectively.

These findings contrasts significantly with the current efforts by the Government aimed at improving Science and Mathematics education in Uganda. Some few examples need to be cited. The In-Service Secondary Teacher Education Project (INSSTEP) was funded by DFID and successfully concluded in 1999 having started in 1994. The project aimed at increasing the efficiency and effectiveness of teaching in Mathematics, Science and English through in-service teacher training and establishment of national teacher resource centres. By the end of the project many secondary school teachers of Mathematics, Science and English had their skills and knowledge upgraded through in-service training. Arua District was a beneficiary of this project. Arua Teachers Resource Center was established. However, the INSSTEP project was not sustainable. Improvement in performance of students in the subjects covered by the project did not happen. The same project has resurfaced in Uganda under a different name, Secondary Science and Mathematics Teacher's Programme (SESEMAT) funded by the Japan International Cooperation Agency (JICA). The project started in 2005 and is still on-going. It aims at improving performance in Science and Mathematics in secondary schools through: building and renovating laboratories; supplying equipment, chemicals and textbooks; recruiting more science teachers; establishment of Teacher's Resource Centres (a duplication from the INSSTEP project); introducing computer science and ICT skills to both teachers and students. Just like the INSSTEP project SESEMAT programme also intends to enhance the quality of teaching and learning of Science and Mathematics through the In-service Education of Training (INSET). Again Arua is benefitting from this project. Some teachers of Ediofe and Muni are involved in it. Unfortunately, the project only targets ordinary level secondary schools, just like the INSSTEP project.

All the Government interventions are being implemented without prior research. Though they are meant to support on Ordinary Secondary Education, it would be interesting to do a study that justify the interventions at the school level for all subjects. Maybe there are some subjects like Physics that would require intervention at the within-student level.

6.2.3 The Effects of Duration of Hybrid E-Learning Intervention on Performance

R-squared statistics are used to show the effect of adding a predictor in subsequent modelling efforts. The statistics show the proportional reduction in variabilities after adding a predictor to the models. The DURATION of the hybrid e-learning intervention, a level-1 predictor, reduced within-person variability in Physics performance by 0.67 (or by 67%). For Mathematics, the within-person reduction was only 43%. This helps to demonstrate an earlier argument that for improvement in Physics performance, adding a level-1 predictor was more useful.

The R-squared statistics may also be interpreted differently. An R-squared statistic of 0.67 means that the level-1 predictor (DURATION of hybrid e-learning intervention) accounted for 67% of the within-person variabilities in Physics scores. Therefore, 33% remained unaccounted for. For Mathematics, 57% of within-person variability remained unaccounted for. It means that another predictor at level-1 must be added to the model to reduce the remaining variabilities. However, adding another predictor at Level-1 to further reduce the within-person variations outside the scope of this study. It was left as an area for further research work. Common student characteristics that are used for fitting individual growth trajectories of students' achievements in schools include Socio-economic Status (SES) or age of the student. In some studies, useful time spent learning a subject, is also considered a Level-1 variable (lee, 2000; Lan & Li, 2003). However, a Level-2 predictor was added in an attempt to further reduce the between-person variance.

6.2.4 The Effects of School Contexts on Performance

For Physics, the initial status (intercept) variance components reduced from 0.5567 (Model B) to 0.4961 for Model C. The R-squared statistic was found to be 0.1089 meaning that it was a 11% reduction in variance of intercepts. For Mathematics the intercept variability increased from 1.1351 (Model B) to 1.814 (Model C) thus resulting in a 60% increase in the intercept variability.

The variance of the average monthly rate of change equally declined from 0.0709 (for Model B) to 0.0418 (for Model C) in the case of Physics. This was a 41% reduction. However, school contexts caused an increase in slope variability in Mathematics by 14%.

One of the properties of R-squared statistic, or the coefficient of determination as it is referred to in some literatures (Menard, 2000 and Exner and Zvara,1999), is that its values must lie between 0 and 1. According to Algina and Olejnic (2000), Fisher (who is considered the father of modern Maximum Likelihood Estimation methods), derived the density function of R -squared in 1928 so that its cumulative distribution function can be evaluated using numerical methods. The authors further report that it was Ezekiel who eventually introduced the concept of R-squared and adjusted R-squared statistics in 1930. Since its introduction, the R-squared statistic has grossly been abused and misused. Some authors use the R-squared statistics for drawing conclusions about the goodness-of-fit of models. Menard (2000), and in an earlier study by Kvalseth (1985), caution against the use of R- squared statistic, which is biased (Pokrojac and Obradovic, 2001), for making inferences about models.

One of the problems of R-squared statistic is that it can show a negative value. It depends on sample size or degrees of freedom. This offers a lot of difficulty in interpreting what the statistic means. For Mathematics students in this study, the level-2 sample size reduced from 21 students at level-1 to 11 students for Ediofe and 10 for Muni at level-2. This reduction in sample size and consequently the degrees of freedom can affect the R-squared statistic. Algina and Olejnik (2000, 2003) present regression equations that can be used for determining sample size for R-squared statistic for up to 20 predictor variables. The statistic is only suitable when regressors are random (Helland, 1987) and it is not suitable for fixed origin or fixed intercept models (Exner and Zvara, 1999, Becker and Kennedy, 1992). R-squared statistic can also become negative when the model is run with a categorical variable, like in this case where SCHOOL was used as a dummy variable. A negative R-squared, in the argument proposed by Kevin (1991) means that a predictor variable can explain less than 0% of the variance in the scores in Mathematics. He maintains that the presence of 'suppressor effect' which occurs in higher order partitions.

What Kevin calls the 'suppressor effect' are the extremely difficult contexts under which students in the project schools learn Mathematics. The school characteristics are too extreme to facilitate learning of Mathematics. Physics was relatively well done compared to Mathematics. Only two student of Physics (ID = 21 and 25 from Muni) performed poorest in Physics. She first improved in performance but later failed the final UNEB examinations. Mathematics had three students, all from Muni, who did not improve throughout the duration of intervention. They were students with IDs 20, 24 and 26. Physics was better done because it is the only subject that had a qualified A-level teacher (B.Sc degree with a post-graduate diploma in Education). The teacher was also a recognized UNEB examiner and was very useful in the project implementation. Unfortunately, both schools do not have a qualified teacher for Mathematics. For Muni, the situation was complicated by the lack of trust between the leadership, teachers and the students. They were motivated by fear. The necessary support and scaffolding of the students by the teachers did not happen, especially in Muni. Ediofe students who had more conducive learning environment had higher rates of improvement in Mathematics. This created a lot of variation in the performance. There was more variability in Mathematics performance than in Physics.

It is unacceptable to use a R-squared statistic which is negative. More research needs to be done to see how in such difficult rural contexts, what adjustments need to be done to the negative R-squared statistic. For purposes of this study, it can only be concluded that the role of the school context was negatively imparting on the performance of students. The school, especially Muni does not support students' learning in Mathematics.

6.2.5 Co-evolution in a Triple Helix Process

When the proposal for the project was developed, the main thinking was to identify the girls' schools in Arua and connect Internet to the schools as part of the e-learning support for the learning of advanced-level Physics and Mathematics subjects. All that changed after visiting the schools. The financial situation in both schools, Muni and Ediofe, could not justify increasing operational costs of sustaining Internet connectivity. Both schools cannot maintain networks. A decision was made to deliver content in CD ROM format to the schools but set up the ICT/GIS Research Centre with VSAT Internet connectivity within the vicinity of the two schools. The Arua District Council provided buildings for the Research Centre. Faculty of Technology, with financial support from Sida/SAREC, equipped the Centre. The Business community agreed to use the services at the Centre to make it sustainable. Eventually, the project evolved into a Triple Helix process (Lating, Kucel and Trojer, 2007 b) between Government, Academia and the Business with each represented on the Management Board of the Centre. What started as an e-learning project for 29 students of Muni and Ediofe, co-evolved into a concrete implementation of a Triple Helix process. Triple helix model means the three different spheres of business (industry), higher education (academia), and public institutions (Government) working together in support of innovations in industry. According to Leydesdorff and Etzkowitz (1998, 2001), the future location of research is in the intersection of the academy and industry for purposes of supporting innovations and universities must transform themselves, as demanded by the prevailing situations, by one taking on some role of the other. Leydesdorf (2001) maintain that innovation systems must be knowledge-based. Juunainen (2002) highlights the problems and contradictions that are encountered when universities try to commercialise their research results. The author mentions the problems of intellectual property rights, industrial collaboration and the difficulty of forming hybrid companies by universities. He highlighted these problems when discrediting the triple helix concept. But it must be noted that the research results that they were trying to commercialise were generated outside the triple helix process. They were disciplinary results from a biotechnology research. Other triple helix partners were not involved in the research.

6.2.6 The 'Mode 2' Knowledge Production

This study did not only co-evolved in a Triple Helix process; it further co-evolved in the co-production of knowledge (Gibbons et al, 1994; Nowtony, Scott & Gibbons, 2001). Socially distributed knowledge production in the context of the problem in Arua was the main research activity that took place in that local, situated context. Distributed 'communities of practice' which emerged during the study were socially networked through personal face-to-face interactions, e-mails, mobile phones, SMS text messages, etc. The 'communities of practice' continuously produced knowledge and applied it. Actors in this process included students, their subject teachers, examiners, curriculum experts, programmers, graphic artists, academicians, statisticians, politicians, businessmen, etc. The end result was the evolution from a strict disciplinary research to a transdisciplinary one. In the seminal works of Lave (1988) 'Communities of Practice' are groups of people who share a passion for something that they know how to do, and who interact regularly to learn how to do it better. As a result of this simultaneous collaborative knowledge generation and application, the hybrid e-learning tools and applications were developed and deployed for use by the students involved in the project. Mode 2 method of generating knowledge in a specific context of its application and implication is gaining ground in the present knowledge-based world economy. Knowledge is a fourth factor of production. A knowledge economy is strictly driven by innovations. In the e-Yethu ICT project in South Africa, Hodgkinson-Williams, Slay and Sieboger (2008) called the 'community of practice' as 'social constructivism'.

Most higher education institutions graduate students who have research methods skills. When such graduates join industry, they start their own Research and Development Departments. A lot of research is taking place in industries, not in Universities as has been the case in the past. To remain relevant, universities must, in addition to strict disciplinary research done on their campuses, also handle transdisciplinary research in the contexts of the problems. Hagoel & Kalekin-Fishman (2002) refer to transsdisciplinary research as crossing borders among disciplines. The reader is referred to the works of Dalke and McCormack (2007) for more information about transdisciplinary research. This is the main reason why universities like Makerere University have added 'service to the communities' in addition to their traditional mandate of teaching and research.

It must be emphasized that universities can only offer efficient 'service to the communities' within the framework of the triple helix processes. Universities should champion their relevance in the knowledge economy by leading the process of innovations within industries. Innovation in industry is a fuzzy process which requires the blurring of boundaries in what is called 'Mode 2' of the production of scientific knowledge.

In South Africa, Winberg (2006) reports that Universities in that country are under pressure to produce knowledge that is more relevant to the country's social and economic needs, more representative of the diversity of its knowledge producers, and more inclusive of the variety of the sites where knowledge is produced.

6.3 Challenges Experienced during the Study

There were quite a number of challenges that were experienced during the study.

6.3.1 Limitations of Multilevel Modelling

Multilevel analysis is quite suitable for the analysis of nested, correlated, or dependent data. It has superior advantage over other traditional methods of analysis. The ability to simultaneously model data collected from different levels of a hierarchical structure is the first advantage of multilevel analysis. This is reflected in the composite or integrated model (3.1). The second advantage is that multilevel analysis does not require restrictive assumptions to be made like in the traditional linear RM ANOVA /MANOVA regressions. The only assumptions are: linearity of the outcome variables with their predictors; distribution family of the residual errors; the outcomes must be measured using the same metrics or scales and an assumption must be made about the variance-covariance matrix. It must be mentioned that multilevel analysis is robust to misspecification of the variance-covariance matrix. The third advantage is more relevant for longitudinal studies. The subjects in the study serve as their own control in repeated measures studies. The fourth advantage is that multilevel analysis can handle missing data and unbalanced designs where intervals of measurements of outcomes are unequal. The final advantage of multilevel analysis has not been mentioned in most literature sources but it is implied. Multilevel analysis is quite suitable for analysis of social contexts. Raudenbusk and Bryk (1986) who are considered as the fathers of HLM, use the method in studying school effects. HLM is widely used in school effectiveness studies. In this regard, the reader is referred to the works of Ma and Klinger (2000), Lee (2000), von Secker and Lissitz (1999) and Rivkin, Hanushek and Kain (2005). Despite the numerous advantages of multilevel analysis, the method has some disadvantages.

Multilevel models are relatively new statistical tools and have been in use for about twenty years. Fitting of multilevel models require the use of specialized software packages. Unfortunately, there are no packages that can handle more than three levels of data analysis. Most packages can only handle two levels of data analysis. The packages are mainly proprietary and are generally not affordable by researchers. Analysis of multidimensional data is very complex. That is why in the analysis of a 22-dimensional, highly unbalanced repeated measures data Fiews and Verbeke (2006) recommend the use the method of pairwise fitting of the multilevel models. However, some studies show that pairwise testing of outcomes leads to inflation of the Type 1 error and α also increases. This phenomenon is called the familywise errorrate, given by the expression

$$F_{ER} = 1 \quad (0.95)^n \qquad (6.1)$$

at 95% confidence level, and n is the number of pairwise tests done.

6.3.2 Software Issues for Fitting Multilevel Models

Hierarchical, nested or clustered data structures are common throughout research. However, until the mid 1980s, there were no appropriate statistical techniques for analyzing such data. The recent developments in computing power led to the emergence and refinement of software packages which can facilitate the complex data analysis involved.
There are quite a number of software programs and packages that are designed or can be used for multilevel analysis. Some of the packages like TERRACE, NLME, BUGS and OSWALD are minor packages that were developed by researchers to enable them do specific data analysis in the course of their research. The major specialized software programs that can do multilevel data analysis are MLwiN, HLM and VARCL. Programmes like SPSS, STATA and SAS are general purpose packages that were modified to have procedures for handling nested data.

All the software packages and programmes mentioned above are proprietory and are mainly based on Windows platforms. They are commercial.

Within the context of this research, criteria for choosing a software package to use were developed. The main requirements of the software were its availability, affordability, and the ability to perform Full Maximum Likeilhood parameter estimation.
From the websites of the developers of the software packages, MLwiN was costing 900 USD a copy, HLM (425 USD), VARCL (350 USD) and STATA (1,750 USD plus additional 42 USD for getting a procedure that does Maximum Likelihood Estimation, 3rdedition). STATA also charges additional 65 USD for a package Stat Transfer, a software and manual that allows conversion of data sets into other formats (for example SAS) to STATA and vice versa. The cheapest price for SPSS is 639 USD and the annual license fees are based on unlimited number of named and current users of the software.

Documentation and additional support are charged differently by the companies selling the programmes. For example, User's Guide, Data Management and Quick reference for STATA costs 179USD, Getting Started with STATA costs 15 USD.

Experience shows that the cost of transporting the software and its documents to Uganda by speed delivery companies like DHL may be equal to the costs of the items. These are the costs of acquisition.

Further costs are to be incurred. Training is required. The annual license has to be renewed. Newer versions of the software have to be paid for. All these costs are well beyond the limited budget for this research. For example, to upgrade to HLM 6 from the older versions like HLM2, HLM3 or HGLM, costs 180 USD. Thereafter, 100 USD is paid per user. Note that all the prices quoted are for single users. For institutions and organizations the number of users of the software must be paid for additionally.

Makerere University's Institute of Statistics and Applied Economics purchased STATA Version 9 with some documentation. I was one of the researchers trained in the application of the software in statistical data analysis. Unfortunately, STATA cannot perform Full Maximum Likelihood Estimation just like SAS. It can do Restricted Maximum Likelihood Estimation. Therefore, the software could not be used for statistical analysis in this project.

SPSS, though widely available in Uganda as pirated products, uses the Repeated Measures ANOVA which cannot handle cases of missing data, assumes that the data is balanced.

With this software dilemma, a decision was made to do the calculations manually with support from the functionalities available in Microsoft Excel.

6.3.3 Sustainability of the ICT/GIS Research Centre

In applied action research, it is difficult to know at the beginning which direction the research will take. This happens in situations where research and development take place simultaneously. It was not known at the beginning that an ICT/GIS Research Centre would be set up in Arua. Yet the study was allocated a fixed budget from the start. In setting up the Centre, 12,000 USD was used to renovate the two buildings provided by the Arua Local Government, 25,000 USD was used to purchase equipment (computers, and servers), and 11,000 USD was used to install VSAT Internet. The operational costs of the Centre are also high. Staff payments amount to nearly 1000 USD, electricity bills- 250 USD per month, VSAT Internet access 450 USD per month, annual fees for Internet service- 350 USD and monthly maintenance of ICT equipment costs on average 250 USD per month. All these expenditures were deducted from the research budget of the author. The study was concluded after the approval of a supplementary budget. The Centre charges some little user fees and can meet most of the operational costs except Internet acces. The public cannot pay the market rate for Internet access. They surf at bellow cost. VSAT Internet connectivity in a rural community is not sustainable. Additional report on the sustainability of the ICT/GIS Research Center is available in Taban-Wani and Lating (2007).

6.4 Recommendations

From this study it is necessary to make the following recommendations:

1. It is evident that teachers who are either holders of diploma in education or Bachelors in education (BED) cannot teach at A-Level. Such teachers are good in teaching methods but very inadequate in knowledge of the subject matter. Many such teachers were found to be teaching at A_Level in Muni and Ediofe due to shortage of qualified teachers. The coverage of the topics by such teachers is shallow

and does not go deep enough to meet the requirements of the examination body, UNEB. Both Muni and Ediofe have very few science students. The cohort in the study consisted of 12 students of Ediofe and 7 students of Muni taking Physics. For Mathematics, Ediofe had 11 students and Muni had only ten 10. This is well below the standard requirement by the Ministry of Education and Sports (MOES) that a class should have 40 students. The fact that those few students cannot be taught well enough so that they pass their examinations should raise questions about the teachers. A-Level classes must be handled by graduates with Post Graduate Diploma in Education. The Ministry of Education and Sports should provide qualified A-Level teachers in secondary schools. The qualified Physics teacher of Ediofe, though he also doubled as the Deputy Headteacher of the school, was very helpful in the project. There was no such scaffolding of students of Mathematics because there was no qualified Mathematics teacher, either in Ediofe or in Muni. Hybrid e-learning helped the students but the effect would have been much better if the face-to-face teaching was handled by qualified teachers.

2. There was no evidence in both rural schools that the inspectorate role by the Education Standards Agency (ESA) of the MOES was being done. Both schools were found operating without the curriculum, examination syllabus, teaching syllabus, schemes of work, lesson plans, science practical manuals and some other teaching aids like dissection kits for A-Level Biology students. Subject teachers dodge classes and do not appear for their lessons. Teachers only shallowly cover one third of the syllabus and present students for UNEB examinations. In 2006 students of Muni did only three Physics practical lessons instead of 30 recommended by the syllabus (one practical session per week during the school term). In Muni teachers beat students yet corporal punishment of students was abolished in all schools in Uganda by the MOES. Some teachers abuse alcohol and even come to teach under the influence of alcohol. There is absolutely no evidence that the schools were supervised. It is recommended that the ESA should be strengthened to carry out its functions of inspection of schools.

3. To improve Science and Mathematics performance in Uganda, the MOES has been carrying out in-service training of secondary school teachers, building and equipping laboratories and libraries, repairing the existing laboratories and libraries. All these are very expensive ventures and only a few schools benefit every year. It will take many years before all the schools get qualified teachers, laboratories and libraries. Those limited physical structures justify the many school dropouts from one level of education to another since the facilities will never be enough. The numbers of students requiring to progress with education increased exponentially. However, the rate of increase of facilities is linear leading to an ever increasing gap that will never be closed. The education system should be opened up. It is recommended

that the MOES should consider introducing hybrid e-learning in schools as a way of supplementing its efforts in improving science and Mathematics education in Uganda. E-learning policy needs to be developed and implemented in schools.

4. This study was done in the context of the problem; it was a problem driven study. It was not the traditional way of doing research by the academia. Many stakeholders participated in the study as co-actors: students, teachers, drivers, Non-Governmental Organisations like SchoolNet Uganda, collaborating secondary schools like Makerere College School, Swedish collaborating institutions, Makerere University's Faculty of Technology, Arua District Local Government, Internet Service Providers like AFSAT, MOES autonomous institutions like UNEB and NCDC. This made the study transdisciplinary. It is evident that knowledge production also takes place in the context of application, not at universities only. Makerere University's research policy needs to be amended to acknowledge the presence of mode 2 approach to knowledge generation.

5. At the beginning of the study, there was a need to design, host and maintain a website for the research project for two years. The cheapest quotation that was submitted was 3000 USD by a commercial webpage design, maintenance and webhosting company in Uganda. The Swedish collaborating institution identified an open source platform, the Mambo, and a webhosting provider, b-one.net, to host the project website. The annual cost that is being paid is 47 USD. Makerere University uses a downgraded Blackboard as an e-learning platform. The cost of the license was 10,320 USD and annually they charge 20% more. When many students will start using the platform, it is common for the company to charge 100 USD per user. The University does not have money to sustain this platform. Another software problem was encountered when needed to do multilevel data analysis. All the software platforms available on the market were commercial ones. The common platforms costs per user were MLwiN (900 USD), HLM 425 USD, STATA 1,750 USD and SPSS 639 USD. For upgrade to a newer version, 180 USD was required. For use by institutions like Makerere, 100 USD was charged per user. These costs were outrageous for poor, rural communities. Manual analysis of the data was done in this study with support from MS Office Excel. Uganda should look recognise that commercial software are not affordable by developing economies. Uganda has an ICT Policy which does not talk about software issues. It is recommended that this National document should be amended to specifically say Uganda is an open-source country. The country cannot afford the expensive proprietary software platforms.

6. Three papers attached to this thesis were accepted and presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology,

Makerere University. The papers will be published in the newly created journal for the three collaborating technical faculties of Makerere University, Dar es Salaam University and Eduardo Mondlane University. However, by the time of publishing this thesis in December, 2008, the papers had not been published. They were still undergoing peer review before publication. This is the traditional way of disseminating scientific work characterised by slow peer review process by experts in the field of study. Other flaws with the traditional anonymous peer review include lack of accountability, possibility of abuse by reviewers, its possible bias and inconsistency. However, in cases where the research is transdisciplinary, it is difficult to get experts in the field of study. As universities move more towards problem-driven research, research in the social context of application, there is need to adopt and open access and open peer review mechanism. It is more convenient in circumstances of Mode 2 production of knowledge.

7. PEAP 3, the main policy being implemented with the aim of eradicating poverty from Uganda by 2017, does not have an ICT component. Equally disturbing is the fact that the National ICT Policy also does not mention PEAP. The two documents need to be harmonised. At the moment, they are being implemented as two disjoint programmes. These policies must be integrated if Uganda Vision 2025 is to be achieved: Prosperous people, Harmonious nation, and Beautiful country.

8. The experience gained in this study shows that for rural projects to succeed, the communities must own the process. They should appear to drive the process and own it. There must be no hierarchy, all stakeholders are equal and are co-actors. The Rural Communications Development Policy which gives subsidies to private business to roll out ICT services to rural areas may not be cost effective. Handling the poorest of the poor cannot be driven by market forces. Private individuals invest where they will get returns on their investment. It is true that the policy helped to take ICT services to rural areas. But the target group, the poorest of the poor, appear to have not benefitted from the policy.

6.5 Future Directions

Clearly, as identified earlier in the thesis, there are several areas where further investigation would be beneficial. The following areas form the main issues that have been illuminated for future investigation:

1. In this study, the DURATION of hybrid e-learning intervention could explain 67% of the scores in Physics and only 43% in Maths. This means other predictors should be added at Level-1. It would be interesting to know how Socio-economic Status of a rural student affects her performance. This will need further research. It would also be interesting to do a study on the effects of the usage of science laboratories by students on their performance. There are cases where schools have laboratories and students do not use them for the right reasons. Both Muni and

Ediofe use the science laboratories as classrooms, because of shortage of classrooms. Time of effective use of a laboratory in a given period is also another good level-1 predictor variable.

2. For each of the subjects taught at A-Level, a study should be done to establish at what level an intervention must be made. Is it at the student level (level-1) or at the school level (level-2)? This will make the interventions more effective. The current intervention at the school-level only may not be appropriate.

3. Development of software for fitting the individual growth models needs to be done. The software should be able to carry out a doubly multivariate analysis (simultaneous modelling of all outcomes in one equation)

4. The presence of Makerere University ICT/GIS Research Centre in the poor, rural and remote District of Arua is portraying a good image of the University in a rural set up. The Research Centre will be consolidated and converted into an Institute under the Faculty of Technology, Makerere University. It will continue to be used as a research centre on sustainability of ICT infrastructure in rural Uganda. Research will be done on the appropriate rural Internet connectivity. Optimisation of bandwidth research will also be done there. A Master of Science degree programme in E-Learning will be developed and conducted in that Research Centre in Arua. The Masters degree programme must focus on the use of open source platforms. The Centre will also be used for doing research in mobile learning. Furthermore, the GIS component of the Research Centre need to be started also. Similar ICT/GIS Research Centres will be started in Bushenyi (Western Uganda) and Busia (Eastern Uganda).

5. The multimedia learning CD-ROMs and DVDs that were developed in the study will be produced for distribution to other equally disadvantaged A-Level schools in Uganda. Additionally, text books for Advanced Level Physics and Mathematics based on the local content developed may be printed.

References

African Union. (2005). The New Partnership for Africa's Development. http://www.nepad.org/2005/files/inbrief.php

Algina, J., & Olejnik, S. (2000). Determining sample size for accurate estimation of the squared multiple correlation coefficient. Multivariate Behavioral Research 35(1), 119-137.

Algina, J., & Olejnik, S. (2003). Sample size tables for correlation analysis with applications in partial correlation and multiple regression analysis. Multivariate Behavioral Research 38(3), 309-323.

Anderson, C.J. (2008) Lecture notes: Multilevel analysis/Hierarchical linear modeling. Retrieved on 11th November, from www.ed.uiuc.edu/courses/EdPsy490CK/lectures/

Arnold, M.L., Biscoe, B.B., Farmer, T.W., Robertson, D.L., and Shapley, K.L. (2007) How the Government defines rural has implications for education policies and practices. Issues & Answers, South West, USA, Issue No. 10. http://ies.ed.gov/ncee/edlabs/regions/southwest/pdf/REL_2007010_sum.pdf

Attewell, P. (2001). Comment: The first and second digital divides. Sociology of Education, 74(3), 252-259.

Becker, W., & Kennedy, P. (1992). A lesson in Least Squares and R-squared. The American Statistician 46(4), 282-283.

Brown, J.S., Collins, A., & Duguid, S. (1989). Situsted cognition and the culture of learning. Educational Researcher, 18(1), 32-42.

Bryk, A.S., & Raudenbush, S.W. (1987). Application of hierarchical linear models to assessing change. Psychological Bulletin 101(1), 147-158.

Card, D., & Krueger, A. B. (1998). School resources and student outcomes. Annals of the American Academy of Political and Social Science 559, 39-53.

Dalke, A., & McCormack, E.F. (2007). Synecdoche and surprise: Transdisciplinary knowledge production. Journal of Research Practice 3(2), 1-13.

de Leeuw, J., and Kreft, I. G.G. (1986). Random coefficient models for multilevel analysis. Journal of Educational Statistics 11(1), 57-85.

de Leeuw, J., and Kreft, I. G. G. (1995). Questioning multilevel models. Joiurnal of Educational and Behaviorial Statistics 20(2). 171-189.

Dewey, J. (1931). Context and Thought. Berkeley, California: University of California Press.

Dewsbury, D.A. (1992). Book Review: Vygotsky's Psychology: A bibliography of ideas by Alex Kozulin. Harvard University Press 1991. ISIS, 83, 518-519.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National

Systems and 'Mode 2' to a Triple Helix of University-Industry-Government relations. Research Policy 29, 109-123. Retrieved on November 24 2008 from http://www.uni-klu.ac.at/wiho/downloads/Etzk.pdf

Evoh, C.J. (2007). Collaborative partnerships and the transformation of secondary education through ICTs in South Africa. Educational Media International 44(2), 81-98.

Exner, O., & Zvara, K. (1999). Coefficient of determination in some atypical situations: use in chemical correlation analysis. Journal of Physical Organic Chemistry 12, 151-156.

Fiews, S., & Verberke, G. (2006). Pairwise fitting of mixed models for the joint modelling of multivariate longitudinal profiles. Biometrics 62, 424-431.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., & Trow, M. (1994). The new production of knowledge: the dynamics of science and research in contemporary societies. London: Thousand Oaks; New Delhi: Sage publications.

Gorard, S. (2003). What is multilevel modeling for? British Journal of Educational Studies 51(1), 46-63.

Government of Uganda. Ministry of Finance, Planning and Economic Development.

(2004). Poverty Eradication Action Plan 2004/5-2007/8.

Government of Uganda. Ministry of Finance, Planning and Economic Development.

(1998). Vision 2025: A strategic framework for national development, Vol.1, Main Document.

Government of Uganda. 1995 Constitution of the Republic of Uganda.

http://www.ugandaonlinelawlibrary.com/files/constitution/constitution_1995.pdf

Govindasamy, T. (2002). Successful implementation of e-learning: Pedagogical considerations. Internet and Higher Education 4, 287-299.

Hagoel, L. & Kalekin-Fishman, D. (2002). Crossing borders: toward a transdisciplinary scientific identity. Studies in Higher Education 27(3), 297-308.

Hanushek, E. A. (1981). Throwing money at schools. Journal of Policy Analysis and Management 1(1), 19-41.

Haraway, J.D. (1997). Modest Witness@Second Millennium. New York: Routledge.

Hedeker, D., Gibbons, R.D., & Waternaux, C. (1999). Sample size estimation for longitudinal designs with attrition: comparing time-related contrasts between two groups. Journal of Educational and Behavioral Statistics 24(1), 70-93.

Helland, I.S. (1987). On the interpretation and use of R-squared in regression analysis. Biometrics 43(1), 61-69.

Henry, P. (2001). E-learning technology, content and services. Education + Training 43(4), 249-255.

Hernandez-Lloreda, M. V., Colmenares, F., & Arias, R. M. (2003). Application of Hierarchical Linear Modelling to the study of trajectories of behavioural development. Animal Behaviour 66, 607-613.

Hodgkinson-Williams, C., Slay, H., & Sieboger, I. (2008). Developing communities of practice within and outside higher education institutions. British Journal of Educational Technology 39 (3), 433-442.

Juuninen, J. (2001). Reconsidering the Mode 2 and the Triple Helix: A critical comment based on a case study. Science Studies 15(2), 36-58.

Kevin, R.R. (1991). Partitioning predicted variance into constituent parts: How to conduct communality analysis. Paper presented at the Annual Meeting of the Southwest Educational Research Association, San Antonio, TX, January 25-27, 1991.

Kvalseth, T.O. (1985). Cautionary note about R-squared. The American Statistician 39(4), 279-285.

Laird, N. M., & Ware, J. H. (1982). Random-effects models for longitudinal data. Biometrics 38, 963-974.

Lan, M.C., & Li, M. (2003). The relationship between classroom practices and student performance in Mathematics on TIMSS 2003. Retrieved January 8, 2009 from http://www.iea-hq.org/fileadmin/user_upload/IRC2006/IEA_Program/TIMSS/Lan___Li.pdf

Lating, P.O., Kucel, S.B., & Trojer, L. (2007 a). Longitudinal Analysis of Performance of Ugandan Rural Advanced-Level Students in Physics Practicals. The paper presented at Conference on Collaborative Research for Technological Development, Kampala, Uganda.

Lating, P.O., Kucel, S.B., & Trojer, L. (2007 b, December 17-21). E-learning for

Development in Rural Uganda- Co-evolution in Triple Helix Processes. The paper presented at Conference on Collaborative Research for Technological Development, Kampala, Uganda.

Lating, P.O. (2006). Hybrid e-learning for rural secondary schools in Uganda. Licentiate Dissertation Series, Blekinge Institute of Technology, Karlskrona, Sweden.

Lave, J. (1988). Cognition in practice: mind, mathematics and culture in everyday life. Cambridge: Cambridge University Press, UK.

Layton, J. E.T. (1974). Technology and knowledge. Technology and Culture 15(1), 31-41.

Lee, V. E. (2000). Using Hierarchical Linear Modeling to study social contexts: The case of school effects. Educational Psychologist 35(2), 125-141.

Leydesdorff, L., & Etzkowitz, H. (1998). The Triple Helix as a model for innovation studies. Science and Public Policy 28(3), 195-203.

Leydesdorff, L. & Etzkowitz, H. (2001). The transformation of university-industry-

Government relations. Electronic Journal of Sociology. ISSN:11983655. http://epe.lac-bac.gc.ca/100/201/300/ejofsociology/2003/v07n03/th.html

Leydesdorff, L. (2001,September 14). Knowledge based innovation systems and the model of a triple helix of university-industry-Government relations. Paper presented at a conference: New Economic Windows: New Paradigms for the New Millennium, Salerno, Italy.

Liang, K.Y., and Zeger, S.L. (1986). Longitudinal data analysis using Generalized Linear Models. Biometrika 73(1), 13-22.

Littell, R. C., Pendergast, J., & Natarajan, R. (2000). Modelling covariance structure in the analysis of repeated measures. Statistics in Medicine 19, 1793-1819.

Ma, X., & Klinger, D.A. (2000). Hierarchical Linear Modelling of student and school effects on academic achievement. Canadian Journal of Education 25(1), 41-55.

Maas, C.J.M., & Hox, J.J. (2004). The influence of violations of assumptions on multilevel parameter estimates and their standard errors. Computational Statistics and Data Analysis 46, 427-440.

Menard, S. (2000). Coefficients of determination for multiple logistic regression analysis. The American Statistician 54(1), 17-24.

Nowotny, H., Scott, P., & Gibbons, M. (2001). Rethinking science: knowledge and the public in an age of uncertainty.Polity Press in association with Blackwell Publishers Ltd.

Nowotny, H., Scott, P., & Gibbons, M. (2003). Introduction "Mode 2" Revisited: The New Production of Knowledge. Minerva 41, 179-194.

Orhan, F. (2008). Redesigning a course for blended learning environment. Turkish Online Journal of Distance Education 9(1), 54-66.

Pokrajac,D., & Obradovic, Z. (2001). Neural network-based software for fertilizer optimization in precision farming. Center for Information Science and Technology, Temple University, USA.

Quene, H., & van den Berg, H. (2004). On multi-level modeling of data from repeated measures designs. Speech Communication 43, 103-121.

Raudenbush, S., & Bryk, A.S. (1986). A hierarchical model for studying school effects. Sociology of Education 59(1), 1-17.

Richer, S. (1975). School effects: The case of Grounded Theory. Sociology of Education 48(4), 383-399.

Rivkin, S.G., Hanushek, E.A., & Kain, J.F. (2005). Teachers, schools, and academic achievement. Econometrica 73(2), 417-458.

Rollin, J. (1999). Book reviews: Robert Chambers, Whose reality counts? Putting the first last. London: Intermediate Technology Publications, 1997, 317 pp. ISBN 1 85339 386. Africa: Journal of the International African Institute 69(3), 474-475.

Rydhagen, B. (2002). Feminist Sanitary Engineering as a Participatory Alternative in South Africa and Sweden. Doctoral Dissertation, Blekinge Institute of Technology. Karlskrona. Sweden

Shaw, R.G., & Mitchell-Olds, T. (1993). ANOVA for unbalanced data: An overview. Ecology 74(6), 1638-1645.

Singer, J.D., & Willett, J.B. (2003). Applied longitudinal data analysis: Modeling change and event occurrence. New York, USA :Oxford University Press.

Skill, T.D., & Young, B.A. (2002). Embracing the hybrid model: Working at the
intersections of virtual and physical learning spaces. New Directions for Teaching and Learning 92, 23-32.

Small, S.A. (1995). Action-oriented research: models and methods. Journal of Marriage and the Family 57(4), 941-955.

Steenbergen, M.R. and Jones, B.R. (2002). Modeling multilevel data structures. American Journal of Political Science 46(1), 218-237.

Strauss, C. (1990). Book Review: Vognition in Practice: Mind, Mathematics and Culture in Everyday Life by Jean Lave. Contemporary Sociology 19(1), 150-151.

Taban-Wani, G., & Lating, P.O. (2007, December 17-21). Sustainability of Rural ICT
infrastructure. This paper was presented at the Conference on Collaborative Research for Technological Development, Kampala, Uganda.

The Republic of Uganda. (1995), Constitution of the Republic of Uganda.

Turyagyenda, J.B., Lugujjo, E., & Mugisa, D. (2005). Proceedings of the Workshop on engineering education and training in East Africa. Paper presented at the Re-directing engineering education to meet the needs of society, Jinja, Uganda.

Uganda National Examinations Board, Uganda Advanced Certificate of Education, Regulations and Syllabuses, (2004-2008, 2005), Kampala: UNEB Publications.

Uganda National Examinations Board, Uganda Certificate of Education, Regulations and Syllabuses, (2006-2010, 2005), Kampala: UNEB Publications.

United Nations. (2003). Indicators for monitoring the Millennium Development Goals. New York, United Nations Publications.

United Nations Publications. Geneva Declaration of Principles.
http://www.itu.int/wsis/docs/geneva/official/dop.html

United Nations Publications. WSIS Plan of Action.
http://www.itu.int/wsis/docs/geneva/official/poa.html

Verma, R., and Ivens, S. Securing women's access to land: Linking research and action.
Project progress presentation from http://www.landcoalition.org/pdf/08_presentation_gender final.pdf

Voci, E., & Young, K. (2001). Blended learning working in a leadership development. Industrial and Commercial Training 33(5), 157-160.

Von Secker, C.E., & Lissitz, R.W. (1999). Estimating the impact of instructional practices on student achievement in science. Journal of Research in science teaching 36(10), 1110-1126.

Winberg, C. (2006). Undisciplining knowledge production: Development driven higher education in South Africa. Higher Education 51, 159-172.

Zeger, S.L., Liang, K.Y., and Albert, P.S. (1988). Models of longitudinal data: A Generalized Estimating Equation approach. Biometrics 44(4), 1049-1060.

PART II

Introduction to the Papers

This doctorate thesis is concerned with applied research activities when implementing hybrid e-learning project in two disadvantaged rural girls' advanced-level senior secondary schools: Muni and Ediofe. The intervention was aimed at supporting Physics and Mathematics education of the female students in the remote, poor and insecure District of Arua, in the West Nile region of Uganda. The compiled part of the thesis includes the following papers:

Paper I. *Strategies for Implementing Hybrid E-Learning in Rural Secondary Schools in Uganda*, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. A poster presentation was made from this paper and exhibited at the SPIDER stand during the Tunis WSIS Summit in November, 2005. The paper was published by Elsevier Ltd, UK, in the proceedings of the First International Conference on Advances in Engineering and Technology, 16-19 July, 2006, Entebbe, Uganda, ISBN- 13: 978-0-08-045312-5 and ISBN- 10: 0-08-045312-0, pgs. 538-545. The international conference was organized by Faculty of Technology, Makerere University.

Paper II. *Implementation of Hybrid E-Learning in Advanced-Level Rural Girls' Secondary Science Education in Uganda: Arua Case Study*, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. This paper was presented at the First International Conference on ICT for Development, Education and Training, Addis Ababa, Ethiopia, May 24-26th 2006. The abstract for the paper was published by ICWE GmbH, Berlin, Germany in the Book of Abstracts, ISBN 3-9810562-2-1. The full paper was published in the conference CD.

Paper III. *Design and Development of Interactive Multimedia CD-ROMs for Rural Secondary Schools in Uganda*, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. The paper was published by Elsevier Ltd, UK, in the proceedings of the First International Conference on Advances in Engineering and Technology, 16-19 July, 2006, Entebbe, Uganda, ISBN-13: 978-0-08-045312-5 and ISBN- 10: 0-08-045312-0, pgs. 546-553.

Paper IV. *Development of Sustainable Hybrid Digital Libraries for Secondary Schools in Uganda: Arua Case Study* by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. (2006). The paper was presented at the Third International E-learning Africa Conference, Accra, Ghana, May 28-30 2008. The abstract for the paper was published by ICWE GmbH, Berlin, Germany, in the Book of Abstracts, ISBN 978-3-941055-00-1. The full paper was published in the conference CD.

Paper V: *Longitudinal Analysis of Performance of Ugandan Rural Advanced-Level Students in Physics Practicals* by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. This paper was presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology, Makerere University. The paper will be published in the newly created journal by the three collaborating technical faculties of Makerere University, Dar es Salaam University and Eduardo Mondlane University. The journal is titled 'The Journal of Engineering, the Built Environment and Technology', JEBET.

Paper VI: *E-learning for Development in Rural Uganda- Co-evolution in Triple Helix Processes* by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. This paper was presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology, Makerere University. The paper will be published in the newly created journal by the three collaborating technical faculties of Makerere University, Dar es Salaam University and Eduardo Mondlane University. The journal is titled ' The Journal of Engineering, the Built Environment and Technology', JEBET.

Paper VII: *Sustainability of Rural ICT infrastructure* by Gyavira Taban-Wani and Peter Okidi-Lating (2007). This paper was presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology, Makerere University. The paper will be published in the newly created journal by the three collaborating technical faculties of Makerere University, Dar es Salaam University and Eduardo Mondlane University. The journal is titled ' The Journal of Engineering, the Built Environment and Technology', JEBET.

PAPER I

Strategies for Implementing Hybrid E-learing in Rural Scondary Schools in Uganda

P. O. Lating, Sub-Department of Engineering Mathematics, Makerere University, Uganda
S.B.Kucel, Department of Mechanical Engineering, Makerere University, Uganda
L.Trojer, Division of Technoscience Studies, Blekinge Institute of Technology, Sweden

Abstract

This paper discusses the strategy that should be used while introducing e-learning in rural girls' secondary schools in Uganda for the benefit of female students of advanced level Physics and Mathematics. The strategy was formulated after numerous field visits to Arua, one of the poorest districts in Uganda. Urban secondary schools where Uconnect and SchoolNet projects are being implemented were also visited. Some literatures were reviewed from the Web on the subject. The results show that a limited form of e-learning, the Hybrid E-learning, can be introduced in rural secondary schools and the main delivery platform is the CD-ROM. To implement the hybrid e-learning, multistakeholder participatory approach, VSAT internet connectivity, and use of open source software are recommended. The implementation of this strategy will result in reducing the digital divide and achievement of one of the Millennium Development Goals of empowering women at reduced costs.

Keywords: ICT; E-learning; Hybrid; Rural; Poverty; Secondary School; Female Students; Gender.

1.0 Introduction

Rural secondary schools in Uganda are poor and have inadequate infrastructure, facilities and qualified teachers for Physics and Mathematics subjects. These are the essential technology and engineering subjects that are required for entry for degree courses in the Faculty of Technology, Makerere University, and the most dominant tertiary institution in Uganda with a sound research base.

Students perform poorly in Physics and Mathematics, especially female students from rural schools. The result is the low participation of female students from rural secondary schools in the engineering and technology profession. This disparity is distinctly evident in the graduation patterns of students from Faculty of Technology, Makerere University, see table 1.

From table 1, it can be seen that in 4 years (from 2000 to 2003) Makerere University produced 417 Engineers out of which 85 were female, giving a 20.4%graduation ratio of female engineers as compared to the total number that graduated in a period of four years.

Table1. Graduations of Undergraduate Students by Gender from Faculty of Technology, Makerere University, March 2000 to March 2003

Course	Civil Engineering	Electrical Engineering	Mechanical Engineering	Total
Male	154	102	76	332
Female	35	34	16	85
Total	189	136	92	417

Source: Academic Registrar's Office, Makerere University

It was observed that in the 2005/2006 admissions into the Faculty of Technology, all the female students admitted were from only four urban, educationally elite Districts of Kampala (the capital city of Uganda) and its surrounding Districts of Mukono, Wakiso and Mpigi. There are 80 Districts in Uganda currently. Therefore, 76 rural Districts failed to produce female students who could perform well in Physics, Chemistry and Mathematics so as to qualify for admission into Makerere University for engineering training. This is a reflection of gender inequality in the education sector: rural female students do not participate in the engineering profession. Such inequalities should be addressed.

The main causes of the poor performance of rural secondary schools in national examinations are:

- Absence of senior laboratories for advanced level experiments. Those that have the laboratories cannot equip them with chemicals and necessary facilities for practical work.
- Such schools lack libraries. Those with libraries cannot stock them with recommended text books.
- Shortage of qualified and committed teachers. Good teachers go to urban and peri-urban schools where they are better remunerated and have attractive fringe benefits.

The schools are too poor to invest in laboratories and libraries. Nor can they attract and remunerate qualified teachers. These are poverty related problems that must be solved by application of ICT in education.

The paper starts by looking at some key international documents that support ICT and Gender research. The relevant policies of the Ugandan government that support this research are reviewed by the researcher. Problems of science education training in rural secondary schools are highlighted. There have been some attempts to introduce e-learning in Ugandan secondary schools under a number of projects with the aim of solving some of these problems. These projects are analyzed to see if they are the appropriate approach to introducing e-learning in schools. At the end of the paper is a strategy for implementing e-learning in rural secondary school science education of female students in Arua district. The research is in progress.

2.0. Why ICT and gender Research?

2.1. United Nations Millennium Development Goals

In September 2000, 189 world leaders under the auspices of the United Nations, (UN), agreed and set eight Millennium Development Goals (MDGs) to guide development of its member countries in the 21st century (UN Publications). By the year 2015, all the 191 UN Member States have pledged to meet these goals. The UN MDG No. 3 specifically deals with empowerment of women. As an indicator for the achievement of this specific goal, gender disparity in primary and secondary education must be eliminated preferably by 2005 and at all levels by 2015.

2.2.The World Summit on the Information Society

In 2003, the World Summit on the Information Society (WSIS) set objectives and targets necessary for UN member countries to achieve the MDGs mainly through the application of Information and Communications Technologies (ICT) in every sector of human endeavour (UN Publications). WSIS operates under the patronage of the UN Secretary General, Mr. Kofi Anan.

2.3.The World Summit on the Information Society Gender Caucus

The WSIS Gender Caucus identified six Plans of Action. The sixth plan recommends strongly the need for Research Analysis and Evaluation to guide actions by UN member countries (UN Publications). It says: “Governments and other stakeholders must apply creative research and evaluation techniques to measure and monitor impacts- intended or unintended- on women generally and subgroups of women. At minimum, Governments and others should collect information disaggregated by sex, income, age, location and other relevant factors. On the basis of these data, and applying a gender perspective, we should intervene and be proactive in ensuring that the impacts of ICTs are beneficial to all”. This particular Plan of Action calls for a more proactive involvement in ICT and Gender Research.

3.0. National ICT and Gender Equality Policies in Uganda

3.1.National ICT and Rural Communications Policies in Uganda

Uganda Government has identified ICT as one of the eight strategic intervention areas. The Government approved the National Draft ICT Policy (2003) for the country. The growth of the ICT use in Uganda was boosted by the Government's decision to exempt all ICT equipment from custom taxes. This helps in making the equipment such as computers more affordable to people.

In 1998, Uganda Communications Commission (UCC) was set up according to the Uganda Communications Act of 1997 as an independent communication regulator in the country. UCC adopted a Rural Communication Development Policy (2001). According to this policy, the three National Telecommunications Operators have been required, directly through the license rollout obligations, to attend to rural communication development. The three National Operators in the country are charged 1% of their annual gross turnover as contribution for the Rural Communication Development Fund (RCDF). UCC set up and manages this Fund (RCDF). The fund, while limited, is being used to leverage investment in rural communications through competitive private sector bidding.

3.2.Gender Policy of the Ugandan Government

There are a number of gender related policies that Uganda government is implementing but the National Gender Policy (2003) is most relevant. At all levels of leadership in Uganda, Gender Mainstreaming is being emphasized. Women have specified number of seats in Parliament and in Local Government Councils. Gender is a component in the composition of Boards of Public Institutions and Corporations. In Education, female advanced level senior secondary school students get additional 1.5 points when they are being considered for entry into public Universities or Tertiary Institutions. Rwendeire (1998) defended educating women in Uganda by identifying the relevant social benefits involved.

3.3.Limitations of the ICT and Gender Policies in Uganda

Unfortunately, both the ICT policy and the National Gender Policy are being implemented without the necessary laws that have been enacted by parliament to guide their implementation.

Access tariffs for Internet, however, remain quite high because Uganda's international access is only through European or American satellites that are expensive compared to our level of development. Minges and Kelly (1997) found that for Dial-up access to Internet for 30 hours a month (i.e. one hour a day), the monthly tariff was almost the same as the annual Gross National Income (GNI) per capita was only 240 USD in 2003. The tariffs consist of fixed ISP and telephone subscription charges and variable telephone usage charges.

UCC established the local Internet Exchange Point for local Internet use. However, services are still affected by lack of appropriate high capacity backbone infrastructure resulting in high local connection costs and bandwidth constraints. There has been a move by UCC to improve this by waiving license fees on Internet Access Service Licenses and use of 2.4GHz spectrum from July 2004. By the end of 2003, Internet bandwidth in Uganda had grown to about 25 Mbps (for up link and 10 Mbps (for down link) from only about 1 Mbps (for both up and down links) in 1998.

UN annually measures the level of ICT penetration and diffusion as one of the Human Development Index parameters. In its Human Development Report (2003), Uganda's number of Internet users (per 1,000 populations) was only 2.5. This is so low if you compare with a country like Sweden that had 516.3 in the same report.

4.0. Internet Connetivity in Rural Secondary Schools in Uganda

There have been some attempts aimed at introducing Internet for learning and teaching in some selected secondary schools in Uganda. Most notably were the SchoolNet Uganda Project and the Uconnect Project .

4.1.The SchoolNet Project

SchoolNet connected Internet to some schools at a capital cost of 30,340 USD. Generally VSAT connectivity methods are used with some schools connected using the Broad Spectrum technology. Dial-up and other wired Internet connectivity methods like ISDN, DSL, Leased Lines and Fiber Optic are not suitable for rural areas. They are narrow band and teledensity is low in rural schools. The project is mainly funded by donors especially the World Bank. However, such schools have problems in sustaining the project and cannot meet the recurrent monthly expenditure of 1,680 USD. And Internet in those schools is not being used for e-learning. Furthermore, the schools that SchoolNet chose are the best urban schools in the country with relatively good science laboratories, libraries, infrastructures and qualified teachers. SchoolNet intends to introduce a commercial, proprietary e-learning platform, the Blackboard. This is a very expensive platform to acquire (the cheapest version id at 12,000USD) and maintain. No rural secondary schools can afford this. Makerere University has also thrown it out.

4.2.The Uconnect Project

Uconnect is an NGO that sells refurbished computers to schools at 175 USD per set, networks them and helps the schools with training of students and teachers in ICT. In some schools they arrange for Internet connectivity by contracting private businesses. Uconnect supplies their clients with the School Axxess server, the LIBRARIAN search engine. Students use it to find web pages of interest to them from among the thousands stored in its web-cache which includes many multimedia sites. There are also full motion interactive training videos that come with the server. This web-caching technology is very relevant for rural schools. Uconnect also encourages the use of open source platform especially the SchoolWeb for e-learning. But none of the schools have any ideas about e-learning.

5. Strategies for Implementing E-learning in Rural Secondary Schools in Uganda

5.1.What does "rural" mean in the Ugandan context?

In the Ugandan context, the word "rural" means "poor" and it is not a classification based on whether an area is sparsely populated or not as is the case in Europe. Therefore, a rural secondary school in Uganda is another name for a poor secondary school.
When implementing e-learning in such poor schools, their unique situations must be borne in mind. And one of the crucial decisions to make is the choice of the delivery platform(s) that will be used.

5.2.Hybrid Type of E-Learning Platforms most Suitable for Rural Secondary Schools in Uganda

The following types of platforms are used for electronic/distance learning purposes:

- *CD-ROMs* are stand-alone instructional or informational programs not connected to Internet or other communication processes.
- *Web-sites* are linked wed pages on an Internet or Intranet. They can be compared to a reference manual or reading a book. They provide passive information.
- *Asynchronous Internet Communication* (AIC) is a listserver forum using communication tools, such as e-mail or bulletin boards, on an Internet or Intranet and is usually accompanied with an archive or database accessible by participants and the instructor. The users log on and write to each other at different times. A listserver is a program that automatically sends e-mail to a list of subscribers. It is the mechanism that is used to keep newsgroups informed.
- *Synchronous Internet Communication* (SIC) is a form of communication like chat, video conferencing via the Internet, and voice chat. The chat function is when the individuals are simultaneously connected to a common site where typed messages are displayed for everyone to see. Each person can type his or her own message. Bulletin boards can be used the same way.
- *Web-based training* is an on-line learning platform containing communication and course management tools on an Internet or Intranet, and can combine the above features.
- *Hybrids* are any combination of the above with classical classroom training or coaching or group facilitation.

In the circumstances of rural, poor secondary schools in Uganda, hybrid platforms are most suitable. And the main course delivery platform should be the CD-ROMs.

5.3.Multistakeholder Best Practices to be used when implementing Hybrid E-learning in Rural Secondary Schools

The implementation of Hybrid E-learning Project should be done using the Multistakeholder participatory approach. Local Government, Businesses, the participating schools, and NGOs, etc. should join hands with Makerere University, Faculty of Technology, in implementing the Research Project. Poverty-related problems cannot be solved single-handedly.

5.4.Internet Connectivity

In circumstances where teledensity is low and private businesses are reluctant to operate in rural areas, VSAT Internet connectivity is only viable method of introducing Internet to schools. The Broad Spectrum technology can be used to connect Internet to schools that are within a radius of 30 kms from a hub, which can be one of the schools itself. Refurbished computers with multimedia capability can be used in rural schools to reduce costs. Four monitors may also be connected to one CPU to further reduce costs. To reduce bandwidth requirement, web-caching will be used. The schools can operate as telecenters and allow the communities to access Internet. This will help to reduce the digital divide.

5.5.Course Management System

For managing the learning environment, a Course Management System will be required and a Website for the Research Project created. This must be open source software, not proprietary. The Mambo is a good product to try and is hosted on an open source server by b-one.net. The author has some experience in using the Mambo.

6. Conclusions

In Uganda, as one of the least developed countries, people in the rural areas face a situation of being among the poorest of the poor in the country. Support to the education system in the rural areas is highly needed. The scarcity of the schools includes teachers (whether skilled or not), textbooks and other learning materials, laboratories, infrastructure like electricity and, in the context of this paper, Internet connection.

Uganda has adopted one of the most radical gender equality policies in the world. When this policy is linked to the policies of development and poverty reduction, the emphasis on well educated women and men in Uganda is inevitable. As elsewhere there is still a long way to go having gender balance especially in higher education. The paper is considering this issue for science education in rural secondary schools. Thus the Faculty of Technology at Makerere University is expected to benefit from the increased admission of female students from the target secondary schools. This is one way to bridge the gender gap existing currently in the Technology and Engineering training, where only about 18 - 20% of the students are female.

Going from policy to practice implies a number of challenges on fundamental levels. Issues such as general technology, ICT, multistakeholder collaboration, open source software, hybrid e-learning platforms, open archive resources as well as web caching for developing digital libraries constitute ways forward. Conclusions have been drawn that e-learning using hybrid delivery platforms can be put into practice in Advanced-level rural secondary science education of female students. This is expected to result in improved performance of female students in Physics and Mathematics.

Still another impact of the hybrid e-learning project is the parallel development of using the targeted schools as telecentres for the surrounding society. If successful, it is expected that Internet use in the rural community will increase. This may have some impact on the digital divide.

References

2003 UN Human Development Report. http://www.undp.org/hdr2003/indicator/cty_f_UGA.html

Minges & Kelly (1997). Uganda Internet: Case Study. http://www.itu.int/africain-ternet2000/Documents/ppt/Uganda%20Case%20Study.ppt#1

Ministry of Gender, Labour and Social Development: National Guidelines in Uganda (1997, 1999, 2003). http://www.ilo.org/public/english/employment/gems/eeo/guide/uganda/- mglsd.htm

Ministry of Works, Housing and Communications: National Information and Communication Technology Policy Framework (Draft). (May 2002). http://www.logosnet.net/ilo/150_base/-en/init/uga_1.htm

Rural Communications Development Policy for Uganda. (2001). http://www.ucc.co.ug/-rcdf/rcdfPolicy.pdf

Rwendeire A. 1998. Presentation at the World Conference on Higher Education, 5-9 October, 1998, Parish. http://unesdoc.unesco.org/images/0011/001173/117374e.pdf

SchoolNet Uganda VSAT pilot project. http://www.schoolnetuganda.sc.ug/hompage.php?-option=vsatproject

Uconnect Schools Project. http://www.uconnect.org/projectextract.html

UN Millennium Development Goals. (n.d). http://www.un.org/millenniumgoals/

World Summit on the Information Society Gender Caucus: Recommendations for Action. (n.d) .http://www.genderwsis.org/fileadmin/resources/Recommendations_For_Action_-Dec_2003_Engl.pdf

World Summit on the Information Society: Objectives, Goals and Targets. (n.d).

All the websites were retrieved on March 10th, 2006.

PAPER II

Implementation of Hybrid E-learning Model for Advanced Secondary School Physics and Mathematics Education of Female Students in Uganda: Arua Case Study

P. O. Lating, Sub-Department of Engineering Mathematics, Makerere University, Uganda
S.B.Kucel, Department of Mechanical Engineering, Makerere University, Uganda
L.Trojer, Division of Technoscience Studies, Blekinge Institute of Technology, Sweden

Abstract

Uganda is one of the Highly Indebted Poor Countries that should achieve all the eight Millennium Development Goals (MDGs) predominantly through application of ICTs. The World Summit on the Information Society (WSIS) strongly recommends that ICTs are the only progressive tools available for acceleration of development in poor countries. MDG No. 3 deals with promotion of gender equality and empowerment of women and a specific target to be met by the UN Member states is: elimination of gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015.

Gender disparity exists in the technology and engineering profession in Uganda. Makerere University, the most dominant University in Uganda, has only 18% female students' enrolment for engineering courses. Furthermore, all the female students admitted on academic merit during the 2005/6 academic year are from the urban secondary schools located in the educationally elite Districts of Kampala (the capital of Uganda) and its neighbouring Districts of Mukono, Mpigi and Wakiso. Uganda has 56 Districts, it means secondary schools in 52 Districts failed to produce a female student who performed well in Physics and Mathematics in order to qualify for admission for engineering courses in Makerere University. These Districts are rural and poor and have no facilities and resources necessary for Science and Mathematics education: there are no laboratories and libraries. In situations where these facilities are there, the poor schools cannot equip the laboratories

and stock the libraries with relevant text books. They cannot attract good, motivated and committed science and Mathematics teachers.

Arua is one of the poorest Districts in Uganda. It has two government-aided advanced level girls' secondary schools. Hybrid e-learning was implemented in these schools using participatory, multistakeholder best practice approach. The academia, donors, business community, central and local government departments and NGOs were involved. The main course delivery platform in hybrid e-learning concept is the interactive multimedia CD-ROM and the traditional face-to-face classroom sessions will continue. Students have access to Internet and can surf relevant websites for additional resources. The learning environment is managed by open source software, the Mambo, hosted on an open source web server, the cascade by B-one. The project website is http://aruaeduc.com.

Advanced level female students of Physics and Mathematics in the two schools will be exposed to the hybrid e-learning until November 2006 when they will sit for the national examinations set and centrally administered by the Uganda National Examinations Board, UNEB. UNEB is an autonomous, legal institution in the Ugandan Ministry of Education and Sports, MOES.

Hybrid e-learning is a cost effective solution for poor, rural secondary schools that cannot afford to construct physical laboratories, libraries and also, cannot attract good teachers due to low remunerations. It is also an option for private school proprietors who are reluctant to invest in science facilities. Their concerns are financial: pay back period and return on investment. Hybrid e-learning should be the government's first step towards giving mass education and open up the closed educational system that is becoming difficult to sustain due to high population birth rate 3.4%. The closed system is leading to more and more school drop out rates.

Keywords: Hybrid. E-learning. Physics. Mathematics. Female students. Gender. Uganda. Arua. Advanced Secondary School.

Introduction

This paper describes how hybrid e-learning was implemented in Advanced level girls' secondary schools in the Ugandan rural District of Arua. It can also be used as a helpful guide to the administrators of the numerous poor rural secondary schools in Uganda who do not have enough financial resources to construct and equip science laboratories, build libraries and stock them with relevant textbooks, attract good and committed teachers. Such schools and those that have problems of space or land for expansion could find that introducing hybrid e-learning is a viable proposition.

The main purpose of introducing hybrid e-learning in rural girls' schools in Arua District was to improve the performance of female students in Advanced level Physics and

Mathematics. These are the essential engineering subjects that female students in rural areas usually perform poorly. It was observed that female students constitute about 18% of the total number of students admitted on academic merit into the Faculty of Technology, Makerere University. And all the female students admitted in 2005/2006 academic year were from schools located in only four urban, educationally elite Districts of Kampala (the capital city of Uganda) and its surrounding Districts of Mukono, Wakiso and Mpigi. There are 56 Districts in Uganda. Therefore, 52 rural Districts failed to produce female students who could perform well in Physics and Mathematics so as to qualify for admission into Makerere University for engineering training. This is a reflection of inequality in the education sector: female rural students do not participate in the engineering profession. Unless such inequalities are addressed, Uganda will have problems achieving some of the Milleniunm Development Goals (MDGs) especially goal No. 3 which deals with promoting gender equality and empowering women. A specific target to be achieved under this goal is *to eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015.* At the close of 2005, gender disparity still existed in secondary education with fewer female students enrolled. The gap is even wider in the engineering profession where no female students from rural schools are participating in engineering education. The World Summit on the Information Society (WSIS) identifies ICTs as tools for reaching the goals expressed in the Millennium Declaration. ICT is strongly recommended as a means of solving poverty-related problems. ICT use in education for learning is called e-learning. In the poor rural District of Arua, hybrid e-learning was introduced in the two Advanced level girls' secondary schools for the benefit of the female students taking Physics and Mathematics subjects.

Hybrid e-learning could be a possible first step of moving away from the closed educational system that Uganda has at the moment towards a more open system. Shortage of facilities like laboratories, classrooms, libraries, dormitories, etc. is limiting enrolment and opportunities for education of many students. The closed system of education has been described in the report. The implementation of the hybrid e-learning concept was done using the participatory, multistakeholder best practice approach methodology. E-learning generally is multidisciplinary and its implementation requires participation of many stakeholders: donors (Sida/SAREC), academia (Makerere University), commercial business community (Internet Service Providers, Web-hosting providers, Course Platform developers), Government (Ministry of Education and Sports, Uganda National Examinations Board, National Curriculum Development Center, Arua District Local Government), Non-Governmental Organisations (NGOs) such as Uconnet, SchoolNet, etc. All these stakeholders were involved at one stage or the other in the following areas of hybrid e-learning implementation: Interactive local content creation and CD-ROMs production, VSAT Internet connectivity to the Faculty of Technology ICT Research Station in Arua town choosing the Course Management System platform- the Mambo- and web-hosting it by B-one. There is a discussion section where key decisions made during the implementation were justified.

Background

Brief introduction about Uganda

Uganda attained independence in 1962 from Britain. It is a Highly Indebted Poor Country with very poor development indicators Mugambe (2004). Gross Domestic Product (GDP) per capita was 320 USD and a foreign debt of 3.8 billion USD in 2003. In 2005, the absolute GDP per capita was only 249 USD. About 85% of the 27 million population lives in the rural areas. Uganda's population growth rate is 3.4%. This makes it one of the fastest growing populations in the world.

Education System in Uganda

Education in Uganda falls under the Ministry of Education and Sports, MOES. Formal education system consists of seven years in primary, six years in secondary (four years in Ordinary level, two more years in Advanced level) before joining any of the Universities for three to five more years of training, depending on the course. Ordinary secondary education is generally called O-level and for advanced secondary education, A-level. A few of the students who drop out this academic line join either vocational or other tertiary institutions for skills or diploma course training, depending on which level the unfortunate situation occurred. Uganda liberalized the education sector to allow private educational institutions to be set up and supplement government efforts. By 2005, there were 1,651 government aided secondary schools in Uganda and about 1,898 private ones. There were 6 public universities and 27 privately licensed ones. However, Makerere remains the most dominant tertiary institution and accounts for more than half of the total enrolment in universities.

National Examination- Based Transition

Transition from one level of education to another is based on national examinations set and administered centrally by the Uganda National Examinations Board, UNEB. UNEB is a legal, autonomous institution in the MOES. Another autonomous institution under the MOES is the National Curriculum Development Center, NCDC, which is responsible for curriculum matters in schools and technical institutes.

Enrolment in Ugandan Educational Institutions

Table 1 shows the 2003 enrollment by gender in all educational institutions in Uganda.

Table 1: 2003 Enrolment by gender in Ugandan educational institutions

Item	Primary	Ordinary level	Advanced level	University level
Males	3,872,589	325,831	57,821	34,648
Females	3,760,725	273,346	40,509	24,176
Total	7,633,314	599,177	98,330	58,823
% female	49.3%	45.6%	41.2%	41.1%

Primary education has been free since 1997 when the government introduced the Universal Primary Education (UPE). Because of this, enrolment jumped from 3.1 million pupils in 1986 to 7.6 million pupils in 2003. There is almost equal participation in primary education by both male and female pupils due to UPE. In 2003, 49.3% of pupils in primary were girls. However, this percentage constantly dropped to 45.6% at O-level, 41.2% at A-level and 41.1% at University level.

Transition rates from one level to another are very low. In absolute figures, of all the 7,633,314 pupils in primary in 2003, only 599,177 will join O-level. Those are the available places in lower secondary schools. This means 7,034,137 pupils will not join secondary schools. Also 500,847 students in O-level in 2003 did not have places in A-level, while 39,507 A-level candidates dropped out because there were no places for them in the Universities.

Shortage of Educational Facilities

Students drop out of schools because there are not enough facilities at the next level of education. The worst affected is the secondary school level with extremely low transition rates. Common facilities that secondary schools lack are: laboratories for core science subjects, libraries, classrooms, dormitories. Laboratories lack equipment and chemicals for practical work. In most cases the schools do not have any more land or space for expansion. Lack of funds by both the schools and government prevent construction of such facilities. In Bitamazire (2005) it can be seen that the government puts more emphasis on UPE, which takes up to 70% of the education budget in Uganda, and secondary education, 16%. This makes the Ugandan education system a closed system. It is locking out many students from climbing the academic ladder. With a population growth rate of 3.4% (probably the highest in the world), the problems of the closed education system will intensify.

Shortage of Science Education Facilities

Absence of science facilities in secondary schools frustrates the enrolment and performance of students in science subjects. Students drop science subjects at the earliest opportunity, usually at A-level where subjects are elective. Taking science subjects means you will perform poorly at national examinations and that will be the end of your academic career. In 2004, A-level science students who sat for UNEB examinations were only 15% of the students who were examined. They were in senior six and were candidates for university admission for the 2005/2006 academic year.

Most private schools in Uganda predominantly offer arts and humanities subjects only. They are reluctant to invest in science facilities which are very expensive.

Rural Female Students Performance in Engineering Subjects

Science education is heading for total collapse in the rural secondary schools, especially the engineering subjects of Physics, Chemistry, and Mathematics. Rural students no longer accept to pursue that combination of subjects. Mostly affected are the rural female students. That is why there were no female students from rural schools who were admitted into Makerere University, Faculty of Technology, FOT, for engineering courses for the 2005/2006 academic year. All the female students (18% of the total enrolment into the FOT) were from the four urban, educationally elite districts of Kampala (capital city) and its neighbouring districts of Mukono, Mpigi and Wakiso. Uganda has 56 districts, and secondary schools in 52 districts did not send any female student for engineering training. Arua is one such district. Arua is about 500 kilometers from Kampala, the Capital City of Uganda and it is situated in the North Western part of the country. It is the eighth poorest district in Uganda. Hybrid e-learning has been introduced in the two advanced-level secondary schools in Arua district. It was an intervention for the benefit of female students taking advanced level Physics and Mathematics.

Method

Introductory Remarks about E-Learning

To start with, Uganda can introduce Hybrid E-learning in secondary schools. This will be the first phase of moving away from the closed educational system to a more open one. The benefits of e-learning are:

- Savings of between 50% and 70% when teacher-led training is replaced with an electronic approach of training. However, this can vary dramatically depending on audience size, number of deliverables and complexity of development
- A 50% to 70% improved consistency
- A 50% time saving compared to classroom learning
- Up to five times as much training at one third of the cost.

Definitions of E-learning

The term e-learning, which describes a particular means of providing education, has been in existence for several years, however, with the expansion of the World Wide Web and the Internet, it has become more widely used. Definitions of e-learning vary. Capper (2001) defined e-learning as `the use of networked technology to design, deliver, select, administer and extend learning.` Cisco Systems provided an expanded definition of e-learning, saying that the `components of e-learning can include content delivered in multiple formats, management of the learning experience, and a networked community of learners, content developers and experts´. The Commission of the European Communities Lepori, Cantoni and Succi (2003) has yet a different definition of e-learning: `the use of multimedia technologies and the Internet to improve the quality of learning by facilitating access to resources and services as well as remote exchange and collaboration`.

The Concept of E-learning

Mohmoud and Mendler (2001), noted that e-learning should be understood as a subset of distance education, which includes any of the following (see fig.1):

1. Computer-Based Learning (CBL). This is a Localized Education. In this case, interactive multimedia content from portable devices like CD-ROMs are retrieved using a computer with appropriate software and hardware capabilities. This option is quite suitable for students in remote rural schools.
2. Networked Education. This is online learning which includes:
   a. Internet-Based Learning (IBL) via Internet, intranet or extranet.
   b. Web-Based Learning (WBL) which offers on-demand dedicated content delivered over TCP/IP networks, displayed by a web-browser (http protocol) or accessible via the Internet (Internet Based Learning).

Differentiation should be made between Internet-Based Learning and Web-Based Learning. Michaelson (2003) clarifies that the Internet is the infrastructure (networks plus communication protocols) which allows the particular resource which is called the World-Wide-Web to function. The World-Wide-Web is an application based on two protocols: HTML (a hypertext mark-up language) and URL (the Uniform Resource Locator- or address). Internet applications such as e-mails and Internet Relay Chat were available a long time before the Web was created. Students can access resources from the numerous web sites using appropriate web browsers (e.g. Microsoft Internet Explorer, Netscape, Firefox Mozilla, etc). Or a dedicated Electronic Learning Environment can be created for the students using an elaborate instructional platform that enables the development and delivery of content to learners. This platform should support content development that follows sound pedagogical principles.

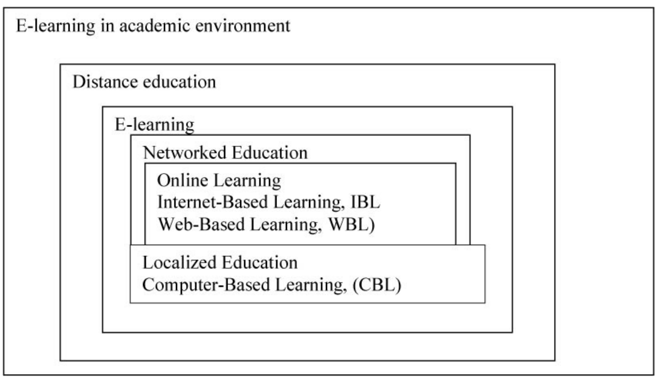

Fig. 1 Subsets of Distance Learning

Hybrid E-learning

Course content delivery methods is the main issue in e-learning. How the students access the content is the most important consideration that must be made when introducing e-learning.

In hybrid e-learning, the computer-based learning, networked learning (Internet and Web based learning) and the traditional face-to-face classroom delivery methods co-exist. This is considered a suitable model for disadvantaged, rural, poor schools that are financially constrained like those in Uganda.

Hybrid e-learning is significantly different from blended e-learning. Jonsson (2005) from Lund University, Sweden, successfully implemented blended e-learning in training upper secondary school teachers of Physics. Most of the training was on-line and synchronous. Face-to-face contacts were made only twice (and very briefly) during the duration of the course: at the beginning (to introduce the course) and in the middle – to attend lectures by specialists. Ijab and Anwar (2004) describe how e-learning was introduced in the teaching and learning of e-commerce courses in Malaysia. Three components of e-learning were combined: the interactive multimedia CD-ROMs, the Web, the face-to-face meetings, and the Internet based support systems that provide continuous real-time interaction between students and the faculty. Though the authors called it hybrid e-learning, it is actually a blended e-learning because of the synchronous tutorial courses offered by the tutors. The synchronous tutorial requires a lot of bandwidth that poor rural communities cannot afford. In hybrid e-learning, there is permanent presence of students in the classrooms and the main course delivery platform is the interactive multimedia CD-ROMs. Actual lessons must be delivered in face-to-face interactions. Face-to-face interactions are not for purposes of meetings only but for delivering some content. In the Maldives, hybrid e-learning was introduced in secondary schools Shareef and Kinshuk (2003). This is a country which is 99% water and consists of 1,190 islands of which only 200 are sparsely inhabited. Communication between schools in different islands is difficult. In this case, secondary school teachers develop multimedia instructional content which is then delivered to the students via the Internet or burnt onto CD-ROMs and mailed or a combination of both. In East Africa, Omwenga, Waema and Wagacha (2004) used the concept of hybrid e-learning while applying ICT in the distance education programme of Nairobi University. Implementation of this project was done with due consideration of the Kenyan context.

Participating A-Level Schools

There are two government-aided girls′ A-level secondary schools: Muni and Ediofe Girls' Senior Secondary Schools. Muni is Protestant founded while Ediofe is Catholic founded. Both are classified as Rural Boarding Secondary Schools by the MOES. The schools will hereafter be referred to as Muni and Ediofe.

A-Level Subjects Covered by the Project

Advanced level Physics and Mathematics are the two subjects that were started with. These are the subjects that students perform very poorly at national examinations. They are the essential subjects necessary for admission into universities for technology and engineering training.

Female Students Participating in the Project

Students who are participating in the project are those who were admitted into the schools in senior five in 2006 and are taking Advanced Level Physics or Mathematics or both.

Production of the Interactive Multimedia CD-ROMs

Interactive local content based on the recommended syllabus for both subjects- Physics and Mathematics- were created by all the subject teachers in Arua during a Workshop held in September, 2005 (Lating, Kucel & Trojer, 2006a). The Workshop started by first training the teachers in content writing skills by curriculum experts from the National Curriculum Development Center (NCDC). NCDC is an autonomous body under the Ministry of Education and Sports (MOES). The manual local content created was later digitized. A specialized group of senior Physics and Mathematics teachers who are also UNEB examiners were involved in reviewing the content created. Production of CD-ROMs by multimedia programmers was done and is being used by the female students. It is planned to publish local content created by teachers into teacher's guides for use in schools.

CD-ROMs have some disadvantages also. They are read only memory. It is not possible to keep other random data like student records, communication messages, etc. on them. Nor are they suitable for testing, evaluation, updating school calendars, links to some lessons, chat rooms, etc. to ease communication.

Setting up the FOT ICT Research Station with VSAT Internet Connectivity

Muni and Ediofe schools currently access Internet from the Faculty of Technology ICT Research Station in Arua town. Sida/SAREC provided the funding under the `ICT/GIS for Sustainable Technological Development in the Lake Victoria Region` Project. The Faculty of Technology is the implementing agency. Arua District Local Government provided two buildings to accommodate the research station. Nearly 23.75 million shs. (12,803 USD) was spent on renovating this building, burglarproofing it and converting it into classrooms for students, teachers and the general public. The Research Station is equipped with 21 training IBM computers, 1 IBM server. All the computers supplied have multimedia capabilities. These computers were networked by Afsat/iWay into a Local Area Network. VSAT Internet connectivity was done by Afsat/iWay with a satellite disc of 2.4m. Management of the Research Station is done by the Network Administrator, a permanent employee at the Station.

Computer Resources in the Schools

The schools have, through their own efforts, purchased refurbished computers. Muni has 10 and Ediofe acquired 14 computers. The computer laboratory in Muni is still under construction while Ediofe installed ten of the computers in the small library store. Both schools heve networked the computers in a peer-to-peer configuration since they have no servers. The schools were assisted in upgrading their computers to multimedia capabilities. Content is delivered to the schools using CD-ROMs. Both schools are within a 5 km radius from the ICT Research Station. The participating students together with their teachers have free access to Internet resources and content from the project website from the Research Station. The costs of Internet connectivity are so high in Uganda. Rural schools cannot afford Internet connectivity.

Open Source Course Management System Introduced

Some course materials are delivered through the web. A website for the project http://www.aruaeduc.com was created. The Mambo, a Course Management System (CMS), is being used to manage the hybrid e-learning environment. It is open source software. Open source software is free, reliable, not subject to frequent virus attacks and upgrades, not subject to spyware attacks. Gichubo and Hampel (n.d) makes clear the advantages of open source systems as compared to the commercial, proprietary ones. Proprietary software poses a number of potential impediments including: high cost of acquisition; high recurrent costs of maintenance and upgrades; piracy; higher hardware specifications; requirements for higher computer skills; and higher costs of version management. On the other hand, an open source paradigm creates new opportunities. It is not resource intensive and therefore extends the lifespan of hardware in situations of meager financial resources. Expenses arising from software licensing are eliminated. The more the numbers of students using proprietary software like the Blackboard, the higher the costs. But in open source e-learning you are not penalized for success as more people get on board. Open source creates a collaborative forum in the development of distributed process like distributed learning. Further access to source code of open source software enables adaptation of software for local requirements in a sustainable manner; proprietary software cannot be shaped to such specific needs.

The web host for the project website is B-one. The website http://www.aruaeduc.com/ is hosted on an open source server, cascade. This website was created in November, 2005. The Mambo was downloaded free on the b-one.net open source server for which only 374 SEK (about 47 USD) was paid for one year of hosting. The 47 USD includes set up fee, annual domain fee and hosting charges. All the students and the subject teachers in the project have been given e-mail accounts. Some content materials will be delivered through e-mails. The students and their teachers have all been trained in basic ICT skills, Internet use and working with e-mails.

Hybrid Digital Libraries for the Schools

Digital libraries were found to be required since the schools have no functional traditional libraries. In Lating, Kucel and Trojer (2006b) depict how hybrid digital libraries were created for the schools. These libraries consist of both the physical text books and training materials and electronic sources delivered to the schools in portable devices like CD-ROMs. Again, the students and their teachers have access to Internet resources from the ICT Research Station where they can surf and get some materials on their own. They download some open source ebooks. Building these libraries is an ongoing process.

The hybrid e-learning will be used by the participating students throughout 2006. In November 2007 the Uganda National Examinations Board, UNEB, will examine the students. The results of this assessment will be used for creating a longitudinal model for analyzing the impact of such an intervention on performance of students in rural schools.

Discussion

Problems of the Ugandan Closed Education System

Uganda has a closed education system. The system closes out many students from progressing to higher levels of the educational ladder. Out of the nearly eight million pupils in primary level of education in 2005 only 600,000 have places in the next level, O-level. About 100,000 of these will progress from O-level to A-level from which universities admit 60,000. The situation will become worse because of the excessively high population birth rate, 3.4% annually. This is one of the highest birth rates in the world.

The closed education system is affecting science education in the country where only 15% of students at advanced level take science combinations.

Lack of facilities in schools is responsible for the high drop out rates of pupils/students from schools. There is shortage of laboratories, libraries, classrooms, dormitories, etc. Science subjects are usually dropped at the earliest opportunity by students. Physics and Mathematics are usually the first to be dropped. In 2004, only 15% of students who sat for A-level examinations were taking sciences. Neither the government nor the private school proprietors have enough money to build more schools and construct new buildings so that most pupils in primary level of education can progress to secondary and tertiary levels of education. In 2005 there were 1,651 government-aided secondary schools in Uganda and 1,898 private ones. Each school requires a set of 3 laboratories for the core science subjects- Physics, Chemistry, Biology. Agriculture is also considered a main science subject in secondary schools. A good laboratory costs 98,000 USD to construct and equip. A school needs four laboratories, which require 392,000 USD. The 1,651 government-aided secondary schools will need 647,192,000 USD. This is one of the reasons why private schools are reluctant to invest in science facilities. It is expensive to build and equip laboratories. In a country where the break even period is long, no businessman will accept to invest in laboratories. This is drastically affecting science education in the country. Government intends to build 40 laboratories per year in government-aided secondary schools. If each school needs 4 laboratories, it means 10 schools will benefit annually.

To complete the exercise and cover all the whole country will take many years. This does not help a situation in science education which is already desperate, with only 15% of the students taking science subjects at A-level of education. Of all the science subjects, Physics and Mathematics, are poorest done. The few students, who take science subjects, avoid those two subjects. The only schools that still do well in sciences are those located in the urban elite districts of Kampala (capital city) and the surrounding neighbouring districts of Mukono, Mpigi and Wakiso. Such schools have students whose parents are well to do and can afford to pay exorbitant fees to the schools for purposes of paying teachers well and constructing school facilities like laboratories, classrooms, dormitories. Rural areas, where 85% of the Ugandan population lives, is not playing any role in science education.

ICT in Education

The above scenario is a description of Uganda as a poor country except that education statistics are used. The solution to poverty-related problems should be found within the framework of the eight Millennium Development Goals, MDGs. According to the World Summit on the Information Society (WSIS), the MDGs should be achieved essentially through the application of ICT. ICT when used in education is termed as e-learning.

ICT suitable for enabling or supporting e-learning is called e-learning technology. According to Hoppe and Breitner (2003), e-learning technology includes Hardware, System Software and E-learning Applications e.g. Software applications which are suitable to support or enable e-learning. These applications are generally known as Platforms or Course Management Systems. The e-learning technologies together with the e-learning content constitute the Technical System for e-learning implementation. The authors further argue that the technical system is supplemented on the one hand by the manware i.e. the people who use, administrate, maintain and/or develop other components of the system. And on the other hand it is supplemented by the orgware, i.e. all organizational regulations and concepts concerning e-learning and its management.

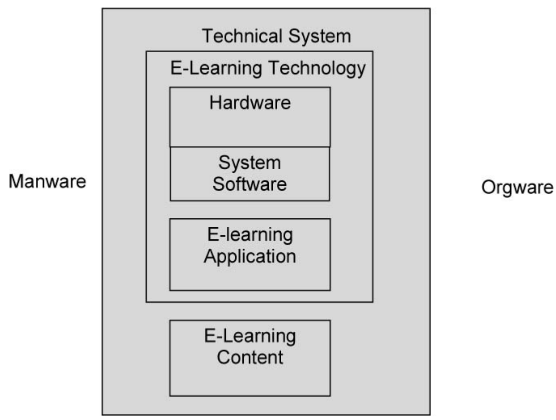

Fig. 2: Components of an E-learning system

CD-ROMs, the Main Delivery Platform in Hybrid E-Learning

To enable a student to participate in pure e-learning programmes, the student should have a multimedia computer (with CD-ROM and DVD drives), appropriate software (including browsers), Internet access (preferably broadband) and tuition for the course. These are facilities that an ordinary student in the developed world can afford. A poor student in a rural setting in Uganda, especially Arua district where the Socio-Economic Status of the community is extremely low, cannot afford to have these facilities. Therefore, in this project, the traditional way of enrolling students in physical schools will continue. Secondly, there has not been a major policy shift in Uganda towards pure e-learning in secondary school education. Students still have to be enrolled in the schools where they were admitted. So, the traditional face-to-face contact between teachers and students will have to continue in the Ugandan context. Classroom sessions will continue as some aspects of e-learning will be progressively introduced.

CD-ROMs are the main delivery platform in this study. Lating et al. (2006a) give the advantages of CDs which make them suitable within the context of poor rural secondary schools. They have big memory capacity, have interactive multimedia capabilities and have wider applications since they are standard and can use hardware with CD-audio, CD-ROM and CD-i drives.

Mambo, an Open Source Platform for Managing the Learning Environment

Mambo, the open source Course Management System (CMS) software is used for managing the virtual learning environment. No rural secondary school can afford to acquire and maintain proprietary software like the Blackboard or WebCT. A few figures will help to explain why proprietary software was not under consideration. Blackboard charges for its software based on the number of students enrolled, with a typical institution paying about 50,000 USD per year, Young (2002). Makerere University got an inferior version of the Blackboard which usually goes at 7,500 USD for acquisition and monthly payment of about 300 USD. The university has thrown out the Blackboard and is trying to use Kewl.NextGen, an open source software. Vuorikari (2004) justifies why Europe needs free and open source software and content in schools. If European schools cannot afford proprietary software in its schools, then developing countries like Uganda have no business acquiring and using such software. In introducing Mambo the advantage is that one of our collaborating institutions, Blekinge Institute of Technology, BTH, in Sweden, uses it. There is a reliable skills base in using *Mambo*. BTH trains our staff and gives technical support in the use of Mambo.

Hosting of the Mambo with an Open Source Web Hosting Provider

A crucial decision that we had to make was where to host the *Mambo*. We had to choose a Web hosting provider. This is finding a home for our website. Computers that can do such things are called *servers*, because they serve 'stuff' out to the Net. Computers that specialize in distributing webpages are called *web servers*. Our webpage cannot be on the web until we store it on a web server. Because this computer is playing 'host' to our pages, such machines are called *web hosts*. Companies that run these web hosts are called *web hosting providers*. There were three choices to be made:

- Use an existing Internet Service Provider, (ISP)
- Find a free hosting provider.
- Sign up with a commercial hosting provider.

Our local project ISP in Uganda does not have a web server. The commercial hosting providers in Uganda were extremely expensive. The cheapest quotation we got was 2,000 USD for hosting for a year. They also limit the storage space allotted to you, bandwidth that you can use, getting a domain name is difficult, and e-mail use is restricted. Furthermore, the operating server is based on Windows only and not compatible with Unix or Linux platforms. The uptime for this host's server is low. All these are serious issues that cannot encourage hosting the website locally in Uganda. We finally hosted our site with *B-one* on an open source server, the cascade after paying only 374 SEK (about 47 USD) for one year of hosting. B-one charges 1.25 Euros per month for a web space of 500 MB. There is unlimited data transfer (bandwidth) and unlimited e-mail accounts. The set up fee is only 12 Euros. The .com domain name is free. The *Mambo* was downloaded free on the *B-one* web hosting server. All the students and the subject teachers in the project have been given e-mail accounts. Some content materials will be delivered through e-mails. It is planned to train the students at the beginning of the school term in 2007.

VSAT Internet Connectivity of the Participating Schools Using Broad Spectrum Technology

Internet connectivity to the schools offered some technical challenges. Thermal electricity is supplied to both schools by Wenreco (West Nile Electricity Company). They supply electricity for 18 hours a day. The services are sometimes unreliable. There are no fixed telephone lines in Muni but Ediofe has one. However, mobile telecommunications are available using the GSM technologies. Both schools have refurbished computers that were procured without UPS from the NCDC at 175 USD per computer unit. Both schools have no computer laboratory but these computers can be installed and networked in the libraries that are spacious with few text books. There were two options when deciding how to connect Internet to such schools: wired or wireless Internet connectivity. Among the wired connectivity methods we considered were: dial-up, ISDN, Digital Subscriber Line (DSL), Leased Lines, and fiber optic method. Dial up Internet connectivity is being phased out in the first world and in some developing economies. They are being replaced by broadband technologies such as DSL and cable modems. The main disadvantage of dial-up is that it is narrow band with a maximum download speed of 56 Kbps and a maximum upload speed of only 33.6 Kbps. This is too low for educational purposes. ISDN supports up to 128 Kbps full duplex (2x64 Kbps channels). DSL is more expensive and has a maximum distance of only 5 Kms which limits its use to only urban areas which are very close to the exchange. Generally wired connectivity is not suitable for Internet connectivity in schools. There are hardly any wired telecommunications infrastructures in rural areas i.e. low teledensities and copper/fiber would have to be put into the ground and exchanges built. The costs incurred in laying copper/fiber wires and building such exchanges is high compared to potential revenue and so unattractive to telecommunications companies. And usually if inferior quality copper is used, you get bad data lines. Wireless solutions are usually satellites, mobile terrestrial network standards and the WiFi. WiFi technologies are suitable for Local Area Networks (LANs). Mobile terrestrial network standards include technologies like GPRS, CDMA which are suitable for Wide Area Networks (WANs). Brandt, et al (n.d) rightly noted that wireless technologies can be easily deployed in rural areas where teledensity is low. Rural schools without any wired telephone lines can be connected to Internet using the wireless technologies. However, wireless technologies cannot offer bandwidth that wired technologies can offer. Satellite networks support data, audio and video streaming which makes them attractive for educational purposes. In this study, the ICT Research Station was connected to VSAT at a cost that none of the schools can afford. The Spread Spectrum technology could have been used for connecting the schools using the VSAT disk at the Research Station as a hub. The schools would have a client antenna and a base station was to be put on the MTN mask. Even that, the charges of MTN are extremely high. In the mean time, both the students and their teachers come to the Research Station for Internet resources and receiving/ or sending e-mails.

The experience of SchoolNet used in connecting schools using the Spread Spectrum technology must be taken into account. It connected three other schools to VSAT using the VSAT disk in Busoga College Mwiri as a hub. There were so many problems with such connectivity that the idea was dropped. Firstly, if there was any problem with the hub, all the other schools would not get any signal. Complains became unbearable. Secondly, the technology works on the basis of line-of-sight. If there is any obstruction in the line of sight, no signal would be received at the school. Trees became a problem along the lines of sight. Tall trees were blocking the lines of sight. Constantly, trees had to be cut down.

Choosing the E-learning Model for the project

In the situation above, hybrid e-learning will be used during the project implementation. This means that teacher-centered pedagogy will continue while appropriate interactive multimedia CD ROMs will be used to support learning of Advanced level Physics and Mathematics students. Internet will be accessed from the ICT Research Station. The teachers and the students can access content from the project website from the same Station.

“Hybrid” is the name commonly used to describe courses that combine face-to-face classroom instruction with computer-based learning. However, the concept of e-learning hybridization in the developed world especially Europe and US mean something else. These communities understand hybridization as having the two modes of delivery of education previously separated i.e. the on-campus and non-campus education- will converge. It means that the markets for distance education and resident education are not clearly separated any longer. In other words the term means that the traditional distinction between presence teaching (based on face-to-face lectures and tutoring) and distance learning (based on printed textbooks) is becoming increasingly blurred. Thanks to ICT, distance learning is acquiring some features of presence education, like synchronous communication (e.g. through videoconferencing) and interactivity between teachers and students. On the other hand, some features of distance education like course materials available online or electronic communication, are increasingly used also for the students on campus. This understanding of hybridization is very different from that of a community which is yet to be developed like Uganda.

Conclusions

Female students from rural advanced level secondary schools in 76 out of the 80 Districts in Uganda failed to perform well in order to qualify for admission for engineering training in Makerere University during the 2005/2006 academic year. The few female students admitted (18% of the total enrolments) were from schools located in the educationally 'elite' urban Districts of Kampala (the capital city of Uganda) and its surrounding Districts of Mukono, Wakiso and Mpigi. Typical Ugandan rural schools have no facilities and resources required for students to perform well in Physics and Mathematics, the essential subjects needed for admission for engineering courses. There are no senior laboratories where experiments can be done. Those that have laboratories cannot equip them. Though some of the schools have libraries, the schools cannot afford to stock them with the relevant text books. Dormitories and classrooms are usually not enough and this limits enrolment in schools. Many of the schools cannot attract good teachers because of poor remuneration and lack of fringe benefits. Good teachers remain in urban schools especially science teachers. The budget of these schools, which is usually around 200,000 USD a year, cannot warrant any significant improvement in the situation. They cannot build laboratories and equip them, nor can they stock their libraries. It requires big investment that Uganda government cannot afford.

This is a manifestation of poverty in Uganda. Solutions to poverty-related issues should be sought within the framework of the eight UN Millennium Development Goals (MDGs). Goal No. 3 encourages UN member states to promote gender equality and empower women. The specific target to be achieved is *to eliminate gender disparity in primary and secondary education preferably by 2005, and in all levels by 2015*. In the specific area of engineering profession, if something is not done to improve rural Physics and Mathematics education in secondary schools, there will be insignificant number of women in the profession.

The UN World Summit on the Information Society (WSIS) strongly recommended that ICTs should be used as the only viable tool for achieving the MDGs. ICTs when used in education are broadly termed as e-learning. E-learning can be used to deliver A-level Physics and Mathematics courses virtually using electronic means. Physics experiments can be simulated so there is no need to invest in laboratories and equipment. Interactive multimedia CD-ROMs for Physics and Mathematics can be produced so that the school may not worry about shortage of good and committed teachers. Students can access some materials from the Internet or the Web. Content can also be delivered through e-mails. But what model of e-learning is appropriate for disadvantaged, poor rural secondary schools.

Pure e-learning is out of the question. This is possible only where students have broadband Internet connectivity at home. And they can afford to own computers with multimedia capabilities. In the context of Ugandan rural schools, the face-to-face sessions will have to continue. Broadband is still not universally affordable in Uganda. Many rural families do not have electricity. Fixed telephone lines are only in a few government offices in the District headquarters. So, Internet connectivity in homes of the students is not possible at the moment. The main content delivery form is through interactive multimedia CD-ROMs. CD-ROMs have big memory capacities, have multimedia capabilities and are universally standardized. The participating schools can access Internet from the ICT Research Station a few kilometers away from each of the schools. Students will also be able to get some relevant materials from the Internet and the Web. This type of e-learning is called Hybrid E-learning which was implemented in two girls' secondary schools in Arua District, the eighth poorest District in Uganda.

E-learning is a multidisciplinary issue. Therefore, in implementing it in Arua, the participatory multistakeholder approach was used: donors, academia, and government departments, NGOs, business community, etc. were involved. Makerere University, Faculty of Technology, set up an ICT Research Station in Arua town with financial support from Sida/SAREC. Arua District Local Government provided the building where the station was set up. VSAT Internet connectivity was done using Computer venders and Internet Service Providers. Content for Physics and Mathematics was developed by all the A-level subject teachers in Arua and Koboko Districts in a Workshop arranged in Arua in September, 2005. Multimedia programmers from the NCDC helped in the production of the CD-ROMs. Platform for managing the virtual e-learning environment, the *Mambo*, was downloaded free since it is an open source software. The *Blackboard*, a platform which requires up to 30,000 USD annually acquiring and maintaining, did not warrant thinking about within the context of the poor rural schools. The project website, http://aruaeduc.com is hosted by *B-one* on an open source server, the cascade. The cheapest local web host in Uganda was charging 2,000 USD per year, while B-one accepted 47 USD.

The proposed hybrid e-learning model will help to inspire hope in advanced secondary level Physics and Mathematics education in rural areas where existing facilities are inadequate for students to perform well in science subjects. The model capitalizes on the existing infrastructure and technology in the country reducing the costs of implementation, operation and maintenance. This can be used as a model for introducing e-learning in most disadvantaged rural secondary schools in Uganda. Other schools will be encouraged to replicate this innovative solution to learning in disadvantaged schools.

The female students will use the hybrid e-learning until November, 2007 when they will sit for the university entrance examinations. When their results come out early in 2008, the impact of such an intervention will be evaluated using a longitudinal model.

Acknowledgements

For their funding generosity, we would like to thank Sida/SAREC. Thanks also go the School of Graduate Studies, Makerere University. We wish also to acknowledge the invaluable academic input from the staff of the Department of Human Work Science and Media Technology, Blekinge Institute of Technology (BTH). Special thanks go to Anita Carlsson, Ulrika Carlsson and Madeleine Persson who did all the printing of the materials I needed. My lap top could not be configured to use the available printer in BTH.

References

Bitamazaire, N. G. (2005). A presentation by the Minister of Education and Sports on the topic: Status of Education for rural people in Uganda. http://www.fao.org/sd/erp/addisababa/Papers/Uganda%20Revised_EN%20with%20cover.doc

Capper, J. (2003). E-learning: Current status and international experience. http://empresas.sence.cl/documentos/elearning/E-learning.%20Art%C3%ADculo%20de%20Joanne%20Capper%20(Ingl%C3%A9s).pdf

Lepori, B., Cantoni L., & Succi, C. (2003). The introduction of e-learning in European universities: models and strategies. http://www.newmine.org/newmine_edum_lepori_alii_article_gmw03.pdf

Gichuho, M. A., & Hampel, T. (n.d). E-learning in Kenya- asynchronous distributed knowledge spaces for teacher education. http://iug.uni-paderborn.de/hampel/Kooperationen/International/Nairboi.pdf

Hoppe, D. O., & Breitner, M. H. (2003). Business models for e-learning. http://opus.zbw-kiel.de/volltexte/2003/1288/pdf/dp-287.pdf

Ijab, T.M., & Anwar, R. (2004). Teaching and learning of E-commerce courses via hybrid e-learning model in Unitar. http://www.igi-online.com/downloads/pdf/ITJ2549_AXJ5RD77XK.pdf

Jonsson B. (2005). A case of successful e-learning: A web-based distance course in medical physics held for school teachers of the upper secondary level.

Michealson, R. (2003). E-learning- how and why should I do this? http://www.business.heacademy.ac.uk/publications/misc/briefing/elearning/e-learning%20-%20Michaelson.pdf

Mohmoud, N., & Mendler, J. R. (2001). Economic feasibility of e-learning: virtual Vs traditional scenarios. http://www.iwlearn.net/course/elearn.ppt

Mugambe, G. (2004). Economic Overview February 2004- Uganda. http://www.swedishtrade.se/i_utlandet/landrapporter/Uganda.htm

Lating, P. O., Kucel, S. B., & Trojer L. (2006a). Design and development of interactive multimedia CD-ROMs of advanced level Physics and Mathematics for rural secondary schools in Uganda.

Lating, P. O., Kucel, S. B., & Trojer L. (2006b). Design and development of sustainable digital libraries for rural secondary schools in Uganda. Unpublished.

Omwenga, E.I., Waema, T. M., & Wagacha, P.W. (2004). A model for introducing and implementing e-learning for delivery of educational content within the African context. http://www.ansti.org/volume/omwenga.pdf

Shareef, A.F., & Kinshuk. (2003). Distance education model for secondary schools in Maldives. http://ieeexplore.ieee.org/iel5/8953/28360/01270664.pdf?arnumber=1270664

Vuorikari, R. (2004). Why Europe needs free and open source software and content in schools. http://www.eun.org/insight-pdf/special_reports/Why_Europe_needs_foss_Insight_2004.pdf

Young, J.R. (2002). Pricing changes by Blackboard and WebCT cost some colleges more- much more. http://chronicle.com/free/2002/03/2002031901u.htm

All Internet sources were retrieved on 12th December, 2005.

PAPER III

Design and Development of Interactive Multimedia CD-ROMs for Rural Secondary Schools in Uganda

P. O. Lating, Sub-Department of Engineering Mathematics, Makerere University, Uganda
S.B.Kucel, Department of Mechanical Engineering, Makerere University, Uganda
L.Trojer, Division of Technoscience Studies, Blekinge Institute of Technology, Sweden

Abstract

The paper discusses the design and development of interactive multimedia CD-ROMs for advanced-level secondary school Physics and Mathematics for use by the disadvantaged rural female students in the rural district of Arua. Multimedia content of the CD-ROMs was developed at a Workshop of advanced level secondary school Physics and Mathematics teachers from the district in September, 2005. The Interface design and production of the two CD-ROMs (one for each subject) were made after some 'trade offs' and are being tested in the two girls' schools in Arua: Muni and Ediofe. It is expected that their use by the female students will result in improved performance in national examinations. This is the first successful case of advanced level course content being delivered to students using CD-ROMs that were locally developed based on the Ugandan curriculum. It is also a successful application of ICT in women empowerment.

Keywords: Interactive. Multimedia. CD-ROMs. Physics. Mathematics. Rural. Secondary School. Uganda. Poverty

1.0 . Introduction

Rural advanced level senior secondary schools in Uganda lack senior laboratories for core science subjects. Those with laboratories cannot afford to equip them and buy chemicals for practical work or experiments. Libraries are not well stocked. Science and Mathematics teachers are few and poorly remunerated and most of them teach in more than one school in order to get more pay. This makes them not committed and in many instances the syllabus is not completed. Government financial assistance to such schools is negligible and schools rely on the meager contribution of the poor parents whose annual income per capita is under 300 USD. The situation has led to students, especially female ones, dropping science subjects especially Physics and Mathematics, key engineering subjects.

A strategy for implementing hydrid e-learning in such rural secondary schools to support disadvantaged female students in advanced level Physics and Mathematics was developed by Lating, Kucel and Trojer, (2006). The Hybrid E-learning research project is currently being implemented in the Ugandan rural district of Arua in the two girls' advanced level secondary schools, Muni and Ediofe. In this project, the main course delivery platforms are the interactive self-study multimedia CD-ROMs which were designed and are being developed based on the local Ugandan curriculum. The project is being financed by Sida/SAREC as part of its support for research activities of Makerere University, Faculty of Technology.

The paper starts by reviewing literatures on the advantages of CD-ROMs before describing the content and interface designs of the CD-ROMs that have been developed for advanced-level secondary school Physics and Mathematics based on the local Ugandan Syllabus. The paper ends by giving the hardware and software used in the production process. The CD-ROMs are being tested in Muni and Ediofe before mass production for use in other Ugandan secondary schools.

2.0 Advantages of Interactive Multimedia CD-ROMs

There are no interactive multimedia CD ROMs based on the local advanced level curriculum that are being used in Ugandan secondary schools at the moment. Therefore, the delivery of content using interactive multimedia CD ROMs for advanced level secondary schools is a new phenomenon in Uganda. But in many developed countries, training CD-ROMs are used quite extensively. The main advantages of CD-ROMs are big memory capacity, multimedia applications and popularity due to its standardization.

2.1 Big Memory Capacity

Advantages of interactive multimedia CD ROMs have been stated by Tapia (2002). As storage medium CD ROMs have high capacity (650 to 700 megabytes) and are relatively cheaper compared to media like floppy disks (1.44 MB). For example, Woolbury (n.d) notes that a CD-ROM disc with a memory capacity of 550 megabytes of data is equivalent to about 250,000 pages of text. And most common CD-ROMs these days have memory capacities of up to 700 floppy discs, enough memory to store 300,000 text pages. Therefore, CD ROMs are very suitable for presenting rich graphic information, videos and animations that would be difficult to download from a website.

Beheshti, Large and Moukdad, (2001), while supporting the use of CD ROMs further clarified that limited bandwidth has hindered the efficient transmission of large quantities of information over the Internet. A related problem in accessing online information is the need for complex networking technologies. Even today, many countries including Uganda, lack the necessary telecommunications infrastructure to effectively and reliably use the Web, especially in rural areas. But such countries can afford to buy inexpensive computers with CD-ROM drives. CD ROMs can be designed and implemented for large class teaching with very modest investments in the equipment.

Interactive CD ROMs have very fast data transfer rates compared to the Internet. The transfer rate for a CD ROM is typically between 300 to 1,200 Kbytes/sec as compared to the Internet technology that Ranky (1997) describes as a relatively slow technology with an equally slow transfer rates from 1.8 Kbytes/sec (for 14.4 modem) to 16 Kbytes/sec (for ISDN). This means that the CD ROM is more capable of supporting real-time learning needs than the Internet.

2.2 Interactive Multimedia Applications

The basic components of an interactive multimedia CD ROM include the interface, texts, graphics, sound effects, animation, narration and video clips.

2.3 Popularity and Standardization of Interactive Multimedia CD ROMs

For a digital delivery medium like CD ROMs, standards are necessary so that software manufacturers have an established unit to run their ever changing software. This gives the consumers confidence that the digital hardware they are purchasing will not be obsolete soon after purchase.

The basic digital hardware for CD ROM is already a standard agreed by two very influential companies: Sonny and Philips. Having set the standard for CD-Audio, the two companies have continued the trend with CD-ROMs, and most recently CD-I, a multimedia offshoot of CD-ROM.

One beneficial effect of standardization of the compact disc is that the runaway popularity of CD-Audio has helped to set the compact disc in the public mind. Since CD-ROM is a close relative, its acceptance is made easier. That is why there are now many drives that will play CD-ROM and CD-Audio. This gives better assurance to those interested in CD-ROMs that it is a delivery medium that is here to stay.

3.0 Design and Develompment Procedure dor the CD-ROMs

3.1 Multimedia Local Content Design

A workshop of advanced-level Physics and Mathematics teachers was held from 4th to 11th September, 2005 in Arua district headquarters. Thirty three advanced level Physics and Mathematics teachers attended the Workshop and created hand-written interactive local content in both subjects based on the current local examination syllabus. The local content created was in English, the official language in all schools in Uganda. It was hand-written since the teachers only 4 teachers out of the 33 teachers had basic computer literacy skills. The facilitators of the Workshop were officials from the National Curriculum Development Center (NCDC), an Institution under the Ugandan Ministry of Education and Sports.

The teachers were guided by the facilitators how they were supposed to structure the content logically. Each topic in Physics or Mathematics was divided into sub-topics, lessons and a number of teaching units. Content was created for all the teaching units under a particular topic. A teaching unit would have a title and a text of 100-300 words and the subject teacher was to indicate where an accompanying illustration, graphic, activity by the student or animation should appear. This would help the programmer/producer to include the interactivity in the CD-ROM. Common interactivities that the teachers were told to use include animations, text entries, multiple choices, drag and drop; match the correct answer, true or false statements, comparing answers and zooming.

The content was written in such a way that it encourages higher-order thinking skills (based on problem-solving approach). Activities must encourage the learner to think and play a role. The student discovers the concept/ideas herself. She should discover her own answer. And every teaching unit would have three activities to introduce the concept. The first one is to be done by the teacher with little student involvement. The second activity was to ensure that the student is involved 50% (i.e. half way). The third activity was to be exclusively done by the student to discover the answer. The learner would have the impression that she is being taught but the teacher is not there.

3.2 Interface Design

Interface was created to establish a seamless navigation among the multimedia content. The design of the interface was based on the following principles:

- *Audience:* Advanced level female secondary school students.
- *Interface consistency*: As much as possible the screens have identical layout, terminology, prompts, menus, colours, and fonts. Navigational aids are situated in the same locations on each screen so that the students will not have to search for them. Colour schemes and type size and fonts are consistent for all screens.
- *Ease of use and learning:* The students should have minimum training, if any, in the use of the interface.

- *Efficiency*: The students should navigate through the materials relatively efficiently.
- *Colourful and meaningful navigational tools*: All the navigational aids and buttons are clearly and vividly marked to be distinguished from surrounding objects.
- *Information feedback*: For every student action, the interface provides a feedback. For example, the buttons are activated when the mouse pointer is moved over them, or they are clicked, and the student is provided with immediate feedback.
- *Error prevention*: the system is error proof. Objects are only activated on the student's command.
- *'Previous" and 'Next' buttons* make it easier to browse through the entire lesson. Other buttons on the screen are Chapter for proceeding to the introductory screen of a particular chapter, Contents for proceeding to the contents screen, etc.

4.0 Production of the Interactive Multimedia CD-ROMs

4.1 Hardware Requirements

For the production of the CD-ROMs DELL computer with multimedia capability was purchased. It has 512 MB of RAM. 80 GB hard disk, Pentium® 4 CPU 2.60 GHz and Integrated Audio and Video cards. The monitor is 17". It has a CD/DVD/RW/R unit with a writing speed of 32X.

4.2 Software

Adobe Photoshop and Corel PhotoPaint are used for resizing images and creating graphical interface elements. Macromedia Flash MX 2004, and Macromedia Flash Player 7 and Macromedia Flash HomeSuite + were installed for purposes of developing animations. Roxio Easy CD Creator 5 and Burn CD&DVDs with Roxio are some software applications that we use for recording CDs. Macromedia Dreamweaver 4 is used for multimedia asset development like graphics, animations, video and sound.

4.3 'Trade offs'

Multimedia assets consume a huge amount of computer storage space and their inclusions in the CD-ROMs were restricted to only the essential parts. The hardware and software requirements for them are prohibitive. For example, a video clip requires 3 MB per minute of disc space. Video clips were restricted. And topics that are relatively straightforward will be delivered in the conventional way just like those that do not have any significant multimedia input. There is no point having a textbook on a CD ROM. Iskander et al (1996) call this a 'tradeoff' when developing CD ROMs. Focus is placed on visualization of abstract and highly mathematical topics, interactive participation in laboratory experiments and on presentation of practical applications.

Secondly, multimedia authoring is enormously time consuming according to Hinchliffe's (2002) experience in production of training CD ROMs. He notes that a 30 second animation, which might occupy the user's attention for two or three minutes only, might take an hour or two to put together. Animations are good interactive methods but they also require a lot of bandwidth. All these considerations were made during development of the interactive multimedia CD-ROMs for A-level Physics and Mathematics.

4.4 Production of the CD-ROMs

Digitalization of the Local Content Created
The stages in the production of the CD-ROMs are shown in table 1. The main stages of the CD-ROM production process included digitalization, authoring, multimedia integration, production of test copies, producing master copies and mass production.

Arrangements were made with some secretaries and the manual hand-written copies of the local content created were converted into electronic copies. The teachers could not do it because of very low computer skills. The scanner we have does not have the capability of recognizing hand written letters and numbers. It is a digital flatbed scanner with photo-quality results of 2400dpi and 48-bit colour. This made the exercise of digitalization very tedious.

Table 1: Timeline for the production of the CD-ROMs

Activity	Responsibility	Expected Completion Date	Status
Local content creation	*Subject teachers in a Workshop*	*19.9.2005*	*Done*
Digitization of content	*Researcher, Secretaries*	*2.11.2005*	*Done*
Copyright permission for some resources	Researcher	On-going	On-going
Interface Design	Researcher, Multimedia Programmer	15.1.2006	Done
Programming	Researcher, Multimedia Programmer	10.2.2006	Done
Narration, Music	Researcher, Multimedia Programmer	30.1.2006	Done
Writing/Editing	Researcher, Multimedia Programmer	February, 2006	Done
Testing	S6 Students of Muni, Ediofe	March, 2006	In progress
CD covers/insert design	Researcher	March, 2006	Done
Production (500 copies)	Researcher	April, 2006	
Marketing in other schools	Researcher	From April, 2006	

For the completed CD ROMs there will be small pamphlets or inserts included in their jewel boxes. The pamphlets will contain information about the CDs and how to use them. They will also have copyright statements and hardware requirements.

Finally, master CDs will be burnt along with the other documents for mass manufacture and possible use in other rural secondary schools.

5.0 Conclusions

In Hybrid E-Learning for poor rural secondary schools, the course delivery platform to be used is the CD-ROM. The main advantages of CD-ROMs are big memory capacity, multimedia applications and popularity due to its standardization. Web-based (Internet) delivery options are inherently not suitable for this purpose and context of rural communities.

In designing and developing interactive multimedia CD-ROMs for advanced -level Physics and Mathematics subjects the main objective was to demonstrate that the technology could be viable for use in poor rural schools that cannot afford to build science laboratories, libraries while at the same time cannot attract committed and qualified teachers. The CD-ROMs are being tested in the two girls' schools in the rural District of Arua, 500 kms from Kampala, the capital city of Uganda. The two girls' schools are Muni and Ediofe. The aim is to encourage more female students to pursue engineering career later after improving their performances at the secondary level of education. This will help to narrow the gender gap currently exists in the engineering profession in Uganda. In a wider context, the CD-ROMs will contribute towards the achievement of Millennium Development Goal No. 3 which specifically deals with women empowerment.

In the design and development of the CDs, multistakeholder participatory approach was used. The content was created based on the local curriculum by the subject teachers in the District of Arua and was facilitated by experts from the National Curriculum Development Center, an Institution in the Ugandan Ministry of Education and Sports. Head teachers of secondary schools in Arua and Koboko Districts willingly allowed their teachers to attend the content creation Workshop. Hardware and software for the production was procured by Makerere University, Faculty of Technology with financial support by Sida/SAREC. This type of participatory approach is good when handling community, poverty-related issues. The community takes ownership of the process.

While designing the multimedia content, the context of the schools where the female students are studying had to be considered. They have earlier versions of refurbished PCs. The multimedia capabilities of such computers may not be very good. They do not have a lot of memory space and the hard disc capacity is also limited. So some 'tradeoffs' were done. Video clips that require a lot of bandwidth were restricted to the remarks of the Dean, Faculty of Technology, Makerere University. Other multimedia assets like graphics, simulations, etc. were also limited to an absolute minimum.

Digitalization was the lengthiest process since the content created by teachers was hand-written, thanks to their low computer skills level. The scanner that could have been used did not have the character-recognizing capability. This caused a lot of delays when creating digital copies of the content.

The final products are the CD-ROMs for advanced-level Physics and Mathematics. It is the first time locally produced training CDs have been produced for that level of education in Uganda.

References

Beheshti, J., Large, A., & Moukdad, H. (2001). Designing and Developing Multimedia CD-ROMs: Lessons from the Treasures of Islam.http://www.ingentaconnect.com/search-/expand?pub=infobike://mcb/264/2001/00000025/00000004/art00001&unc=

Hinchliffe, P. (2002). Developing an Interactive Multimedia CD-ROM to support AS Physics. http://ferl.becta.org.uk/display.cfm?resID=2937

Iskander, M.F., Catten, J.C., Jameson, R.M., &Rodriguez, A. (n.d). Interactive Multimedia CD-ROMs for Education. www.ieeexplore.ieee.org/ie13/4276/12342/0573085.pdf

Lating, P. O., Kucel, S. B., & Trojer , L. (2006) Strategies for implementing hybrid e-learning in rural secondary school in Uganda. Proceedings of the First International Conference on Advances in Engineering and Technology, Elsevier Ltd.

Ranky, P.G., & Ranky, M. F. (1997). Engineering Multimedia CD-ROMs with Internet Support for Educating the Next Generation of Engineers for Emerging Technologies. (A Presentation with and Interactive Multimedia CD-ROM Demonstration). http://ieeexplore-.ieee.org/xpl/abs_free.jsp?arNumber=616247

Tapia, C., Sapag-Hager, J., Muller, M., Valenzuela, F., & Basualto, C. (2002). Development of an Interactive CD-ROM for Teaching Unit Operations to Pharmacy Students. www.ajpe.org/legacy/pdfs/aj660312.pdf

Woodbury, V. (n.d). CD-ROM: Potential and Practicalities. http://calico.org/journalarticles-/Volume6/vol6-1/Woodbury.pdf

All references were retrieved on 28th November from the respective Websites.

PAPER IV

Development of Sustainable Hybrid Digital Libraries for Secondary Schools in Uganda: Arua Case Study

P.O. Lating, Sub-Department of Engineering Mathematics, Makerere University, Uganda
S.B. Kucel, Department of Mechanical Engineering, Makerere University, Uganda
L. Trojer, Division of Technoscience Studies, Blekinge Institute of Technology, Sweden

Abstract

This paper shows how hybrid digital libraries were implemented in disadvantaged, poor, rural advanced-level girls' secondary schools to support Physics and Mathematics education in Uganda. The schools are Muni and Ediofe girls' senior secondary schools in the rural District of Arua, Uganda. Both schools are boarding and government-aided with good physical libraries but with hardly any relevant text-books. The schools have no librarians, and the teachers together with the students had very low computer literacy skills. Internet connectivity and the costs of bandwidth are extremely high for rural schools to afford. Hybrid digital libraries were introduced in these schools using Participatory Rural Appraisal methods. Local digital content for the subjects were collaboratively developed using senior teachers from an 'elite' urban secondary school- Makerere College School. Interactive multimedia training CD-ROMs were produced from the local content and delivered to the schools. All the teachers and students were trained in ICT skills. The students and their teachers were allowed access to the Makerere University, Faculty of Technology ICT Research Center with VSAT Internet connectivity for more content they needed from the Internet or from some Websites. The Center has an offline digital library with a lot of science and Mathematics content developed by experienced Ugandan teachers from advantaged urban secondary schools. While at the Research Center, students and teachers have free access to resources from the Internet, from the project website http://www.aruaeduc.com and other websites. Setting up of the Research Center was based on the collaboration between Faculty of Technology, Arua District Local Council and the Business Community. The Triple Helix Methodology was used in that instance. This was the first ever successful application of the methodology in Uganda. The paper concludes that because of the difficulty of Internet connectivity, maintenance of networks and purchase of adequate bandwidth for educational purposes by rural schools, the structure and organization of hybrid digital libraries should be separated from their distribution media. Physical distribution of information on recordable devices can provide an attractive alternative to networks. This means that CD-ROMs are very practical format for areas with little Internet access. The advantages of CD-ROMs are - big memory capacity (650-700MB), multimedia capability, high data-transfer rates (up to 1200kbps) and their popularity and standardization.

Keywords: Gender; Hybrid Digital Library; Rural Secondary Schools; Uganda; Digitization; Collaborative Research; Participatory Rural Appraisal; Triple Helix Methodology

Introduction

Most secondary schools in Uganda have no functional libraries. Schools that have libraries cannot afford to stock them with relevant text books that the curriculum requires. In a number of cases, there are no qualified librarians in the schools. The situation is particularly bad in the rural advanced-level secondary schools where funding is inadequate. They cannot afford to build physical traditional libraries, stock them with relevant text books and maintain them. Absence of functional libraries is one of the main reasons why rural secondary school students perform poorly at national examinations. Performances of such students are extremely poor in science and Mathematics subjects. Rural secondary schools also lack qualified, experienced and committed teachers. This explains why few rural students are usually admitted to universities and other tertiary institutions for professional training. The number of female students is even fewer. In engineering training, for example, Faculty of Technology, Makerere University, female students constitute on average 20% of total annual enrolment of female students for engineering training. The few female engineering students are almost exclusively from four urban districts located within Kampala and its vicinity. Yet Uganda administratively has 80 districts, most of them rural and poor. One such District is Arua.

Status of libraries in Muni and Ediofe

Arua is in the North Western part of Uganda popularly known as West Nile region of Uganda. There are two rural advanced-level secondary schools in the District of Arua: Muni and Ediofe Girls. Both schools are government-aided boarding senior secondary schools. They have both Ordinary and Advanced Secondary levels of education. The total enrolment of female students in 2005 was 660 in Muni and 630 in Ediofe. Both girls' schools have failed in the recent past to send any female students for engineering training in the Faculty of Technology, Makerere University.

Field trips were made by researchers from the Faculty of Technology to assess the computing status of Muni and Ediofe in 2005.

Muni and Ediofe have physical/traditional libraries that were built and furnished through donations from abroad. The library in Ediofe was built and furnished by Manos Unidas of Spain. The library in Muni Girls was built in 1992 using funds provided by the Swedish students' organization, the Pink Caravan.

Both schools have no trained librarians. Muni Girls assigned a trained professional secondary school teacher to act as a librarian while in Ediofe, a non-teaching staff was designated as a librarian.

The libraries hardly have any text books especially for advanced-level science and Mathematics subjects. For example, the number of recommended text books for Advanced-Level Mathematics and Physics were found to be few, in some cases not even enough for teachers of the subjects. Table 1 shows the quantities of the Physics and Mathematics text books that were in the school libraries in 2005.

Table 1: Inventory of Physics and Mathematics Textbooks in Ediofe and Muni Girls' Secondary Schools in 2005

No	Title and Author	Subject	Quantity in Ediofe Girls SS	Quantity in Muni Girls SS
1	Advanced Level Physics (1995) by Nelkon and Parker, 7th Edition. John Murray publishers Ltd	Physics	3	4
2	Advanced Physics (2000).Tom Duncan fifth edition John Murray publishers Ltd	Physics	1	2
3	A Shorter Intermediate Mechanics by D. Humphrey	Physics	3	1
4	Pure Mathematics Book2 (1985) by J.K. Backhouse 3rd edition	Mathematics	7	20
5	Pure Mathematics Book1 (1985).J.K. Backhouse 3rd Edition.	Mathematics	7	13
6	Advanced Mathematics by L.K. Turner	Mathematics	0	20

ICT Status in the Project Schools

Both Muni and Ediofe have a reliable thermal electricity supply from a private local supplier, the West Nile Rural Electricity Company Ltd, WENRECO. It supplies electricity for 18 hours a day from 6:00 am to midnight. In case of power outage, Muni Girls has a standby generator. There is solar electricity for lighting in some classrooms in Ediofe Girls. The schools have mobile telephone network coverage based on the GPS technology.

Though both schools had no computer laboratories at that time, they 'derived' them from the existing structures. For example, Ediofe girls converted a store in its non-functional library into a computer laboratory and installed 11 of the 15 used computers which they had purchased. There was no more space to install the remaining four computers. Muni has a good computer laboratory located in the newly completed classroom block. There were ten refurbishes computers in Muni. All the useed and refurbished computers in both schools were bought cheaply from the National Curriculum Development Center (NCDC). NCDC is an autonomous institution under the Ministry of Education and Sports, MOES. It is responsible for curriculum development and review in Ugandan primary and secondary schools and technical/business colleges and institutions. Each of these computers was bought at 175 USD in 2004. Unfortunately, the computers hardly had any multimedia capability. The results of technical inspection of the computers in Ediofe Girls are depicted in table 2. They were unreliable and were breaking down frequently.

Table 2: Technical inspection of Ediofe refurbished computers purchased from NCDC

Item	**Specifications**
Processors	Pentium I, Pentium II
Hard Disk Drive capacity	128MB, 232MB, 333MB, 406MB, 1.51GB, 1.3GB, 3GB, 6GB and 40GB
Operating System	MS Windows 95 and Windows 98
RAM	8MB, 32MB, 64MB and 128 MB
CD-Drive	Only 2 out of 10 computers had CD-Drives installed
Applications installed	MS Office 98 installed and others did not have any applications installed.

Only two of the computers had CD-drives while one came with a defective motherboard. Some of the computers had power-related problems. Antivirus software as well as Acrobat Reader and Flask software were not installed.

The computers in both schools had been networked (peer to peer) to avoid the cost of purchasing servers. The networking was to enable the computers share resources (e.g. files).

Furthermore, both schools had no Internet connectivity. Internet connectivity was considered expensive and no rural school can afford. Even the urban, well established schools cannot afford Internet connectivity. The cost of bandwidth is exorbitant.

Teachers and students at both schools had no basic computer literacy skills in both schools.

The above situation lends itself to a logical research question is:

Can hybrid digital libraries be introduced in a typical rural area in support of secondary science and Mathematics education?

According to wikipedia "*A digital library is a library in which collections are stored in digital formats (as opposed to print, microform, or other media) and accessible by computers*". There are different types of digital libraries. In the context of rural secondary schools in Uganda, *hybrid digital libraries* were implemented. These are digital libraries where the main content delivery platforms are the interactive training CD-ROMs. The other sources of content like Internet and websites were considered secondary.

Digital libraries have a number of advantages. Content can be accessed easily and rapidly. Traditional libraries require a lot of space while a digital library occupies very little space. The costs of maintaining a digital library are much lower than that of a physical library. There are no requirements for qualified librarians, dusting and sorting books. Students can access the training materials anytime and anywhere so long as they have computers where they are. Multiple access to the same content by many users at the same time is possible with digital libraries. Digital libraries are good for preservation and conservation of content. An exact copy of the original content can be made any number of times without any degradation in quality. Digital libraries encourage networking and sharing information. A particular digital library can provide a link to any other resources of other digital libraries very easily; thus a seamlessly integrated resource sharing can be achieved.

The paper shows how participatory rural appraisal methods and triple helix methodology were used to create hybrid digital libraries for secondary school students in the rural district of Arua. The paper discuses the situation of rural traditional libraries as a manifestation of poverty in Uganda. The solution of such problems should be in line with the requirements of the Millenium Development Goals (MDGs), World Summit on the Information Society (WSIS) and Uganda's own Poverty Eradication Action Plan (PEAP). Interesting conclusions were drawn.

Method

Hybrid digital libraries were established in the two schools and in Arua town for the benefit of advanced-level students of Physics and Mathematics.

Research Approaches and Methods

Different researchers use different approaches and methods when implementing such developmental projects in poor rural areas. In this study, the aim was to enable local people in the rural district of Arua share, enhance and analyze their knowledge of life and conditions, to plan and to act. While the study was facilitated externally by Makerere University, Faculty of Technology, with financial support from Sida/SAREC, the research process was locally driven. To achieve this aim, *Participatory Rural Appraisal research approach* was found to be most relevant. The *cyclic or learning loops method* of jointly planning, implementing, monitoring of progress and adjustment was used in the generation of knowledge. Many *fieldwork trips* or *site visits* were made to Arua by the researchers from the Faculty of Technology for close monitoring of the project implementation process. Close collaboration between Makerere University, Faculty of Technology with the Arua

District Local Council and the Business Community led to the establishment of the Arua ICT Research Center. This was a direct application of the *Triple Helix Methodology*.

Results

Triple Helix Methodology Applied in Arua

Faculty of Technology, Arua District Local Council and the Local Business Chamber of Commerce and Trade joined hands and set up the Arua ICT/GIS Research Center in Arua town. Arua District Local Council provided buildings. Funding was provided by Sida/SAREC. Makerere University, Faculty of Technology provided senior researchers for the project. The Center has VSAT Internet connectivity with four training classrooms for computer skills training. The Research Center has a hybrid digital library with a content server networked to ten computers. The content server has secondary science and Mathematics materials for students and teachers to access. The Center is being managed by teachers from Muni, Ediofe and Mvara SS. The facility was opened for public use in June 2006. There are 50 computers at the Research Center now, ten of which are exclusively used in the hybrid digital library.

The Research Center is within a radius of 5 kms from each of the schools. All the students and their teachers were trained in *Basic ICT skills, Internet use* and *working with e-mails*. They were all given e-mail addresses for communication during the project. The students and their teachers were allowed free access to resources from the Internet and digital library on Saturdays. To further empower the teachers, they were additionally allowed to come for teaching resources from the Center on working days from 12:00 to 14:00 hours. All subject teachers and some students were given memory sticks/flash disks to enable them transfer any relevant materials they identified from the Internet or Website to the school computers for use by other students. A record of websites the teachers were recommending to their students was also kept. While at the Research Center, the students and teachers were allowed to log into the project website http://www.aruaeduc.com and get additional training materials.

Local Content Issues

To create the hybrid libraries for secondary schools, the content had to be based on the local curriculum of Uganda. On the basis of the local content, CD-ROMs were produced. Content was developed collaboratively with the involvement of many stakeholders.

In Sept, 2005 a Local Content creation Workshop was held in Mvara SS, Arua District. It was facilitated by curriculum experts from the National Curriculum Development Center, NCDC. This is an autonomous institution under the Ministry of Education and Sports and is responsible for curriculum development and review in Uganda. Thirteen advanced level schools in Arua and Koboko districts sent Mathematics and Physics teachers for the Workshop. Thirty three teachers participated. They were trained how to develop local content materials for interactive training CD ROMs production.

The local content developed from the workshop was reviewed by senior teachers of Physics and Mathematics from Makerere College. Makerere College is an 'elite' advanced-level secondary school in Uganda sharing the same campus with Makerere University. The critical observation made by the expert teachers was that the *local content was shallow* and did not go deep enough to cover advanced level secondary school syllabus. This reflected the lack of qualification and experience of the advanced level teachers in rural areas. Furthermore, out of the thirty three teachers who attended the Workshop, only two passed the computer skills competency test; only those two were able to word processing. They were unable to digitize the content they created. In the district, the majority of the teachers and their students were computer illiterate. All the teachers did not have any *Internet skills* and, as a consequence, were not able to *use e-mails*. This offered the first challenges to the implementation of the hybrid digital library project.

Makerere Collage School was approached and accepted to develop local content materials for Physics and Mathematics in the digital form which would be transferred to the school computers in the two schools in Arua. The female students would access the relevant content from their computer laboratories in their respective schools. The same content was uploaded into the content server at the Research Center for public use by other students.

Pedagogic Development of Science Teachers

Uganda has not integrated computer science into the school syllabus. Some universities have not also done so. That is why even graduate teachers in the country are computer illiterate. To enable us implement the project, the teachers had to be developed further.

SchoolNet is a Non-Governmental Organisation (NGO) based in the Ministry of Education and Sports. The institution has been very supportive of the hybrid digital library project in Arua. It was involved in the pedagogic development of the teachers of Muni and Ediofe. SchoolNet organised *ICT in science Education Workshop* for five science teachers from each school in Kampala in April 2007. In all, there were 65 teachers from 13 secondary schools in Uganda. The same teachers returned to Kampala for a review Workshop in June, 2007. The two headteachers of Ediofe and Muni were part of the 13 secondary schools headteachers who were invited for a similar Workshop aimed at helping teachers and schools to integrate ICT in their teaching and learning. Earlier in May, 2007, SchoolNet arranged a Workshop for three science students and one female science teacher from each of the 13 schools which they were supporting. Ediofe sent three female students (all of them were participating in the hybrid e-learning project) and one female science teacher to Kampala. SchoolNet also donated the content server for the digital library at the ICT Research Center in Arua.

Specific Activities in the Girls Schools

All the inferior Pentium I, II computers in the Girls' schools were replaced with those that have multimedia capabilities. It proved impossible to upgrade the old, refurbished computers that were already unserviceable.

Science and Mathematics subject teachers and their advanced level students in both schools were trained in basic computer applications (MS Word, Excel, Access and PowerPoint). Ten Makerere University second year Telecommunications Engineering students were used in this exercise. The training was done during the Recess Semester of Makerere University, from beginning of June to mid August, 2006. The Telecommunications Students did the training as part of their Industrial Training, a key course requirement. Training was done in four schools in Arua: Muni, Ediofe, Mvara and Logiri. The total number of people trained is depicted in the table 7.

Table 7: Records of training done in Arua during the recess semester by Faculty of Technology engineering students

No	School/Institution	Category of trainees	Number trained
1	Ediofe Girls SS	Teachers	2
		A-Level Students	8
		O-Level Students	40
2	Mvara SS (Mixed School)	Teachers	6
		A-Level Students	152
		O-Level Students	128
3	Muni Girls SS	Teachers	40
		A-Level Students	89
		O-Level Students	192
4	Logiri Girls SS	Teachers	11
		O-Level Students	445
5	District Council	Heads of Departments and their staff	120
6	Public		20
	Total		**1253**

Two training DVDs were developed out of the local content created by Makerere College teachers. They are being used by the schools while comments and feedback about the content are being received. They will help in the further improvement of the content.

The content developed by Makerere College School was uploaded on the project website for other advanced level students to access, http://www.aruaeduc.com

Five interactive CD-ROMs for advanced level Physics, Pure Mathematics, Biology, Chemistry and Statistics and Probability were acquired from the UK and copies made for the students, teachers and the Research Center digital library.

The content server which was donated by SchoolNet Uganda also had additional Science and Mathematics content for students, teachers and interested public.

Physical text books for Physics and Mathematics were purchased and delivered to the schools. Copies of the advanced level teaching syllabus for science and Mathematics subjects were purchased and donated to the schools. Content created by Makerere College war printed and manual paper copies were given to students and their teachers.

Discussion

In the works of Levy & Marshal (1995), three crucial aspects of libraries are mentioned: documents, technology and work. A library is a *collection of documents* like textbooks, CD-ROMS, videotapes, electronic files. Furthermore, the authors maintain that libraries are based on technologies that were used to create them. The work done by a library to support its users (usually researchers) and the work done by library personnel in support of its users (service) are all very important aspects of a library.

Traditional physical libraries which depend mainly on textbooks were created based on the paper and print technologies. Digital libraries are based on the digital technologies.

The problems of non-functional traditional libraries in secondary schools in Uganda should be looked at as a manifestation of Uganda as a poor country. It is widely believed that the eight Millenium Development Goals (MDGs), if implemented by the poor countries by 2015, will pull them out of poverty. According to the World Summit on the Information Society (WSIS), the achievement of MDGs by developing poor countries, should be done by using ICT as the main improvement tools. The only progressive ICT that has transformed the world and created the knowledge economy is the Internet.

Internet and adequate bandwidth are the two most crucial requirements that must be considered when introducing hybrid digital libraries in poor, rural schools like Ediofe and Muni. The others are computer hardware and software, electricity supply, human resources, website design and hosting.

Internet connectivity is not affordable by rural secondary schools. The advantaged schools in urban areas cannot also afford it. According to the UNDP Human Development Reports of 2005, while in 1990 Uganda had no internet users, by 2003 there were 5 Internet users per 1,000 populations or 0.5%. For United States, it was 55.6%. The experience in setting up the ICT Research Center in Arua by the Faculty of Technology with financial support from a major donor to the Makerere University, Sida/SAREC, shows that no rural school can afford Internet connectivity. The start up cost amounted to nearly 11,000 USD. That included the cost of VSAT equipment, 2,500 USD, monthly access fees of 450 USD (giving 5,400USD per year), maintenance fees of the Ku band 350 USD plus 18% VAT payment on sales. Currently, the fixed monthly subscription cost is 650 USD; it is too high for a rural school to afford.

Bandwidth is very expensive to purchase in the developing world. Makerere University, the most dominant university in Uganda, has problems paying for sufficient bandwidth from its service provider. According to Atkins, Smith and Deway (2005), Makerere University pays more than 20,000USD per month for a T1 (1544 kbps) connection through its ISP. In the US the same bandwidth can cost only 400 to 500 USD only. The demand for more bandwidth for Makerere has increased and the University has budgeted 480,000 USD in 2006 for purchasing it. For the small ICT Research Station in Arua with VSAT Internet connectivity, 650USD per month is charged for a volume usage of 3000 MB. Neither Muni nor Ediofe can afford to install and maintain VSAT Internet connectivity. Records from Muni show that total actual annual expenditures of the school in 2003 were 135,774USD, 209,881USD in 2004 and 257,642 USD in 2005.

There are five commercial Internet cafes in Arua town and they charge a minimum of 2 USD an hour for surfing. If a student surfs for 10 hours in a day, the total monthly amount of money required is 600 USD. This is equivalent to a gross salary of an average civil servant for nearly seven months. Neither the students nor their parents can afford commercial surfing on the Internet for purposes of enhancing her education.

Internet connectivity and bandwidth costs remain a challenge to even advantaged secondary schools in Uganda. Schools like Makerere College, Trinity College, Nabingo, King's College, Budo have problems with Internet connected to their schools under some donor-funded programmes. They have failed to purchase enough bandwidth for educational purposes.

In 1996, SchoolNet Uganda started implementing a World Links for Development Program, an initiative of the World Bank Institute by connecting 15 pilot schools located in different parts of Uganda to the Internet using VSAT. The project partners were:

- Links Organisation is subsidizing half the bandwidth cost for two(2) year (USD 3,000 @ month), training (technical and pedagogical) , business and technology plan development. This means the total cost of the bandwidth was 6,000 USD per month.
- Bill and Melissa Gates Foundation – donated the earth-satellite dishes (VSATs) each at 2,500 USD
- Ministry of Education and Sports (MOES) – paid for the duty-tax clearance.
- Schools Online USA provided ten of the participating schools with computer labs of 10 (ten) networked computers and a printer each and the micro-wave wireless equipment of the four Jinja schools linked to Mwiri.
- Wilken AFSAT has handled the school-based VSAT installation and commissioning.
- Verester, a global Communication Solution Provider is providing the satellite bandwidth at a very competitive price (US$ 6,000 @ month for whole network). The bandwidth coming to the schools is 256 Kbs (shared among the 15 schools).
- SchoolNet Uganda has played the lead role on the ground.

- Participating schools – hosting the VSATs, providing insurance and security , burglar – proofed room for the computers, underwriting the computer labs' costs (e.g chairs, desks, power points), financing recurrent costs (electricity , satellite bandwidth, maintenance, paper, toner, diskettes) and staffing. Pay a monthly fee of US $ 200 per month for the bandwidth.

Though the schoolNet project targeted elite schools that do not have serious problems like the typical rural ones, the project has not been sustainable. Even the affluent secondary schools cannot afford the high cost of Internet connectivity and bandwidth in Uganda.

The supply of used, obsolete computers to both Muni and Ediofe is a clear sign of using a Government department like the national Curriculum Development Center, (NCDC), for dumping e-waste in Uganda. There is lack of policy on e-waste by the Ugandan Government. There are no standards for ICT equipment being brought into the country. Nearly 75% of the total purchase price/cost of these computers was used to repair and upgrade them so that they could be used. However, it proved technically impossible to upgrade those computers so that they could have multimedia capabilities. For the project to proceed, the computers had to be replaced.

With Internet access and bandwidth costs very high in Uganda, the main content delivery platforms remain the CD-ROMs. The hybrid digital libraries created have contents in CD-ROMs format. The students and teachers had access to the ICT Research Center to get additional resources from the Internet, the project website, other websites and the offline digital library. The offline digital library was created so that materials could be transferred to it from the Internet. In case of Internet outage, students and teachers could still get resources offline. Teachers and some students were given flash disks/memory sticks to enable them transfer content from the ICT Research Center to their computers in the schools. Communication among students, teachers and researchers was through e-mails. It made research a very interesting collaborative activity.

Conclusions

Africa is the only continent where poverty is increasing. Uganda is one such country where, contrary to many interventions by the Government, poverty may be increasing. A manifestation of poverty in the education sector is shown by the inability of rural schools to purchase relevant textbooks in their libraries for the purposes of bettering performance of students at national examinations.

It is generally accepted the world over that ICT mainstreaming should be encouraged while looking for solutions to social problems like poverty. The WSIS recommends that the achievement of the 8 MDGs, which are poverty eradication goals, should be made through application of ICT. The only progressive ICT that has dramatically transformed the world in a short historical period is the Internet. The Internet has revolutionized the world and created the knowledge economy. However, in a typical rural environment, including rural schools, the capital costs and the subsequent operational costs of Internet connectivity together with the costs of bandwidth are prohibitively high.

The female students together with their teachers were allowed to visit the Makerere University, Faculty of Technology ICT Research Center and get Internet resources. The setting up of this Center using the triple helix methodology was the first successful application of this methodology in Uganda.

Research is a very highly collaborative effort. And when doing research in rural areas participatory rural appraisal methods were fount to be most useful. The target group where part of the research process. They were the driving force in the research process with professional guidance from the expert researchers. A lot of knowledge was generated by adopting participatory methods.

Because of the difficulty of Internet connectivity, maintenance of networks and purchase of adequate bandwidth for educational purposes, the structure and organization of digital libraries should be separated from their distribution media. Physical distribution of information on recordable devices can provide an attractive alternative to networks. This means that CD-ROMs are very practical format for areas with little Internet access. This view by Witten et al (2002) is in line with the thoughts of Lating, Kucel and Lena (2006a) where the authors highlight the advantages of CD-ROMs- big memory capacity (650-700MB), multimedia capability, high data-transfer rates (up to 1200kbps) and their popularity and standardization.

References

2005 Human Development Reports: Uganda Country Sheet. A publication of UNDP. http://hdr.undp.org/statistics/data/countries.cfm?c=UGA

Argyris, C. Putnam, R., Smith, D. (1985). Action Science: Concepts, methods and skills for research and intervention. San Francisco: Jossey-Bass.

Atkins, D., Smith, A.D., & Dewey, B.I. (2005). From the great smokies to the mountains of the moon: US and Ugandan librarians collaborate in the digital world. Information Technology and Libraries, 24(4), 192-196

Chambers, R. (1997). Whose Reality Counts? Putting the First Lats. London: IT Publications.

Cleveland, G. (1998), Digital libraries: Definitions, issues and challenges. UDT Occasional Paper No. 8, available at http://www.ifla.org/udt/op/udtop8/udtop8.htm

Digital Library. Retrieved December 1, 2007 from Wikipedia: http://en.wikipedia.org/wiki/Digital_library

Jeevan, V.K.J. (2004). Digital library development: Identifying sources of content for developing countries with special reference to India. Elsevier Ltd.

Ke, H.R. & Hwang, M.J. (2000), The Developing of Digital Libraries in Taiwan. The Electronic Library, 18(5), 336-346

Lating, P.O., Kucel, S.B., & Trojer, L. (2006a). Design and development of interactive multimedia CD-ROMs for rural secondary schools in Uganda. Proceedings of the First International Conference on Advances in Engineering and Technology, Elsevier Ltd, 546-553

Lating, P.O., Kucel, S.B., & Trojer, L. (2006b). Strategies for implementing hybrid e-learning in rural secondary schools in Uganda. Proceedings of the First International Conference on Advances in Engineering and Technology, Elsevier Ltd, 538-545

Levy, D.M. & Marshal, C.C. (1995) Going digital: A look at assumptions underlying digital libraries. Communications of the ACM, vol. 38, no.4. Retrieved December 2, 2007 from http://delivery.acm.org/10.1145/210000/205346/

Lin, X., & Simske, S. (2004). Creating digital libraries: Content generation and re-mastering. Proceedings of the First International Workshop on Document Image Analysis for Libraries (DIAL'04). Computer Society.

Magara, E. (2002). Applications of digital libraries and electronic technologies in developing countries: practical experiences in Uganda. Emerald,51(5), 241-255

Nowotny, H., Scott, P., & Gibbons, M. (2001) Re-thinking science. Knowledge and the Public in an Age of Uncertainty. Polity Press, Cambridge UK.

Rydhagen, B. Feminist Sanitary Engineering as a Participatory Alternative in South Africa and Sweden. Doctoral Thesis No 2002:06, Blekinge Institute of Technology.

Smith, M. K. (2001) Chris Argyris: theories of action, double-loop learning and organizational learning. The encyclopedia of informal education, www.infed.org/thinkers/argyris.htm.

Turyagyenda, J.B., Lugujjo, E., & Mugisa, D. (2005). Situation Analysis of Engineering Education in Uganda. Workshop Proceedings on Engineering Education and Training in East Africa.

Witten, H.I, Loots, M., Trujillo, M.F., & Bainbridge, D. (2002). The promise of digital libraries in developing countries. The Electronic Library, 20(1), 7-13

Zhou, Q. (2005), The development of digital libraries in China and the shaping of digital librarians. The Electronic Library, 23(4), 433-441

PAPER V

Longitudinal Analysis of Performance of Ugandan Rural Advanced-Level Students in Physical Practicals

P. O. Lating, Lecturer, Department of Engineering Mathematics, Faculty of Technology, Makerere University, P.O. Box 7062, Kampala, Uganda. Email: plating@tech.mak.ac.ug
S. B. Kuce, Lecturer, Department of Mechanical Engineering, Faculty of Technology, Makerere University, P.O. Box 7062, Kampala, Uganda. E-mail: sbkucel@tech.mak.ac.ug
L. Trojer, Professor, Division of Technoscience Studies, Blekinge Institute of Technology, BTH, Sweden. E-mail: lena.trojer@bth.se

Abstract

Advanced-level rural students perform poorly in Physics and Mathematics at national examinations in Uganda. Consequently, they fail to get state sponsorship for engineering and technology training in Universities. Hybrid e-learning was introduced for two years in two typical rural girls' advanced-level secondary schools (Ediofe and Muni) in the rural district of Arua to support the learning and teaching of Physics and Mathematics and was expected to result in an improvement in the achievement scores. In the hybrid e-learning project, the main course delivery platforms were the training CD-ROMs that were developed based on the requirements of the local curriculum. The purpose of the study was to investigate the effects of such an intervention on the achievement scores of the female students in both subjects. Multilevel analysis methods were used to analyse repeated measures scores of 19 participants from both schools in advanced-level Physics Practicals. External examinations were given to the participating female students in May, June, July and August 2007. The results of these examinations were analyzed as incomplete longitudinal data. The results of the analysis of the sources of variabilities in performance scores of students show that student level factors were more dominant than school level factors. The intraclass correlation was found to be 32% which shows that within the contexts of rural schools, 68% of the variability in scores is attributable to within-person factors. The hybrid e-learning was found to contribute 64% of a student's scores, making it a very viable proposition for disadvantaged rural schools. The findings also show that even in situations where there is no significant support from teachers, the hybrid e-learning can still lead to achievement of good scores. These results were discussed in light of the Ugandan national policies on science education and achievement of Millenium Development Goal No.3.

Keywords: Multilevel Analysis; Hierarchical Linear Modeling; Incomplete Longitudinal Data; Triple Helix Methodology; Rural Secondary Education; Advanced -Level Physics Subjects; Gender

Introduction

Most secondary schools in Uganda have no functional senior laboratories and libraries for advanced level science students. There are few qualified, committed and experienced teachers for advanced level classes in such schools. The difficult situation is reflected in the generally poor performance of the students in science subjects, especially Physics and Mathematics. Neither the government nor the secondary schools has enough financial resources to build, equip and sustain science laboratories and libraries. Provision of qualified, well paid and properly motivated teachers in rural secondary schools appears to be impossible, even in the far perspective. The situation lends itself to the following research questions:

What effects would introducing hybrid e-learning in rural advanced-level secondary schools have on the performance of the students in external examinations? How much of the variations in students performance scores can be attributed to the within-individual and between-individuals factors? What are the effects of school-level characteristics on the scores of students that are nested within such schools?

In Lating (2006) hybrid e-learning tools and applications were developed for use by advanced-level rural secondary schools in Uganda. The main course delivery platform, according to the authors, were the interactive CD-ROMs for Physics and Mathematics developed based on local curriculum. Throughout 2007, the project was implemented in two typical rural advanced-level girls' secondary schools in Arua: Muni and Ediofe Girls. The implementation of this unique type of blended e-learning was in close collaboration with many stakeholders especially Faculty of Technology, Makerere University; Arua District Local Council; SchoolNet and Makerere College School.

Makerere University, Faculty of Technology, the Arua District Local Council and the Business Community in Arua jointly set up the ICT/GIS Research Center in Arua town using the triple helix methodology. The Center has VSAT Internet connectivity and female students and their teachers who were taking part in the e-learning project were allowed access to it. They would get additional learning materials from either the Internet, project website (http://www.aruaeduc.com), other recommended websites or the digital library with a lot of relevant science materials in the content server. The students and their teachers were trained in Internet use and working with e-mails from the Research Center. The

Mambo, an open source platform hosted by an open source web-hosting provider *b-one.net*, was used to manage the e-learning environment. All the students and their teachers were given e-mail addresses for communication. The teachers and some students were given memory sticks (flash discs) to enable them copy and transfer relevant content from Internet and some websites at the Research Center to their school computers for later use.

SchoolNet Uganda helped in the pedagogic development of the teachers under the theme: ICT in Science Education. Twelve teachers from both Muni and Ediofe, both headteachers of the two schools, and three female students took part in that capacity building program. Refurbished computers with multimedia capabilities were purchased from SchoolNet to replace the inferior ones the schools had earlier purchased from the National Curriculum Development Center.

Makerere College is one of the 'elite' secondary schools in Uganda. The school provided senior teachers of Physics and Mathematics to develop additional local content materials for the hybrid e-learning project. The same teachers would facilitate at monthly Workshops in the schools when they would handle difficult topics for the teachers in the schools. Five Workshops were held between March and October 2007. Each Workshop was for about ten days. Video recordings were made at such Workshops for use later as training materials. After every Workshop, the female students were made to sit for Makerere College examinations. The written examination scripts were taken to Makerere College for marking and grading. The students sat for such external examinations in May, June, and September, 2007. In July, the students sat for another external examination, the Arua District Joint Mock Examinations.

The results of performance in Physics Practicals formed the basis of the statistical analyses in this paper using multilevel methods. Multilevel analysis is a statistical model that allows specifying and estimating relationships between variables that have been observed at different levels of a hierarchical data structure.

Multilevel models were specified and fitted using the repeated measures data. Intraclass correlation and the effect of the application of the blended e-learning on the improvement of performance in Physics practicals were determined. The paper concludes that hybrid e-learning can be applied in rural schools with inadequate resources and infrastructure for science and Mathematics.

Method

Sampling

Multi stage sampling was done and 19 Physics female students were identified; 12 from Ediofe and 7 from Muni.

Data

Table 1 shows the data which are the repeated measures scores in the external examinations which the students sat for. The data collected were standardized from the original raw data given in percentages. A score of 1 is the best mark and 9 is the poorest mark in the standardized grading system.

Intervals between measurement occasions were not equal making the data unbalanced. Furthermore, data from Muni were incomplete.

Table 1: Performance scores in the examinations

Student ID	School	Initial Status, May 2007	June 2007	July 2007	September 2007
1	Ediofe	8	7	2	5
2	Ediofe	4	6	4	6
3	Ediofe	7	7	9	6
4	Ediofe	5	5	7	4
5	Ediofe	9	9	9	6
6	Ediofe	9	1	5	4
7	Ediofe	9	3	5	4
8	Ediofe	9	9	4	5
9	Ediofe	6	4	3	5
10	Ediofe	9	6	1	7
11	Ediofe	3	5	7	5
12	Ediofe	5	6	6	6
13	Muni	4	1	4	
14	Muni	6	9	7	
15	Muni	9	2		
16	Muni	3	3	3	
17	Muni	1	2		
18	Muni	9	4	6	
19	Muni		5	7	

Methodology

Data involving social organizations are hierarchical in nature and often contain variables measured at multiple levels of analysis. Such nested data are dependent and have cross-level correlation between variables of different levels of hierarchy. The traditional Ordinary Least Squares (OLS) regression methods of analysis, which put emphasis on independence of outcomes, normality sphericity, homoscedasticity of variance, balanced and complete data cannot be used for the analysis of the relationship between the outcomes and their predictors. According to Osborne (2000), Hierarchical Linear Modeling (HLM) is a suitable method to be used for analysis of nested data since modeling of cross-level interactions is possible. OLS techniques applied to nested data usually result in reduced standard errors leading to biased tests. This increases the chances of rejecting the null hypothesis, hence wrong inference. Ciarleglio & Makuch (2007) while supporting the use of Hierarchical Linear Modeling, which is also called Multilevel Modeling or Random Coefficients Modeling, raise the issue of missing data. The authors identify three types of missingness of response data: missing completely at random, MCAR, missing at random, MAR, and missing not completely at random, MNAR. They suggest that MCAR and

MAR can be ignored in the analysis if the Maximum Likelihood method of estimating parameters is used. Single imputation, multiple imputation, hot-deck imputation, modeling missing values using regression techniques and simulating the missing values are some of the methods the authors recommend when estimating the values of MNAR. Berg & Quene (2004) earlier disagreed with this position. Multilevel analysis, according to them, can be used to analyse incomplete, unbalanced data. In the current paper, missing data were ignored, but all available data sets were used.

Multilevel analysis is a methodology for the analysis of data with complex patterns of variability, with a focus on nested sources of variability. Longitudinal analysis is a form of multilevel analysis where repeated measurements are taken from the same individuals over time. Two hierarchical levels of data sources are evident in longitudinal studies: level-1 (within person) and level-2 (between-persons). The data can be modeled at different levels.

MODEL SPECIFICATION

Level-1 Model: Within Individual Model

Let Y_{ij} represent score for student *i* at measurement occasion *j*. There were 19 students in the study (*i= 1, 2, 3... 19*) and four measurement occasions (j = 1, 2, 3, 4.). The general form of the level-1 model can be expressed as:

$$SCORE(Y_{ij}) = \pi_{0i} + \pi_{1i}(DURATION_{ij}) + \varepsilon_{ij} \quad (1)$$

where $\varepsilon_{ij} \sim iid\ N(0, \sigma_e^2)$ - residual errors of student *i* during measurement occasion *j* and ε_{ij} is the proportion of student *i*'s outcome that is unexplained on measurement occasion *j*.

π_{0i} - the student *i*'s true initial score (at baseline when time *DURATION =1*) or intercept.

π_{1i} -the rate of change of the student *i*'s score per unit time. This is the slope which shows the rate of improvement in scores.

$DURATION_{ij}$ - level-1 predictor variable showing the duration of the hybrid e-learning intervention for student *i* on measurement occasion *j*.

Level-2 Models: Between Individuals Models

The Level-2 models specify parameters of the Level-1 model and they help to explain differences in scores between students depending on their schools where they were nested. The *SCHOOL* of student *i* is added as a level 2 predictor variable.

Predictors of baseline (initial status) performance can be modeled as:

$$\pi_{oi} = \gamma_{00} + \gamma_{01}(SCHOOL_i) + \varsigma_{0i} \quad (2)$$

Similarly, predictors of initial rate of change in scores can also be modeled as:

$$\pi_{1i} = \gamma_{10} + \gamma_{11}(SCHOOL_i) + \varsigma_{1i} \quad (3)$$

where γ_{00} and γ_{10} are the Level-2 intercepts and γ_{00} is the population average initial status (baseline) and γ_{10} is the rate of change in scores for each of the schools.

γ_{01} and γ_{11} are the effects of school characteristics on the initial status and rate of change in achievement scores respectively.

Residuals ς_{0i} and ς_{1i} are deviations of individual change trajectories around the population averages, where $\begin{bmatrix} \varsigma_{0i} \\ \zeta_{1i} \end{bmatrix} \sim iid\ N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_0^2 & \sigma_{01} \\ \sigma_{10} & \sigma_1^2 \end{bmatrix}\right)$.

Variances in coefficients usually reflect important individual differences in either rate of change in scores or they may show sensitivity to contextual factors. Residuals reflect individual differences which can be input as predictors for other analyses.

The Composite Model

Substituting the Level-2 equations in the Level-1 model, the final combined model becomes

$$SCORE(Y_{ij}) = (\gamma_{00} + \gamma_{01}(SCHOOL_i) + \zeta_{0i}) + (\gamma_{10} + \gamma_{11}(SCHOOL_i) + \zeta_{1i})(DURATION_{ij}) + \varepsilon_{ij}$$

…..(4)

After re-arranging we finally get the combined model:

$$SCORE \square Y_{ij} = [\gamma_{00} \square \gamma_{01} \square SCHOOL_i \square \gamma_{10} \square DURATION_{ij} \square \gamma_{11} \square DURATION_{ij} \square SCHOOL_i] \square$$
$$\square [\zeta_{0i} \square \zeta_{1i} \square DURATION_{ij} \square \varepsilon_{ij}]$$

…………………………………………….………………………...(5)

Level-2 regression coefficients do not vary across level-2 units (therefore, they have no subscripts). They are referred to as *fixed effects*.

Similarly, level-1 regression coefficients can vary across level 2 units, these effects are called *random effects* (hence the terminology *random coefficients models*). The composite model has two parts:

(a) the fixed, deterministic or systematic portion;

$[\gamma_{00} \square \gamma_{01} \square SCHOOL_i \square \gamma_{10} \square DURATION_{ij} \square \gamma_{11} \square DURATION_{ij} \square SCHOOL_i]$ (b) and the random error or stochastic part;

$[\zeta_{0i} \square \zeta_{1i} \square DURATION_{ij} \square \varepsilon_{ij}]$.

MODEL ASSUMPTIONS

Bryk A.S. & Raudenbush, S.W. (1987) maintain that for purposes of realizing the increased flexibility of the HLM, careful attention should be given to statistical assumptions made during the analysis. They recommend that three assumptions must be made. These are assumptions of the distribution of the data, assumptions about the covariance structure and assumptions about the metric in which the outcome variable is measured.

In this analysis, *normal distribution* of the outcome data was assumed and the *unstructured covariance structure* was used. The outcome data collected at each measurement occasion was measured on a *common standardized scale* used by the Ugandan examination body, UNEB. This assumption is very important in growth curve modeling so that changes across time reflect growth and not changes in measurement scale.

RESULTS OF MODEL FITTING

To help understand the complex variabilities in the repeated measures data collected, three models were fitted: the unconditional means model (Model A) with no predictors at either level; the unconditional growth model (Model B) with DURATION of hybrid e-learning as the only predictor at level-1; and the composite model (Model C) with DURATION as level-1 predictor and SCHOOL as level-2 predictor. The results of fitting the three models are shown in tables 2. Ms Excel was used for most of the calculations.

The Unconditional Means Models (With no Predictor Variables)- Model A

The unconditional means model was used to determine the Intraclass correlation (ICC) using the equation

$$\frac{Intercept\ \ Variance}{Intercept\ \ Variance \square \mathrm{Re}\ sidual\ \ Variance}$$

$$= \frac{Between\ \ Variance}{Between\ \ Variance \square Within\ \ Variance}$$ ……………………………………………………

$$ICC = \rho = \frac{\sigma_0^2}{\sigma_0^2 \square \sigma_e^2} = ¿\frac{¿}{¿}¿¿¿¿¿¿¿$$

………………..……….(6)

In this case, the overall ICC equaled $\frac{2.59}{2.59 + 5.45} = \frac{2.59}{8.04} = 0.3221$

ICC shows the proportion of variance that is between-persons. It also shows the average correlation among observations from the same person.

Unconditional Growth Models (with DURATION of Intervention as Predictor of Level-1 Models) –Model B

The unconditional growth models were used to obtain two psudo-R^2 statistics which showed the proportional reduction of the level-1 variance component when moving from the unconditional means model (Model A) to the unconditional growth model (model B). The statistic was a measure of the effect of the duration of the hybrid e-learning on the student's scores is given in equation (7).

Table 2. Table of results of the multilevel analysis

Fixed Effects		**Parameter**	**Model A**	**Model B**	**Model C**	
					Ediofe	**Muni**
Initial status, π_{0i}	Intercept	γ_{00}	5.47 (0.287)	6.24 (0.622)	7.13	4.74
	Difference in intercepts between the schools	γ_{01}			2.39	
Rate of change, π_{1i}	Intercept	γ_{10}		-0.313	-0.551	0.035
	Differences in rates of change between the two schools	γ_{11}			0.586	
Variance Components						
Level-1	Within-person	σ_e^2	5.45 (0.287)	1.971 (0.173)	2.336 (0.221)	1.078 (0.245)
Level-2	In initial status	σ_0^2	2.59 (0.370)	14.00 (0.858)	6.42 (0.731)	28.95 (2.034)
	In rate of change	σ_1^2		3.35 (0.420)	0.655 (0.234)	8.82 (1.123)
	Covariance	σ_{01}		-5.642 (0.584)	-1.698 (0.396)	-12.54 (1.399)
Psudo R^2 statistics	Proportional reduction in level-1 variance components	R_s^2		0.638		
Goodness of fit statistic	Deviance		354.4	118.3		

$p<0.05$

Proportional reduction in
Level−1 variance component

¿
righ
¿
¿
¿
□□
¿ ………………(7)

¿
□¿□¿
$R_s^2 =$ ¿¿
¿
¿
¿

Therefore, 63.8% of the within-person variation in scores was found to be associated with linear time, *DURATION* of the intervention.

The Composite Models with Level 2 Predictors, SCHOOL and Level-1 Predictor, DURATION, (Model C)

The composite model was used for studying the effects of the school characteristics on scores of students. For Ediofe, the initial status γ_{00} was 7.13 and slope γ_{10} of -0.551. For Muni, the initial status γ_{00} was 4.75 and a slope γ_{10} of 0.035. The difference in the initial status γ_{01} of the two schools was -2.37 while the difference in slopes γ_{11} was 0.586. Substituting the values of and in the level-1 equation

$$\begin{aligned} &SCORE\,(Y_{ij}) = \pi_{0i} + \pi_{1i} DURATION_{ij} \\ &SCORE\,(Y_{ij}) = 4.75 + 0.035 \times DURATION_{ij},\ \ for\ Muni \\ &SCORE\,(Y_{ij}) = 7.13 - 0.551 \times DURATION_{ij},\ \ for\ Ediofe \end{aligned} \qquad (8)$$

Performance trajectories of the two schools and the combined performance trajectory for both schools are depicted in the Fig. 1

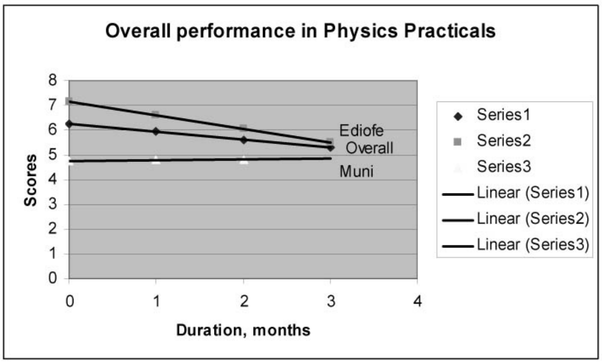

Figure 1: Trajectories of performance in Physics practical examinations by Muni and Ediofe. (Please note that a score of 1 is the best mark and 9 is the poorest mark in the standardized grading system.)

Discussion

The unconditional means model (Model A) was used to determine the intraclass correlation, ICC. ICC measures the extent to which members within a group are more alike compared to members across groups. It also gives the portion of variance accounted for by nesting or clustering of cases.

In this study, ICC was estimated to be 0.3221. This means that 32.21% of the total variation in students' scores was attributable to differences between students. This finding serves to indicate that there was correlation among the repeated measures data. If the data were independent, ICC would be zero. Secondly, the finding also helped to confirm that the use of multilevel or hierarchical modeling approach was the most appropriate as compared to the traditional regression approaches. Mutlilevel models recognize the existence of nested or correlated data hierarchies by allowing for residual components at each level of the hierarchy. It is the unobserved variables which lead to correlation between outcomes of students from the same school.

The low intraclass correlation (about 32%) indicates that there was more variability within students (68%) than between them. This finding is very relevant in the research designs. It makes much more sense to focus the research intervention in rural schools on the students themselves. The student-level characteristics (the contexts) are more severe and affect their outcomes. Effective intervention at the level of the student is more viable than support given at the school level.

The unconditional growth model (Model B) was used for purposes of answering the main research question: what are the effects of application of hybrid e-learning in rural advanced-level secondary education on the performance of female students in Physics and

Mathematics? The predictor variable at the level-1 unconditional means model was the duration of the hybrid e-learning intervention, *DURATION*. It was found that 63.8% of the within-person variation in scores was found to be associated with linear time, *DURATION* of the intervention.

This particular finding has a policy dimension. It is quite interesting that e-learning succeeds in a country that does not appear among the 60 "e-learning readiness" nations like Uganda. To be ready for e-learning as a nation and reap the benefits of e-learning (Loidl, n.d), Uganda needs to sort out the issue of the four Cs:

- Connectivity (especially Internet infrastructure, broadband, PC penetration and software issues)
- Capability (to consume e-learning based on literacy rates and trends in training and education)
- Content of the learning materials
- Culture (behaviours, beliefs and institutions that support e-learning development in the country).

There is need for Uganda to have a policy on e-learning curriculum in schools.

Uganda government has made science compulsory in all secondary schools in Uganda, whether private or government-aided. Yet neither the government nor the schools have that money to invest in science infrastructure and personnel. In such situations, hybrid e-learning would be the right approach to take. Experiments could be simulated and students could do experiments virtually the way it was done in this project.
To assess the uncontrolled effects of the school level characteristics, models were fitted with *SCHOOL* as a level-2 variable. This was an observational longitudinal study and the researchers had no direct role to play in the day to day operation of the schools where the project was being implemented.

The estimated initial average performance of all the participants was 6.24 and the average for Muni was 4.74 while that of Ediofe was 7.13 giving an average difference in performance at the beginning of 2.39. Muni students performed well throughout even if they had problems of discipline with the school administration and their teachers were constantly being changed.

Despite studying under complex situation in Muni, the students continuously performed better than Ediofe. Ediofe was a slow starter but did not manage to catch up with Muni. This is shown by the results of the analysis. The within person variability in Muni was only 1.078 as opposed to Ediofe's 2.336. It can be explained that Muni girls expect no support from their teachers and the school. They fully took advantage of the local content materials from Makerere College and used the Internet effectively. They formed themselves into effective study groups. The students of Ediofe are selfish and do not share ideas among themselves. They are not willing to do more. They are used to being spoon-fed by their teachers and the school leadership.

Conclusions

In 1931 John Dewey wrote: *"I should venture to assert that the most pervasive fallacy of philosophical thinking goes back to neglect of context".* In this study, the complex context under which rural secondary schools was analysed. The interclass correlation of 32% means that the between students factors are not the major cause of variance in performance scores. The remaining 68% of variance within students should be the primary focus of interventions in improvement programs for science education. This is what was done in the design of the hybrid e-learning intervention: the primary focus was the student, not the school.

About 64% in the performance scores of the students was attributable to the effect of the hybrid e-learning intervention. This is a clear indication of the effectiveness of the blended e-learning where the major delivery platform are the interactive training CD-ROMs that were developed based on the local curriculum. Rural secondary schools cannot afford internet connectivity but using the standalone computers with multimedia capabilities they can still learn online.

In Muni where support given to students by teachers was not significant. Several of their students were suspended from school, some of them more than once, ostensibly for indiscipline. Their teachers where not willing to support them during Workshops facilitated by Makerere College. But the students performed better than Ediofe that gives a lot of support to their students. Hybrid e-learning is a self-learning programme designed to replace the teacher. A student can still pass despite lack of support from the school administration or their teachers.

The findings of this study should be explained in terms of some policies of the Ugandan government. In situations where the government has made science education compulsory but has no budget for building laboratories and providing enough qualified teachers, hybrid e-learning could be adopted to fill the gap. If female students are targeted, more will pass national examinations. This will enable them to join universities and other tertiary institutions. The end result will be that Uganda will achieve Millennium Development Goal No. 3: promote gender equality and empower women. This project has helped to rekindle hope and belief thet rural female students can also pass external examinations.

References

Berg, H. & Quene, H. (2004) On multilevel modelling of data from repeated measures design. Speech Communication, 43, 103-121. Retrieved November 28, 2007 from http://www.sciencedirect.com/science/

Bryk, A.S. & Raudenbush, S.W. (1987). Application of Hierarchical Linear Models to assessing change. Psychological Bulletin, vol. 101, No. 1, 147-158.

Ciarleglio, M.M. & Makuch, W. (2007). Hierarchical Linear Modeling: an overview. Child Abuse & Neglect, 31, 91-98. Retrieved on November 28, 2007 from http://www.sciencedirect.com/science/

Lating, P.O. (2006). Hybrid E-learning for rural secondary schools in Uganda. Licentiate thesis, Blekinge Institute of Technology, Sweden, ISBN 91-7295-095-1.

Loidl, S. (n.d). Benefits of e-learning-crucial factors: an evaluation based on case studies. Retrieved November 29, 2007 from http://www.formatex.org/micte2005/84.pdf

Osborne, J.W. (2000). Advantages of Hierarchical Linear Modeling. Practical Assessment, Research & Evaluation. Retrieved on November 28, 2007 from http://www4.ncsu.edu/~jwosbor2/otherfiles/MyResearch/

PAPER VI

E-learning for development in rural Uganda - co-evolution in triple helix processes

Peter Okidi Lating, Faculty of Technology, Makerere University, Uganda
Lena Trojer, Division of Technoscience Studies, Blekinge Institute of Technology, Sweden
Samuel Baker Kucel, Faculty of Technology, Makerere University, Uganda

Introduction

This paper is focusing on the development of an ICT/GIS[1] research centre in Arua district, Uganda, as part of an e-learning research project financed by Sida/SAREC[2]. This development is characterized by a triple helix process including participation of the three main stakeholders: university, district/local government and business sector.

The research project is linked to the Vision 2025 of Uganda, which captures technologically advanced, competitive, self-sustaining and growing economy; a healthy, well educated society with high quality of life; regional integration and international co-operation; harmonious coexistence within a dynamic society where citizenry is responsible, accountable, hardworking and peaceful; effective, participatory and democratic governance; equal opportunities, empowerment and poverty eradication among people. Vision 2025 of Uganda has guided and influenced the development of the Poverty Eradication Action Plan (PEAP), its revisions and other government programmes.

In an information society, prosperity or wealth comes from knowledge. Knowledge is created through accessing, assimilating, sharing and using information. To be really effective

[1] ICT refers to Information and Communication Technology and GIS refers to Geographic Information System.

[2] Sida - The Swedish International Development Cooperation Agency, SAREC - reserach deaprtment of Sida.

at creating that knowledge, people need to be trained in the necessary information skills. There is a need of a higher level of "information literacy" than merely computer literacy. This means that, ICT not only does enable access to vast information resources, it also enables the manipulation, filtering and organization of relevant information, enables rapid communication and transfer of information and, if used by an information skilled expert, can greatly enhance the learning processes and the creation of knowledge hence creation of wealth. Thus, ICT is vital to the success of a nation's economy. But ICT on their own will never solve our social-economic problems. It takes access and empowerment to the people to make use of the ICT and the information delivered by them to solve the problems (Yonah 2006).

But the implementation of ICT in Uganda is not a question about technical transfer form other continents. "Unfortunately, many technological solutions deployed in Africa at large are uprooted from developed countries and in the best cases modified to meet the needs of nations, and in most cases implemented as it is and left to decay before ever been fully utilized. Therefore, African countries need local technological innovations to meet the needs of its people" (Mwamila et al. 2004). Technology development is one of those things that cannot be left to be stirred by market forces alone because of the possible occurrence of the market failure phenomenon and other externalities, which are beyond the control of innovating firms and farms, especially for the less developed countries. Thus, there is a need to inhibit market failure effects by putting in place policies for technology development as well as on the ground collaboration between academia, industry and government for innovation development (Gulbrandsen 2004).

Methodological Considerations

The main part of the R&D work in this project is based on the methodologies characterising distributed knowledge processes (Gibbons et al. 1994, Nowotny et al. 2001). The research is anchored in the tradition of action research methodology (Schön 1983) and nowadays referred to as interaction research as well as technoscientific gender research (Trojer 2006).

Situated knowledge production is a key concept as well as a practice. It refers to the acknowledgement of an empirical inside perspective. You have to be inside what is being developed concretely on the ground in order to be able to understand some of the complex web of processes going on. For instance, it is not good enough for a researcher to discover and map a waiting reality "out there" (context of discovery). Research must focus on the *context of production as well as context of implication* (Nowotny et al., 2001, 2003). Or as Donna Haraway (1997) notices *"Technology is not neutral. We're inside what we make, and it's inside us. We're living in a world of connections – and it matters which one get made and unmade."* Gulbrandsen (2004) emphasizes the character of research as reality producing / world producing.

Karen Barad argues (2003) that *"We" are not outside observers of the world. Nor are we simply located at particular places in the world; rather, we are part of the world in its ongoing intra-activity. This is a point Niels Bohr tried to get at in his insistence that our epistemology must take account of the fact that we are a part of that nature we seek to understand....We are part of the world in its differential becoming".*

The project is strongly dependent on an implemented practice of a triple helix cooperation. A number of important questions about new challenges arise, when participating in such an open system for knowledge production and development of activities (Nowotny et al. 2001, 2003). Perhaps the main challenge is realising that we are taking part in *non-linear* processes. Development occurs through *co-evolution* yielding specific results within the different actors' respective areas of activity. Co-evolution entails *stronger requirements for change* in the respective organisations / sectors. We also notice that what we are doing comprises an i*ntegration of knowledge production and policy production*. Or to put it another way – research and policy are connected. As it is so succinctly put by Nowotny (2005) *"Innovation is the collective bet on a common fragile future and no side, neither science nor society, knows the secret of how to cope with its inherent uncertainties. It has to be done in some sort of alliance and a sense of direction which is shared".*

Innovation entails production of uncertainty and complexity, renewal and change, and is often presented as worth striving for in Government policy. Reijo Miettinen's (2002) discussion of the new models of cooperation between academia, industry and government can be seen as opportunities for collaboration, where the parties' legitimacy, trust and "social capital" must continuously be recreated. This partnership can thus come to play a central role in the development of socially robust knowledge and technology.

Situated e-learning

This paper takes into account a specific aspect of the development of an e-learning project in Arua district in the North Western part of Uganda in the West Nile region. The aspect concerns a process of co-evolution involving three main stakeholder sectors namely the sectors of university, government and business. It is a particular challenge to practice a multi stakeholder process like this in Arua as Arua is a remote, insecure and one of the poorest rural districts of Uganda. It is approximately 500 kms from Kampala, the capital of Uganda. The district is home to many Sudanese Peoples Liberation Army (SPLA) refugees. Going to Arua is fairly difficult because the road passes through Acholi land where the Lord´s Resistance Army (LRA) rebels are active. Leaders of LRA have been indicted by the International Criminal Court (ICC). And being very close to the Democratic Republic of Congo (DRC) skirmishes close to the boarders frequently spills over into Arua district.

The prestory to the e-learning project and its geographical location to Arua started in 2002. A fourth year electrical engineering student wrote her project on rural ICT sustainability in Uganda. She found *that* ICT Centres can be viable in three rural districts in Uganda - Arua, Bushenyi and Busia.

In March 2004 an ICT/GIS[1] research team from Faculty of Technology (FOT) at Makerere University visited Arua district to follow up on these findings. The team met District leaders, Heads of Departments, Head teachers of secondary schools, officials of the District Chamber of Commerce, the Business Community and Women groups. The team also visited Kuluva hospital and some sub-counties in Arua district. Everybody supported the idea of FOT setting up the ICT/GIS Research Centre in Arua. In October 2004 the ICT/GIS team led by professor Tickodri Togboa visited Arua again and addressed the District Council and told them the intention of FOT to set up an ICT/GIS Research Centre in Arua. The District Council supported the idea. The team also addressed women groups and the business community. In March 2005 the team looked at premises to rent before starting up the ICT/GIS Research Centre and held meetings with local government officials, especially the Acting District Chief *Administrative* Officer and the District Information Officer. The team also visited Internet cafes and FM radio stations in Arua. *At* the end of April 2005 the ICT/GIS team applied for the *former* Chief Magistrates court buildings in Arua city to be given for use as the ICT Research Centre. The application was brought to the attention of the District Council, which approved it. The core activities of the e-learning project were now situated at a specific place, from which a number of different learning processes took place.

The main target group for the e-learning project were two advanced level secondary schools - Muni and Ediofe and also for some activities in Logiri, an *Ordinary*-level girls secondary school. This was agreed upon after the researcher Peter Okidi Lating met the District Education Officer in Arua March 2005.

Triple Helix Stakeholder University

As mentioned in the Methodology Considerations above the e-learning project is positioned in an open system for knowledge and technology production. The triple helix model is practiced in Arua, where one of the three cooperating partners is the university. In developing, as well as in developed countries, initiatives for introducing e-learning education most likely come from universities. There you have the skills from higher education including pedagogic skills and the technical knowledge and know how.

Even in a low income country like Uganda the university has resources, which not the other triple helix stakeholders might have to the same extent, namely to

- take initiatives
- network on vital levels
- negotiate with authorities, donors etc
- offer facilities

[1] ICT refers to Information and Communication Technology and GIS refers to Geographic Information System.

- develop knowledge and technologies needed
- develop and offer training
- long term engagement
- keep the functional practices and cultures, which have been developed

The co-evolving processes in the project presented and in which the Faculty of Technology at Makerere University take a substantial part harmonize very well with the third core mission of a university namely service to society. The other two are teaching and research. The mission of service to society also strongly link up to the national policy of Uganda in the Poverty Eradication Action Plan.

The initiatives taken by FOT in order to build the fundamentals for the e-learning facilities in Arua are presented above in the preparatory work for the ICT/GIS research centre.

The concrete work by FOT in cooperation with the students, teachers and heads of the secondary schools in Arua district is presented and discussed in Lating, Kucel and Trojer (2006 a, b, c, d) and Lating, Kucel and Trojer (unpublished).

As a demonstration of university involvement the FOT ICT/GIS Research Centre in Arua opened in June 2006 to the public. A network administrator and a secretary were recruited. ICT coordinators *from* secondary schools were identified and trained as trainers. Ten second year Telecommunications Engineering students from FOT were used as teachers. They did their Industrial training at the Centre. Up to 1253 people were trained during the *period June - August, 2006* in basic ICT skills, Internet use and working with e-mails. These included District heads of Departments, secondary school teachers together with their students and the general public.

Triple Helix Stakeholder Government

The governmental / public sector stakeholders in the current e-learning project are:

District and local government officials

1. Regional District Police Commander's Office
2. District Police Commander's Office
3. Chief Administrative Officer's Office
4. District Medical Officer's Office
5. District Forestry Office
6. Resident District State Attorney's Office
7. District Information Office
8. District *Engineer's* Office

Schools

1. Muni Girls Secondary School
2. Ediofe Girls Secondary School
3. Mvara Secondary School
4. Arua Public Secondary School
5. Arua Public Primary School
6. Uganda Christian University, *Arua Campus*
7. Arua Vocational Training School
8. Arua Core *Primary Teacher's College*
9. St. Joseph's College Ombachi
10. Anyafio Role Model Secondary School

Hospitals

1. Arua Hospital
2. Maracha Hospital

Other Governmental Institutions

1. National Social Security Fund (NSSF)
2. Northern Uganda Social Action Fund (NUSAF)

The numbers of governmental, public stakeholders is impressive and quite unique compared to a Swedish regional context. This fact is a strong sign from the stakeholders for an acknowledged relevance of the e-learning project and its impact in a place like Arua district.

Triple Helix Stakeholder Business

Thanks to a qualified anchoring process of the FOT team the business sector of Arua district has been involved in the project and especially the impact of the FOT ICT/GIS research centre offering facilities much needed. The District Chamber of Commerce has been cooperative. The following companies are concerned

1West Nile Rural Electrification Company (WENRECo)
Uganda Breweries
Private Sector Initiative (PSI) Uganda
Sumandura Construction Works
Boniface Television Networks
Nile Fm / radio station
Arua One Fm / radio staion
Copcoot Uganda /
Westnile Distilleries
Heritage Gardens- hotels business

Multitech Uganda- ICT training business
Kuluva Hospital
Marie Stopes Uganda –Reproductive health provider.

Other Triple Helix Stakeholder

Besides the three main stakeholders mentioned above the project and its facilities has also involved other stakeholders and interested partners and individuals. They are

NGOs and CBO's
Netherlands Development Organisation (SNV) Uganda
United Nations High Commission for Refugees
DED /(Community Based Organisation)
Cream Uganda (Community Based Organization)
PAD (Community Based Organization)
PRAFOD (Community Based Organization)
CAFECC ((A Sudanese Community Based Organization)
World Vision Uganda
WENDWOA (A women organization helping widows and helpless children)
Right To Play
NSEA / Needs Service Education Agency

Others

1. Researchers
2. Students doing online courses in and outside Uganda
3. Visitors to Arua
4. Traveling Agents
5. Students from schools outside Arua District mostly during holidays
6. Community workers
7. Indigenous people who mostly use the Internet for communication with their relatives and friends in and outside Uganda.

The Centre now trains students from West Nile Districts, South Sudan and Democratic Republic of Congo. District leaders from other Districts in West Nile (Koboko, Yumbe, Nebi, Adjumani, Moyo) come for the training on weekends.

Discussion and Conclusion

There are always challenges in a triple helix process, and the one in Arua is no exception. The main ones refer to the following.

1. There is a policy gap existing in Uganda as there is no policy concerning e-learning and ICT integration in school curriculum. The capacity for ICT skills and pedagogic

development is very low among teachers and school leaders. The ICT/GIS research centre had to start with very basic skill development of teachers and other staff.

2. Some district leaders did not see the relevance of the ICT/GIS research centre from the beginning and did not accept it. The time is a quality here. Repeated meetings and discussions had to be conducted. When the centre was in place and could demonstrate its objectives and facilities concretely it was easier for the district leaders to understand and appreciate its advantages.

3. The issue of misconception is a critical one. One district information officer kept on interpreting the ICT/GIS research centre as belonging to his governmental department. He appeared in the centre and gave directives to the centre staff. This highlights the mission of the centre to be a neutral arena and sustain that neutrality. The centre is clearly a non profit organization, however, struggling very hard to find ways to be long-term sustainable.

4. So far the challenges linked to the business sector are minor. One reason might be the good relationship with the Mayor of Arua town, who is also the chairman of the Chamber of Commerce.

The paramount result of the collaboration of the university, district and local government and the business sector in Arua is the FOT ICT / GIS Research Centre. The project has shown exceptionally good results in an unexpected short time.

What are the success factors? One of them is the frame of understanding in the triple helix model, which has been translated into practical work in Arua district. The internal university process, more precisely among the participating researchers and teachers from FOT, is characterized by moving from strict disciplinary research to interdisciplinary research and further on to transdisciplinary research and development. With transdisciplinarity is meant knowledge production in the context of application and implication. The triple helix process will not start working without a very important function, which constitutes a broker or facilitator. That person must have trust among all the main stakeholders and be able to move around in all sectors, anchoring the project, get people moving etc. in this e-learning project that person has been the researcher Peter Okidi Lating from FOT.

The mindset of the involved partners seems to be changing from linear development mindset to collaborative development mindset. This transformation of mindsets is a condition for a triple helix process in operation. Another way of expressing the relation between the stakeholders is a change from strict contract negotiation to co-evolution.

References

Barad, K, 2003, "Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter, Signs: Journal of Women in Culture and Society, vol. 28, no. 3.

Gibbons M., Limoge C., Nowotny H., Schwartzman S., Scott P., Trow M., 1994, The new production of knowledge. SAGE Publications, London, Thousand Oaks & New Dehli.

Government of Uganda, December 1998, "Vision 2025, A strategic framework for National Development", Ministry of Finance Planning and Economic Development.

Gulbrandsen, Elisabeth, "How can universities become more active partners in innovation systems? Lessons from the Nordic countries?" in Gulbrandsen, Elisabeth, Nsengiyumva, Albert, Rydhagen, Birgitta and Trojer, Lena, 2004, ICT, innovation systems and the role of universities in societal development - a (post)colonial strain?, National University of Rwanda Press.

Haraway, Donna, 1997, Wired 5.02 Feb.

Lating, Kucel & Lena. (2006, a). Strategies for implementing hybrid e-learning in rural secondary schools in Uganda. Elsevier, Conference proceedings, ISBN 13: 978-0-08-045312-5, and ISBN 10: 0-08-045312-0, pgs. 538-545.

Lating, Kucel & Lena. (2006, b). Design and development of interactive multimedia CD-ROMs for rural secondary schools in Uganda. Elsevier, Conference proceedings, ISBN 13: 978-0-08-045312-5, and ISBN 10: 0-08-045312-0, pgs. 546-553.

Lating, Kucel & Lena. (2006, c). Implementation of hybrid e-learning in advanced level rural girls' science education in Uganda: Arua case study. ICWE GmbH, Berlin. E-learning Africa conference proceedings CD. ISBN 3-9810562-2-1.

Lating, Kucel & Lena. (n.d, d). Unpublished. Development of sustainable digital libraries for advanced level rural secondary schools in Uganda.

Miettinen, Reijo, 2002, National Innovation System: Scientific concept or political rhetoric? Helsinki

Mwamila B.L.M., Trojer L, Diyamett B. and Temu A.K. (eds.),2004, "Innovation Systems and Innovative Clusters in Africa", Proceedings of a Regional Conference, Bagamoyo, Tanzania,

Nowotny, H., Scott, P. och Gibbons, M., 2001, Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty, Polity Press, Cambridge UK.

Nowotny, H, Scott, P and Gibbons, M., 2003, "Introduction, 'Mode 2' Revisited: The New Production of Knowledge", Minerva Vol. 41, No.3, pp. 179-194.

Nowotny, H., "A plea for transparency" in RTDinfo, May 2005

Schön, D.,1983, The reflective practitioner. How professionals think in action. NewYork: Basic Books, Inc. (first edition). (1995) Aldershot: Ashgate ARENA

Trojer, L., 2006, "Building Epistemological Infrastructures - interventions at a technical university" in Computation, Information, Cognition - The Nexus and the Liminal, Cambridge Scholars Press

Yonah, Z.O., 2006, report on ICT Cluster in DSM: Information Literacy Enhancement Initiative, Towards an Information Society Where Visions Become Reality with Endless Possibilities for Wealth Creation Using ICTs, ISCP-Tz, CoET, UDSM.

PAPER VII

Sustanability of a Rural ICT Infrastructure

G. Taban-Wani, Senior Lecture, Department of Engineering Mathematics, Faculty of Technology, Makerere University, P.O. Box 7062, Kampala, Uganda. Email: wgyira@tech.mak.ac.ug
P. Okidi-Lating, PhD Student, Department of Engineering Mathematics, Faculty of Technology, Makerere University, P.O. Box 7062, Kampala, Uganda.

Abstract

Information and Communication Technology (ICT) has become a potent force for transforming social, economic, education, recreation, commercial, political, etc. life globally. In an attempt to bridge the "digital divide" (between those who have access to information resources using ICT and those who have not), the Government of Uganda enacted the so called National ICT Policy in 2000.

Uganda as a developing country needs to harness the increasingly vast potentialities for socio-economic development and poverty alleviation provided for by the present level of information communication technology (ICT). The role of ICT cannot be under estimated in the fields of education, poverty alleviation, in terms of reduced costs and time of information delivery. This aspect is highly beneficial to rural farmers, rural schools and district administrators, service providers, entrepreneurs, etc.

The paper discusses the ICT activities of the: "Makerere University Faculty of Technology/ Arua District ICT/GIS Research Centre"; and its impact on the general sustainability of an ICT infrastructure in a rural setting.

The Centre is located in the Town of Arua; and is used as a research platform by PhD students and members of staff of the Faculty of Technology, Makerere University, whose main research areas are centered on the use of ICT and GIS in rural development. The main purpose of the Centre is the collection and generation of data on the use of ICT in favour of sustainable rural development.

At the present time, the centre has managed to generate a lot of sustainability data. Some of the data collected has been analysed, processed and conclusions and recommendations made as are discussed in this paper.

The achievements to date are as follows:

(i) Generation of data for the creation of sustainable rural networking programme of ICT infrastructure, which may later be disseminated to ISPs, mobile telephone SPs, and other stakeholders interested in Rural ICT implementation and also for the generation of further interest in rural ICT for other stakeholders.

(ii) Rural Internet connectivity and networking issues have been addressed at the district level, and there is hope of addressing these for low level connections to sub-counties (the last mile).

(iii) Capacity building in ICT for local stakeholders and rural content development (for use in rural secondary schools) with an important component for raising ICT awareness at the district decision-making levels has been addressed.

(iv) Sensitization of district decision-makers and administrators on the central role of ICT in the management of resources and administration of institutions has been accomplished.

(v) Results on the optimum means for the creation of sustainable capacity in ICT skills at the district and sub-county levels and rural learning institutions have been achieved and are presented.

(vi) Issues of gender balance and positive discrimination towards the rural girl-child education by the use of ICT have been addressed by the design and development of interactive multimedia CD-ROMs for advanced-level secondary school physics and mathematics education for use by the disadvantaged rural female students.

Keywords: Information and Communications Technology (ICT); Digital divide; ICT Infrastructure; National ICT Policy; Developing country; Role of ICT; Sustainability; Sustainable rural development; Achievements; Rural Internet connectivity; Interactive CD-ROMs; Rural female students.

Introduction

To face the unprecedented challenges brought about by the changing global economy, dynamic political contexts, environmental degradation and demographic pressures, and to make political decisions, people at all levels of society must be able to access critical information and to communicate.

Information Technology is a multipurpose tool. It has the potential to be integrated within a wide variety of efforts that have objectives such as local participation, training, education, research, technical support, and institutional strengthening.

With the ongoing decentralization, there is greater need for community leaders and community intermediaries to embrace the tools of Information Technology to enhance the development in rural areas. Information and Communications Technology (ICT) initiatives for rural development need to be approached with some degree of caution. It is not realistic to expect the less privileged farmers and food-insecure residents of rural communities to list computers and digital telecommunication services as high- priority items for improving their lives. However, there are various intermediaries serving these populations, which together with the small and medium scale enterprises in rural areas could take advantage of these technologies.

There has been a rapid increase in the use of Information and Communication Technology (ICT) in Uganda. However this expansion is still largely a Kampala phenomenon. People in the rural areas should be assisted to take advantage of ICTs in order to aid them in achieving sustainable development through enhancement of information gathering and ease of communications.

The aim of this project is to determine the most appropriate methods of connecting the rural areas to the information high way. In this project various ICT access technologies available in Uganda have been investigated and evaluated in regards to start-up costs and reliability with the aim of determining the cost of achieving sustainable rural ICT connectivity. In addition to the above, a base line survey has been done in the chosen rural areas for the study, in order to get the views of the people and also to see the viability of the project.

Problem Statement

The world is slowly turning into a global village with Information Communications Technology (ICT) as one of the major driving forces. In Uganda and indeed in many other African and developing countries, this is confined to the urban areas. Therefore, there is need for the introduction of this new development to the small and medium scale enterprises together with the intermediaries that serve the population in rural areas. This will enable them to take advantage of these technologies to improve their work, improve communication capacity, gain efficiencies and reduce telecommunication costs.

It is also quite important that school going children are introduced to these new technologies as early as possible irrespective of their areas of residence. This is the only way we can be sure that these children will cope up with this fast- changing world. Pupils, students and their teachers in basic education institutions lack the basic computer skills, which their counterparts in developed countries like UK or USA take for granted. In Uganda, these problems are very typical of rural areas and are exacerbated in those districts, which are not connected to the national electricity grid like Arua, Adjumani, Moyo, Nebbi and Yumbe. As a result national Internet Service Providers (ISPs) and other investors shun these areas.

In addition, after these students finished school, they will be required to work in government departments at district levels, private companies and NGOs in various capacities like financial managers, public health officers, personnel officers to mention but a few. Hence lack of capacity in ICT brings about loopholes in accountability and mismanagement of allocated funds caused by inefficient record keeping.

Proper and efficient use of ICT will greatly enhance administration, management of allocated funds, greater accountability, collection of data for processing (use of data bases), quick provision of required information like prices of commodities in the international market, new cash crops, planting and harvesting periods, and availability of market for a particular commodity.

Aims of the project

The main objective of this project was to determine the most appropriate way of connecting rural areas of Uganda to the information high way. This can enhance national development through (ICT/GIS Research Project Proposal (2001) :

- *Planning and Market Information for Agricultural Producers*

Rural communities and small-scale agricultural producers are deeply affected by global economy, environment and political forces. Armed with ICT knowledge these small-scale producers can be provided with lower-cost inputs, better storage facilities, improved transportation routes, and collective negotiations with buyers.

- *Community Development Applications*

By providing Internet services to rural areas through development-oriented organisations, which act as local communication intermediaries.

- *Research and Education*

The cost of accessing printed material in developing countries is normally very high so that teachers and students have great difficulty in acquiring books and journals. Via Internet, any information published on-line can be accessed almost instantly and at a low cost.

- *Small and Medium Scale Enterprises Development*

ICTs will help small and medium scale enterprises to advertise and promote their products and/ or services through the opening of websites. They will also be able to access information on markets, lower cost of inputs, and new and viable trade links.

- *News Media Networks*

Internet can be used to make local news become accessible to all. Email discussion groups involving people in rural and urban areas can be formed to foster sharing of information and experiences. The Internet can also be used to access leading newspapers and other news sources around the world.

- *E-commerce*

Internet connectivity can provide an unparalleled opportunity to people in remote rural areas to expand their business activities beyond local confines to reach globally.

- *e-governance*

The sustainability of development in the current environment requires good governance, a government that is democratic, accountable, and transparent.

- *Tele-medicine*

It will address the existing lack of capacity in trained and experienced medical human resources at the district level so as to enable them to deliver services to the people.

ICT Infrastructure Setup

At the feasibility stage of the project, there were extensive consultations with the community leaders and also some representative members of the community. The results of these consultations were very positive as the community expressed a lot of support to the project. One of the marked supports to the project was the allocation of space, which also contained buildings in which the project is now housed. This was thanks to the Arua District leadership.

The District Executive Engineer, Eng. Lawrence Pario then supervised the renovation and repair work on the building. And the project team then together with experts from Ms Cyberbase Limited, an ICT company, initially installed 10 computers, with network. Internet access
installation was done by iWay Africa., using a VSAT link.

The donated space contains one small building and a large main building. The main building has been be partitioned so that three ICT training classrooms and an Internet access room were created; a beginner's classroom, an advanced training classroom and a specialised ICT training classroom. The small building houses the administration office.

Working with Neighbouring Senior Secondary Schools and the Arua District Staff

The ICT Centre's main activity presently is to assist rural secondary schools girls improved there performances, especially in physics and mathematics, through the use of ICT. The emphasis on these subjects is not surprising since the form the basis for high school candidates' entry to the Faculty of Technology, Makerere University. These subjects are also shunted by most high school students, especially girls. This is due to both Ugandan tradition of branding girls as having no ability in the sciences and especially mathematics.

Hence, the centre hopes to overcome this myth. This subject has been assigned a PhD research, and a PhD students has been recruited by the Faculty for this task. He is on the last touches of this vital research.
The collaborating schools include:

St. Mary's Ediofe Girls Secondary School, an A'Level School
This is one of the two schools were the thrust of the research centres. Lack of facilities like classrooms and dormitories limit admission into the school. For example, there is only one classroom for A level. The school participates in programmes aimed at promoting education of the girl-child education. The school has about 580 girls both in O and A levels, 107 are in A level with only 5 doing the PCM combination The school did not have a laboratory for a long time but UNHCR gave them 98 million UgShs to build one but it was not equipped. The school has 14 computers, 10 were supplied by the Ministry of Education and Sports through the National Curriculum Development Center. The 4 were acquired earlier. 5 out of the 40 teachers are computer literate of which 3 teach sciences. Only one female teacher teaches science subjects (Biology) and at O level only.

Mvara Secondary School
This will only plays supporting role to the research. Teachers of Mvara showed interest in the Research and accepted to take part willingly in developing local content course materials.

Muni Girls Secondary School
This is the second A'Level girls'school were the research also centres.

Logiri Girls Secondary School
Logiri is about 35 kms from Arua town and less than 4 kms from the Democratic Republic of the Congo boarder. It has 430 students and there is limited accommodation. It has a library and a librarian but not enough furniture in the library. Classrooms look overcrowded. There are few teachers for Physics, Chemistry and Mathematics. There are no laboratories but part of a classroom was converted into a laboratory with few equipment and chemicals. It uses a generator for electrical supply. There are 16 teachers, only 6 teachers are female. No teacher is computer literate. The school admits girls who were once married. This school plays a supporting role to the research.

Other collaborators include:
Arua Teacher's Resource Centre
The was started as a group of such centres in 1996 as projects funded by the British Department of International Development with the aim of improving performance in English language and sciences (Physics, Chemistry, Biology and Mathematics) in O level schools. That time Uganda had 39 districts and the project was divided into 3 phases, each phase covered 13 districts. Arua was in the second phase. However, the third phase did not materialize. In Arua, the Resource Centre is situated in Muni NTC. Computer

training was as a TOTs, who later trained the District Subject Teacher Trainers (DSTTs) who in-turn trained Heads of Departments. The heads of departments trained the subject teachers. All these in-service training was done during holidays. A hall was created where teachers could use computers, and access to the Internet using a VSAT link and some few reference books were stocked in it. Activities of the ICT/GIS Centre to date
The following activities are now being carried out at the centre:

- Computer competency training for the public
- Computer competency training fro the district staff and teachers
- Internet access for all.

Sustainability of the ICT Infrastructure

Table 1. Start up costs

Date	Expenditure item	Amount, UGX	Amount, USD
21.7.2005	2 Metallic signposts with stands	766,000	358.1
November-2005	Arua ICT in Education website design and development, including hosting for a year, http://www.aruaeduc.com	87,757	47
June 2005	Design and development of ICTSRD website, includes hosting for 1 year	3,574,700	2,000
May 2005	7 Desktop computers, 40 GB HDD, 256 MB RAM, 15" Monitor, and DVD/CD ROM drive	8,330,000	4,692.43
May 2005	1 Canon Photocopier	3,250,000	1,830.80
May 2005	1 UPS 1 KVA APC	1,100,000	620
May 2005	1 HP 1320 Laser Jet Printer	750,000	423
August 2005	20 Tripplite Omni IVSINT 800VA UPS	7,551,965	4,050.94
August 2005	14 IBM Desktop Computers	25,577,510	13,720
August 2005	1 IBM server512 MB RAM, 3.2 GHz processor, 2 X73 GB HDD, etc	8,524,544	4,572.64
October 2005	Networking and cabling	10,950,400	5,874
December 2005	VSAT Internet Installation with 1 year access	19,937,101	10,822.50
2005/2006	Repairs and renovation of the ICT Research buildings	24,000,000	15,238
2004	Fieldwork trips	4,500,000	2,616.40
2005	Fieldwork trips	39,603,375	22,015.76
2006	Fieldwork trips	51,850,200	28,737
July 2007	10 Dell computers for hybrid digital library	14,388,727	9,135.70
Jan 2007	Internet Access for 12 months	10,686,375	6,785
	Total	**235,428,654**	**133,529.3**

The center now has 57 computers, including 23 CPUs purchased from SchoolNet Uganda; and 10 computers donated by the Faculty of Technology.

Table 2. Monthly Internet usage

Month	In Bound	Out Bound	Total, Mbytes	Available Volume/ Excess Volume used	Amount paid by FOT, Shs
Nov 2006	-2,530.88	-523.62	-3,054.50	17.50	960,000
Dec 2006	-2,893.29	-613.95	-3,507.24	-435.24	960,000
Jan 2007	-2,335.48	-603.62	-2,939.10	132.90	960,000
Feb 2007	-2,822.94	-773.44	-3,596.37	-524.37	960,000
March 2007	-2,531.54	-585.12	-3,116.66	-44.66	960,000
April 2007	-2,166.08	-526.74	-2,692.82	+379.18	960,000
May 2007	-2,040.63	-467.82	-2,508.45	+563.55	960,000
June 2007	-3,598.38	-729.99	-4,328.38	-1,256.38	960,000
July 2007	-4,285.48	-1,073.54	-5,359.02	-2,287.02	960,000
August 2007	-4,113.32	-1,053.44	-5,166.76	-2,094.76	960,000

Note: We are paying monthly for the volume of 3,072 MB. This costs 450USD per month and an annual fee of 350USD. If we exceeed the volume we are paying for 3 consecutive months, we shall be billed 650 USD for that month.

Table 3. Revenue for a typical month

Revenue source	Nov 2007	June 2007	May 2007	April 2007	March 2007
Internet	295,700/=	232,350/=	260,000/=	210,600/=	21,000/=
Training	1,218,500/=	1,862,050/=	1,236,000/=	2,422,500/=	
Photocopying	28,200/=	3,000/=	9,350/=	88,300/=	5,150/=
Printing	0/=	42,900/=	54,400/=	117,600/=	18,300/=
Total					

Table 4. Fixed monthly expenditures

Expenditure item	
Internet	960,000/=
Electricity	400,000/=
Salaries	1,130,000/=
Repairs and maintenance of equipment	1,000,000/=
Contingencies	1,000,000/=
Total	

Analysis of the Results

The previous section has given the costs of setting up the ICT Research Centre. Also, the monthly usage of bandwidth at the Centre. The usage is apparently more than the 3,000MB being paid for. But note that the revenue from sale of Internet is under 300,000/= per month yet payment is 960,000/=. May be a lot of usage was for the female students, and their teachers who were accessing internet free. But VSAT is not viable in Arua. ICT training, photocopying and printing jobs appear to be viable.

Conclusions and Recommendations

Conclusions

From the previous cost analysis it can be seen that the money earned in a year from accessing Internet/E-mail alone is about twice the cost of setting up the ICT centre. So if also the money earned from other services is included this implies the profit increases and therefore will be able to recover the start-up costs (installation), running and maintenance costs. Therefore the project will be viable and could be sustained.

During the course of carrying out the base line survey in the rural study areas people were very much eager to see the ICT services reaching out to them and many of them wished the project success. Very many of them showed their commitment to pay for the ICT services and indeed the conclusion is that the project will be viable (Nanyonjo, 2001). The sustainability data presented above has partially proved this right. The biggest hurdle is the cost of the bandwidth, which is in the range of 7,000 USD annually.

Recommendations

The following strategies are recommended in order to make rural ICT connectivity sustainable:

(i) The centre should continue with grass roots advocacy.

(ii) Sensitisation and training of the people about computers and what benefits the Internet has to offer, should be continued at a higher level, though the Centre is doing very well in this angle..

(iii)The project should continue to seek more donor support, infact the project leaders are already looking for other avenues of sustaining the centre, including corporate responsibility of some of the more affluent multinationals of the area, including MTN, UTL, WENRECO, etc and also to seek for more donors or partnerships.

(iv) May be also organisation of fundraising activities by well wishers can also help?

(v) The Active involvement of schools and tertiary institutions should continue. It will be good to liaise with the proposed West Nile University. In fact, there is a proposal on the ground to convert the Centre into an Institute of ICT Research as a part of a future constituent of the proposed Makerere University College of Engineering and Technology.

(vi) The present constant consultation and contact with the community should be maintained.
(vii) There should b e a massive advertising campaign by the centre to attract clients from all over the area, including the neighbouring countries of South Sudan and the Democratic Republic of the Congo about its services and charges.

Acknowledgements

We wish to acknowledge Sida/SAREC for the financial support of the ICT Research project and also the Faculty of Technology Staff for their tireless work with little remuneration. We would also like to thank the Makerere University School of Graduate Studies for arranging the travel, especially the Accounts staff. Special thanks go to the Arua District Executive Engineer, Eng. Lawrence Pario, for supervising voluntarily the renovation and repairs of the FoT ICT Research station.

References

Nanyonjo , F. (2001) unpublished. The Most Appropriate Way of Connecting Rural Areas of Uganda to the Information High Way. Final year project report.

Tusubira, F. F., Bugaba, S., I. Kaggwa, I. Tibenderana, C.(2001), Information and Communication Technology as tool for Modernisation

Noronha, F. Why does a farmer in a Srilankan village need a Telephone? Goa, India Available at: http://www.bytesforall.org/STH/srilanka.htm

Souter, D The Role of Information and Communication Technologies in democratic development. Available at: http://www.cto-ict.org/pages/forum/general/social-economic/ds-soc-ecdev 1.html

University of Dar es Salaam, (2002). Priority Research Area Framework- Documents, Sida/SAREC cooperation, extended support 2002-2004.

Benjamin, P. (2000). Literature Review for the tele-centre study Available at: http://www.communitysa.org.za/T2000litRev.htm

Uganda National Council for Science and Technology (UNCST),(2001) National ICT policy framework for Uganda

(InfoDev) for the African connection secretariat. Rural Access to Information and Communication Technologies: The Challenge for Africa, final report. Available at: http://www.telecommons.co/uploaddocuments/final%20June%20Report. Doc

Kavulu, R. (Final year project report July 2001)- unpublished- Department of Electrical Engineering, Cost Effective Internet Access Information Database for Uganda.

ICT/GIS Research Proposal (2001). ICT and GIS for Sustainable Rural Development. Faculty of Technology, Makerere University. Kampala, Uganda.

Brief Summary of the Papers

Paper I is the main paper that is guiding the action research activities in rural secondary schools in Uganda. The paper identifies the root causes of low female students' participation in engineering training in tertiary institutions as absence of functional senior science laboratories, and libraries and shortage of qualified and committed teachers. A number of international and national documents that deal with ICT and gender research are reviewed. Consideration of activities of some NGOs that are introducing ICT generally, and Internet in particular, in Ugandan secondary schools is made. Finally, the paper concludes with the following recommendations:

- Interactive training CD-ROMs is the main course delivery platform in rural, disadvantaged secondary schools. However, where there is Internet connectivity, open source course delivery platforms may be used.
- Multistakeholder, participatory approach should be followed when implementing a multidisciplinary concept like hybrid e-learning in rural areas. Stakeholders to be involved are the academia, local governments, and business communities.

The implementation of the strategy paper creates the next three papers.

Paper II contains literature review on the concept of e-learning. Many field trips have been conducted to the two typical rural advanced-level girls' secondary schools in Arua district. They are Muni and Ediofe Girls Secondary Schools. Situational analysis of the science infrastructure in the schools has been done. Using a multistakeholder approach, the Faculty of Technology has set up an ICT Research Station with VSAT Internet connectivity in Arua town, within 5 kms from each of the schools. The stakeholders involved in setting up the Research Station are: Sida/SAREC (financial support), Faculty of Technology, Makerere University (researchers/academia), Arua District Local Government (Buildings for the Station), AFSAT (Internet Service Provider- VSAT equipment, Ku-band, 256kbps bandwidth). There is a website for the research project (URL http://www.aruaeduc.com) and the Mambo, open source Content Management System, is being used for managing the hybrid e-learning environment. The Mambo is an open source platform and hosted by B-one. The participating students and their teachers use the ICT Research Station for accessing A-level content from the project website, e- mails and additional resources from the Internet. The teachers also visit the Research Station in order to add content into the content server so that students can access it at a later date. Portable devices like CDs and memory sticks are used for transferring relevant content from the Research Station to the school computers.

Paper III contains the methods used to design and develop advanced-level CD-ROMs for Physics and Mathematics subjects for the two girls' schools participating in the hybrid e-learning project. The rationale of using CD-ROMs is given. The paper identifies the main advantages of CD-ROMs as big memory capacity (up to 700 MB), fast data transfer rates, interactive multimedia capabilities (can support sound, flash animations, video clips, graphics, text) and popularity because of their standardization. Interactive local content was collaboratively developed at a Workshop by the 33 advanced level teachers for Mathematics and Physics. The context of the schools was considered when developing the training CD-ROMs. These schools use refurbished computers with limited multimedia capabilities: low memory, low hard disk capacity and lack of relevant multimedia software. This necessitated that trade-offs was done. Video clips and animations that require a lot of bandwidth and capacity were eliminated in the final production of the CDs.

Paper IV gives a situational analysis of the status of libraries in Muni and Ediofe. A review of literature on digital libraries is done. The procedure followed in creating hybrid digital libraries in the two schools is described. Again the paper finds that CD-ROMs are more convenient as the only media for delivering library content to the disadvantaged schools. The paper looks at the actual status of the libraries in the two participating schools, Muni and Ediofe. Both schools have spacious and well furnished libraries built with support from donor organizations. However, the schools have failed to stock their libraries. Science text books are considered very expensive to purchase. In most cases there are only one or two copies of the relevant text books for advanced-level Mathematics and Physics. The copies are not even enough for the subject teachers. There is also uncontrolled donation of text books for the schools by individuals and some non-governmental organizations. There are many irrelevant text-book titles in both libraries. The paper looks also at the computer resources available in the schools. When creating a digital library to support the schools, both the teachers and students had to be trained in basic ICT skills, Internet use and working with e-mails. Local content for the digital library was collaboratively developed and digitized before delivery to the schools in CD-ROMs format. Some training CD-ROMs were outsourced and delivered to the schools. Again for Internet requirements, the teachers and students of the school were given free access to the ICT Research Station, within 5 kms from either school. The costs of VSAT Internet connectivity to the Research Station by Faculty of Technology with support from Sida/SAREC were given. These are very high costs that a poor school like Muni or Ediofe cannot bear. Because of the difficulty of Internet connectivity, maintenance of networks and purchase of adequate bandwidth for educational purposes, the structure and organization of digital libraries should be separated from their distribution media. Physical distribution of information on recordable device can be an attractive alternative to networks. At CD-ROMs are very practical format for areas with little Internet access. The hybrid digital library also has an offline content server with science materials in it. When Internet is present, materials are downloaded into the content server. In the unfortunate situation if the service is disconnected due to non payment, the students can still access content offline.

Paper V gives results of longitudinal analysis of repeated measurements done on the Physics students when doing practical examinations. The examinations were independent of the school. They were set and administered by Makerere College School, one of the best A-Level schools in the country. The results were analysed using multilevel methods. The intraclass correlation coefficient showed that 68 % of the variation in scores was within-students, not between them. Furthermore, it was found in this paper that up to 64% of the variation in scores within-students was explained by the hybrid e-learning project. The contribution of the schools was not much felt in the analysis. It becomes difficult to conclude that schools do not add value and, therefore, are not required.

Paper VI is a typical example of how simultaneous applied research and development trajectories are not linear, as in a disciplinary research. It was not foreseen at the research proposal stage that this study would take the dimension it took. A study that was meant to support Physics and Mathematics education in Muni and Ediofe in a poor, remote, rural district of Arua co-evolved into something unthinkable. Using Triple Helix Methodology, the Faculty of Technology set up an ICT Research Centre in Arua with collaboration between the Arua Local Government and the local business community with financial support from Sida/SAREC. The Research Centre has 50 computers, VSAT Internet connectivity, ICT three training classrooms, an Internet cafe and a digital library for schools. The place is a resource Centre for ICT training, Internet surfing and technical assistance to the community and businesses not only in the West Nile region of Uganda, but also Southern Sudan and Eastern Democratic Republic of Congo. This co-evolution into triple helix processes is the climax of this study.

Paper VII is gives an insight into the running of the ICT Research Centre in Arua. Take note that the Centre was created as an unforeseen, unplanned expenditure item. There was budget only to support the 29 students of Physics and Mathematics of Ediofe and Muni. Running a Centre as big as the one that was established, posed a big challenge. VSAT Internet equipment and access for a year required 11,000 USD. Repairs of the buildings provided free by the Arua District Council needed 24,000,000 UGX (15,238 USD). The 50 computers required close to 35,000 USD. However, the running costs are very high, more than the Centre can cope with. That is why Paper VII talks about sustainability. The paper concludes that VSAT Internet access in a rural area where people are poor is not viable. The ISP charges 450 USD per month yet an average income from Internet sales is under 150 USD. The paper also concludes that photocopying and printing services in the rural District of Arua is viable. More research needs to be done in areas of appropriate Internet access and bandwidth for rural communities.

PART III

Epilogue

Statements of Scientific Contribution and Originality

My deliveries of results from the research project to different beneficiaries are the following:

1 Scientific Contributions to Uganda

This thesis has linkages to a number of international and national documents. The Millennium Development Goal (MDG) number 3 requires UN member states like Uganda to 'eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education not later than 20015'. The study aimed at increasing the number of female students in the engineering and technology professions where participation of female students is low, between 17-20% in Uganda. The study is also linked to the World Summit on the Information Society (WSIS). WSIS was a pair of UN-sponsored conferences about information society that took place in Geneva in 2003 and Tunis in 2005. One of its chief aims was to bridge the global digital divide separating the rich countries from poor ones by spreading access to the Internet in the developing world. WSIS believed that in the achievement of the MDGs, ICT should be streamlined as the only progressive tools available to accelerate development of poor countries. The Internet is the only progressive ICT that has transformed the world and created the knowledge economy. In this study, the VSAT Internet was made available to not only the disadvantaged students of Physics and Mathematics of Muni and Arua, but to the wider community in the West Nile region of Uganda, Southern Sudan and Eastern Democratic Republic of Congo, DRC. At the African continent level, the New Partnership for African Development (NEPAD) is implementing the NEPAD e-Schools initiative. This is a multi-country, multi-stakeholder, continental initiative, which intends to impart ICT skills to young Africans in primary and secondary schools and to use ICT to improve the provision of education in schools. Uganda is one of the few countries where this project is being piloted. There is absolutely no difference in what NEPAD e-Schools initiative is doing and the project that was implemented in the two girls' secondary schools: Muni and Ediofe. Uganda is one the few developing countries that first developed a Poverty Eradication Action Plan (PEAP) after realising that earlier economic reforms did not address poverty. From 1995, PEAD has been revised a number of times and the current document released in 2004 has five pillars. The fifth pillar puts 'human development ' as one of the priority areas of focus of Ugandan Government. This study augments this effort of the Ugandan Government. However, it must be noted that the PEAP document is silent on the role of ICT in poverty eradication. The 1995 Constitution of the Republic of Uganda is the main legal document for the country. Article 30 of the constitution states that all persons have a right to education. Article 30(1) further says that 'notwithstanding anything in this constitution, the state shall take affirmative action in favour of groups marginalized on the basis of gender, age, disability or any other reason created by history, tradition, or custom, for the purpose of redressing imbalances which exist against them'. Further down, Article 33(5) states that ' without prejudice to article 32 of this Constitution, women shall have the right to affirmative action for the purpose of redressing the imbalances created by history, tradition or custom'. This study is directly addressing those articles in the 1995 Constitution of the Republic of Uganda.

2 Scientific Contributions to Makerere University

- A composite model was specified and used for the analysis of the effects of variables on the performance of students at external examinations.

- The variance-covariance models for the longitudinal performance of students were created.

- Scientific hypotheses were tested using deviance statistics.

- My Licentiate Dissertation on the topic: *Hybrid e-learning for rural secondary schools in Uganda'* was published in 2006 in BTH, Sweden. ISBN No. 91-7295-095-1.

- I was part of the Doctoral students who wrote the handbook for PhD research students *'How to get a quality PhD at the Faculty of Technology, Makerere University'.* The handbook was published in 2007 by Mixiprint, Olofstrom, Sweden. ISBN No. 9970-812-05-8.

- Seven scientific papers were written and presented at various conferences as indicated hereunder. These papers helped to improve the visibility of Makerere and its ranking internationally. The papers are:

Paper I. *Strategies for Implementing Hybrid E-Learning in Rural Secondary Schools in Uganda*, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. A poster presentation was made from this paper and exhibited at the SPIDER stand during the Tunis WSIS Summit in November, 2005. The paper was published by Elsevier Ltd, UK, in the proceedings of the First International Conference on Advances in Engineering and Technology, 16-19 July, 2006, Entebbe, Uganda, ISBN- 13: 978-0-08-045312-5 and ISBN- 10: 0-08-045312-0, pgs. 538-545. The international conference was organized by Faculty of Technology, Makerere University.

Paper II. *Implementation of Hybrid E-Learning in Advanced-Level Rural Girls' Secondary Science Education in Uganda: Arua Case Study*, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. This paper was presented at the First International Conference on ICT for Development, Education and Training, Addis Ababa, Ethiopia, May 24-26th 2006. The abstract for the paper was published by ICWE GmbH, Berlin, Germany in the Book of Abstracts, ISBN 3-9810562-2-1. The full paper was published in the conference CD.

Paper III. *Design and Development of Interactive Multimedia CD-ROMs for Rural Secondary Schools in Uganda*, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. The paper was published by Elsevier Ltd, UK, in the proceedings of the First International Conference on Advances in Engineering and Technology, 16-19 July, 2006, Entebbe, Uganda, ISBN-13: 978-0-08-045312-5 and ISBN- 10: 0-08-045312-0, pgs. 546-553.

Paper IV. *Development of Sustainable Hybrid Digital Libraries for Secondary Schools in Uganda: Arua Case Study* by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. (2006). The paper was presented at the Third International E-learning Africa Conference, Accra, Ghana, May 28-30 2008. The abstract for the paper was published by ICWE GmbH, Berlin, Germany, in the Book of Abstracts, ISBN 978-3-941055-00-1. The full paper was published in the conference CD.

Paper V. *Longitudinal Analysis of Performance of Ugandan Rural Advanced-Level Students in Physics Practicals* by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. This paper was presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology, Makerere University. The paper will be published in the newly created journal by the three collaborating technical faculties of Makerere University, Dar es Salaam University and Eduardo Mondlane University. The journal is titled 'The Journal of Engineering, the Built Environment and Technology', JEBET.

Paper VI. *E-learning for Development in Rural Uganda- Co-evolution in Triple Helix Processes* by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. This paper wase presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology, Makerere University. The paper will be published in the newly created journal by the three collaborating technical faculties of Makerere University, Dar es

Salaam University and Eduardo Mondlane University. The journal is titled 'The Journal of Engineering, the Built Environment and Technology', JEBET.

Paper VII. Sustainability of Rural ICT infrastructure by Gyavira Taban-Wani and Peter Okidi-Lating (2007). This paper wase presented at the Conference on Collaborative Research for Technological Development - Kampala 17th - 21st December 2007. The conference was organized by the Faculty of Technology, Makerere University. The paper will be published in the newly created journal by the three collaborating technical faculties of Makerere University, Dar es Salaam University and Eduardo Mondlane University. The journal is titled ' The Journal of Engineering, the Built Environment and Technology', JEBET.

3 Scientific Contributions to Arua Community

In Arua District, there are contributions by the ICT Research Center and the direct contributions to Ediofe and Muni.

Contribution of the ICT Research Centre in Arua

- Internet access and ICT training costs in Arua lowered by half because of the Research Centre. The community is the main beneficiary in this case.
- After training all the district officials free, efficiency of District Leaders has improved. Many are now computer literate and can communicate freely on e-mails with Central Government offices in Kampala.
- The Centre provides employment of the local people in Arua. It is in line with the Government's poverty eradication plan.
- The Centre is helping to bridge the bridge the Digital Divide in Arua.
- Teachers and students in Arua have access to resources from the Internet, project website www.aruaeduc.com, offline digital library, interactive multimedia CD-ROMs. These resources will help to improve performance of the students in the district.
- The Centre is training students from not only West Nile region of Uganda but from Southern Sudan and Eastern Democratic Republic of Congo. It is a regional centre that is portraying a positive image of Makerere in the rural area.

Contributions to Ediofe and Muni

- The 41.4% of the participants who qualified for higher education will have better education and better standards of living.
- The interactive multimedia CD-ROMs are in the schools for use. It will help to improve further their performance beyond the project.

4 Statements of Originality

During the course of the study, the following contributions were found to be new in the Ugandan context:

- The methodological findings were found to be new. Participatory Action Research (PAR) methodology as the main theory guiding practice during the research. Action or practice was treated as a qualitative research. The quantitative part of the research uses the Multilevel Analysis Theory which is not widely used in Uganda.

- When setting up the Faculty of Technology ICT Research Station, the Triple Helix Methodology was used. This methodology brings together the academia, government and the business community to solve social problems in a community. In the case of Arua, Faculty of Technology joined hands with Arua Local Government and the Local Chamber of Commerce to start the ICT Research Station with funding from Sida/SAREC. The District Local Government provided buildings for the Station. The district also provides armed policemen to guard the site. Such type of cooperation is unique in Uganda.

- Hybrid e-learning concept is new in Uganda. Actual status of science education in the participating schools was analyzed before recommending that hybrid e-learning was the most appropriate for poor rural secondary schools. Rural schools cannot afford Internet connectivity. The associated costs are too high. Annual operational costs are extremely high. However, the schools can afford to purchase some used, refurbished computers with limited multimedia capabilities. Such computers can be upgraded to multimedia capabilities and content can be delivered to the schools using CD-ROMs. The concept of hybrid e-learning in this study is that CD-ROMs are the main content delivery platforms. This is a new concept in the Ugandan educational terminology.

- The ICT Research Station in Arua signifies the beginning of the end of Makerere University being portrayed as an Ivory Tower. The initiative of Faculty of Technology to set up a Research Station in the rural area is commendable. The fact that the station is helping not only Ugandans, but interested parties from DRC and Sudan means that the Faculty is playing a bigger role in sustainable rural development than originally was thought. The massive training being done at the station using Faculty of Technology students are helping to spread ICT skills, thus narrowing the digital divide gap.

- The emphasis on the study on the use of open source platform is also commendable. Most ICT in Education projects in do not mention anything about software. SchoolNet, Uconnect and CurriculumNet projects do not mention anything about software. Yet software is a sustainability issue. Most ICT projects fail because they cannot renew commercial licenses when the software is upgraded. Software is the hidden devil in ICT projects. In this study, the use of the Mambo an open source platform for managing the hybrid e-learning environment is found interesting.

- In trying to introduce ICT into the curriculum, the National Curriculum Development Center (NCDC) developed some CD-ROMs for primary 4 and 5 mathematics and social sciences and senior 1 and 2 mathematics and geography. Advanced level subjects were not covered. In this study, based on the local content materials CD-ROMs for advanced level mathematics and Physics were developed. These CDs are new in the A-level education in Uganda. They were locally developed based on the national curriculum.

- It is also an interesting innovation when the content server was put at the ICT Research Station in Arua. A-level mathematics and Physics teachers visit the station to access Internet. They are allowed to enter content into the content server. Students, not only from the participating schools, come to the station, get contents from the content server. They are encouraged to download relevant content into portable devices like CDs and memory sticks. The Station is now acting as a digital resource centre for A-level students in the district. This concept is also new in Uganda.