# Hybrid E-learning for Rural Secondary Schools in Uganda

Peter Okidi Lating

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# Hybrid E-learning for Rural Secondary Schools in Uganda

Peter Okidi Lating



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

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This work is dedicated to my wife, children, mother, brothers and sisters

# Abstract

This licentiate thesis is concerned with the development of appropriate tools and implementation of hybrid e-learning to support science and mathematics education of female students in typical rural advanced-level secondary schools. In Uganda few rural female students participate in technology and engineering education in tertiary institutions because they perform poorly in science and mathematics subjects at advanced secondary school level of education.

Rural secondary schools in Uganda are usually very poor and financially constrained schools. Generally, such schools have non-functional science laboratories and libraries. They also have difficulty in attracting and retaining qualified science and mathematics teachers, especially at advanced level of secondary education. The financial situations of the schools make capital investments in science infrastructures like laboratories and libraries impossible. Fortunately, such schools can afford to acquire computers preferably with multimedia capabilities. Hybrid e-learning can be introduced in such disadvantaged schools to support science and mathematics education. The main delivery tools under hybrid e-learning are the CD-ROMs due to their superior advantages over other portable storage devices: big memory capacity, high data transfer rate, multimedia capability and widespread standardization. Used computers with inferior capabilities that are being sold to rural schools cheaply are not useful for educational purposes. The cost of acquisition is low but the total cost of ownership is extremely high. The costs of Internet installation, bandwidth, commercial platforms and web-hosting make introduction of pure e-learning in Ugandan schools not viable, even in educationally elite secondary schools. Hybrid elearning is the only realistic option in the complex financial situation of Ugandan secondary schools. Experience has shown that where there is Internet presence for use in education, open source web-hosting providers and open source platforms must be used. They are cheap and affordable even by poor rural secondary schools. Hybrid e-learning tools were developed to support such Ugandan schools using participatory methodology.

The thesis is organized in three parts. Part I consists of six chapters including background information, concept discussions, problem statement, research questions, objectives of the study and research location. A justification of the use of participatory methodology in the research is also made in part I. Part II includes the four papers upon which the thesis is based. Part III contains a brief summary of the papers, conclusions and future research.

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# List of Abbreviations

# Introduction

ADB	African Development Bank	PRA
CAD	Canadian Dollars	PTA
CD	Compact Disk	RCDF
CDMA	Code Division Multiple Access	
CD-ROM	Compact Disk-Read Only Memory	RLO
CMS	Content Management System	RRA
DFID	Department of International	SARE
	Development	SEK
DRC	Democratic Republic of Congo	Sida
DSL	Digital Subscriber Line	
GDP	Gross National Product	SPIDE
GIS	Geographical Information System	
GNI	Gross National Income	SPLA
GPRS	General Packet Radio Service	SPSS
HLM	Hierarchical Linear Model	
HTML	Hypertext Mark-Up Language	SSTD
ICC	International Criminal Court	
ICT	Information and Communication	STATA
	Technologies	STEP
IDRC	International Development Research	
	Center	UCC
INSSTEP	In-Service Secondary Teacher	UGX
	Education Project	UK
ISDL	Integrated Services Digital Network	UN
ISP	Internet Service Provider	UND
LAN	Local Area Network	
LCMS	Learning Content Management	UNE
	System	UNES
LMS	Learning Management System	
LRA	Lord's Resistance Army	UNH
MDG	Millennium Development Goal	
MOES	Ministry of Education and Sports	UPPT
NCDC	National Curriculum Development	
	Center	URL
NEPAD	The New Partnership for Africa's	US
	Development	USD
NGO	Non-Governmental Organisation	VLE
OAI	Open Archive Initiative	VSAT
OAU	Organisation of African Unity	WAN
PAR	Participatory Action Research	WEN
РСМ	Physics, Chemistry and Mathematics	
PEAP	Poverty Eradication Action Plan	WSIS

Participatory Rural Appraisal Parents and Teachers Association RCDF Rural Communication Development Fund Re-usable Learning Object Rapid Rural Appraisal The research arm of Sida SAREC Swedish Kroner Swedish International Development Agency SPIDER Swedish Program for ICT in Developing Regions Sudanese Peoples' Liberation Army Statistical Package for Social Sciences (software) SSTDS Secondary Science Teacher Development System STATA A general purpose statistical package STEPU Science and Technical Equipment Production Unit Uganda Communications Commissioner Uganda Shillings United Kingdom United Nations 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 UPPT Universal Post-Primary Education and Training Uniform Resource Locator United States of America United States Dollars Virtual Learning Environment Very Small Aperture Terminal Wide Area Network WENRECO West Nile Rural Electrification Company Ltd World Summit on the Information

This licentiate study is 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 female students in Physics and Mathematics at national examinations in Uganda. More specifically the licentiate study focuses on tool development and implementation of hybrid e-learning.

The research is motivated by the requirements of international and national documents aimed at ending social inequality through the application of the Information and Communication Technologies (ICTs) in Uganda. In that regard, the research is linked to the requirements of the following international and national documents:

- the Millennium Development Goals (MDGs);
- the World Summit on the Information Society (WSIS): objectives, goals and targets;
- the WSIS Gender Caucus Recommendations for Action;
- the New Partnership for Africa's Development (NEPAD) and
- the Poverty Eradication Action Plan (PEAP) of the Ugandan Government.

#### The United Nations Millennium Development Goals

In September 2000, 189 world leaders under the auspices of the United Nations (UN), agreed and set up eight Millennium Development Goals (MDG) to guide development in the 21st century. All the 191 UN Member States (including Uganda) have pledged to meet these goals by the year 2015. At that Summit, Kofi Anan, the UN Secretary-General, said:

We will have time to reach the Millennium Development Goals - worldwide and in most, or even all, individual countries - but only if we break with business as usual. We cannot win overnight. Success will require sustained action across the entire decade between now and the deadline. It takes time to train the teachers, nurses and engineers; to build the roads, schools and hospitals; to grow the small and large businesses able to create the jobs and income needed. So we must start now. And we must more than double global development assistance over the next few years. Nothing less will help to achieve the Goals.

Society

Millennium Development Goal 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. This indicator is measured by considering the ratio of girls to boys in primary, secondary and tertiary institutions.

# The World Summit of Information Society: Objectives, Goals and Targets

In December 2003, the World Summit on the Information Society (WSIS), held in Geneva, 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. It must be mentioned that the fundamental ICT that has revolutionized the world and created the knowledge economy is the Internet. In the contemporary world, knowledge has become a third factor of production after labour and capital in leading economies, thanks to the Internet. Internet application in solving practical social problems like poverty, hunger and diseases should be widely encouraged.

# WSIS Gender Caucus: Recommendations for Action

At the end of the WSIS summit in Geneva in December, 2003, the WSIS Gender Caucus suggested six recommendations for action by UN Member states. Action point no. 6 calls for Research analysis and evaluation to guide action and states that:

Governments and other stakeholders must apply creative research and evaluation techniques to measure and monitor impacts - intended and 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 people.

This action point recommends research on the impact of ICT application on women.

# The New Partnership for Africa's Development, NEPAD

The NEPAD strategic framework document arises from a mandate given to the five initiating Heads of State (Algeria, Egypt, Nigeria, Senegal and South Africa) by the Organisation of African Unity (OAU) to develop an integrated socio-economic development framework for Africa. The 37th Summit of the OAU in July 2001 formally adopted the strategic framework document. NEPAD is designed to address the current challenges facing the African continent. Issues such as the escalating poverty levels, underdevelopment and the continued marginalisation of Africa, needed a new radical intervention, spearheaded by African leaders, to develop a new Vision that would guarantee Africa's Renewal. NEPAD objectives are:

• to eradicate poverty;

• to place African countries, both individually and collectively, on a path of sustainable growth and development;

• to halt the marginalisation of Africa in the globalisation process and enhance its

- full and beneficial integration into the global economy;
- to accelerate the empowerment of women.

ICT implementation and achievement of MDGs in areas of health and education are one of the priority areas of NEPAD.

#### Poverty Eradication Action Plan (PEAP) of the Uganda Government

PEAP is Uganda's comprehensive development framework and action plan to eradicate poverty. This plan, officially launched in 1997 and revised in 2001 and 2004 in light of emerging global and international challenges like requirements of MDGs, WSIS and NEPAD, is the overall planning guide informed by sector plans and priorities. PEAP also determines national investment priorities, the allocation of resources to these priorities and the monitoring of progress towards achieving poverty reduction targets. The expenditure implications of the PEAP are translated into sector plans and interventions completing a two way planning model where sector priorities inform the PEAP and the latter guiding sector priorities to focus on poverty eradication and social transformation as the overarching development agenda. PEAP is structured around the following five pillars:

- Macro economic management: Emphasis is on macro-economic management, tax policy, financial sector development, investment and trade policy.
- Enhancing production, competitiveness and incomes: focus is on increased production, marketing and efficiency so as to raise the incomes of the poor.
- Security, conflict resolution and disaster management: targets to overcome the challenge of insecurity through: ensuring security and defense, involving in conflict resolution, disaster preparedness, post conflict and disaster planning.
- Good governance and Poverty: Focus is on ensuring respect for human rights, pursuing democratization, making government affordable, transparent and efficient, and providing a good judicial system.
- Human Development: Emphasis is on healthy and well educated population. The focus sectors are education, health, water and sanitation.

Although none of the 5 PEAP pillars deals directly with ICT and women, pillar no. 5 is concerned with education. As a consequence, ICT and gender research, the main essence of this thesis, is linked succinctly to this pillar.

ICT could thus be applied as a viable solution to the low participation of disadvantaged rural female students in engineering education in Uganda. The broader availability of ICT in education is a means of opening doors to economic and social prosperity of the user communities. This is expected to result in bridging the digital divide generally and the gender divide in engineering field specifically.

# The thesis is organized in three parts.

# Part I consists of six chapters.

Chapter one gives the background to the study. It looks at the difficult financial position of the education sector in Uganda. With inadequate funding, capital developments in secondary schools like building and equipping senior science laboratories, building libraries

and stocking them with adequate copies of the relevant textbooks becomes difficult. In the background is also included some attempts to introduce ICT in the schools. These are mainly elite urban secondary schools in the country. The inability of such schools to afford Internet connectivity for even one hour a day is noted. Also noted is the use of CD-ROMs as a delivery platform in the CurriculumNet project. Chapter two focuses on concept discussions. It gives a more in-depth review of literature on e-learning to distinguish the research from other previous work. The problem statements and the research questions are included in Chapter three. Chapter four contains the general and specific objectives of the research. Chapter five gives the research location. It describes the case study area- Arua District where the research is being conducted. Chapter six dwells more on justifying the appropriateness of using Participatory methodology in this study.

Part II includes the four papers upon which the thesis is based. Part III contains a brief summary of the papers, discussion, conclusions and future research.

# Part I

# Chapter one: Background

#### 1.1. Status of Advanced Level Secondary Science Education in Uganda

#### 1.1.1. Education System in Uganda

The Ugandan education system consists of primary (7years), secondary (6 years) and tertiary (3-5 years) levels of education. Secondary education has to levels: ordinary level (abbreviated as O-level) and advanced level (usually abbreviated as A-level). O-level is four years while A-level is for 2 years. A-level is a pre-university level of education. Therefore, the academic levels of education in Uganda are primary, secondary and tertiary.

The other level of education is the vocational and skills training level. This consists of those who dropped out of the academic line. They join vocational institutes and colleges for skills training. These are students who cannot continue with the academic line because of inadequate facilities at the next levels of education. Even vocational institutes are limited by inadequate facilities. Students, who fail to join these institutes and colleges, completely drop out of school.

At the end of each level, all students are subjected to national examinations, centrally set and administered by the Uganda National Examinations Board (UNEB). UNEB is an autonomous legal entity under the Ministry of Education and Sports (MOES). It sets examinations for primary, secondary and vocational colleges. Tertiary institutions set their own examinations.

### 1.1.2. Enrollment for Sciences in Ugandan Tertiary Institutions

According to statistics compiled by UNESCO there is a very small percentage of University students who graduate in sciences or science-related courses in Uganda: 21% in 1999, 17% in 2000 and only 11% in 2002. Furthermore, the 2005 Human Development Report published by the United Nations Development Programme (UNDP) shows that tertiary students in science, mathematics and engineering in Uganda constituted an average of only 8% of the total tertiary students between 1998 and 2003.

Despite the fact that few students take science and science-related courses, the proportion of female students is even lower in tertiary institutions, which includes universities. The situation is particularly bad in technology and engineering courses.

# 1.1.3. Enrollment by Gender for Engineering Training in Uganda

The most dominant tertiary institution with a relatively sound research base in Uganda is Makerere University. Makerere University accounts for over 50% of enrollment in tertiary institutions. Engineering students are admitted into the Faculty of Technology, Makerere University. The female students' participation as shown by the graduation pattern from 2000 to 2003 from the Faculty of Technology is only about 20% (Lating, Kucel and Trojer, 2006). Earlier study by Turygyenda, Kibira and Lugujjo (2005), found that for the last 35 years of the existence of the Faculty of Technology, female graduates constituted only 20.5% of the graduates. Furthermore, during the 2004/5 academic year, the Faculty of Technology had a total enrolment of 1094 undergraduate students of which only 208 were females giving a female enrolment ratio of 19%. The participation of female students appears to consistently fall within the range of 20%.

Yet in Uganda, female students are awarded 1.5 points more than male students when their applications are being considered for entry into public universities and other tertiary institutions. Implementation of this policy started in 1991/2 academic year. It would appear that the policy has not helped to significantly increase female students' participation in technology and engineering. The major beneficiaries of this policy are the arts and humanities faculties.

1.1.4. Poor Performance of Rural Advanced-Level Students in Mathematics and Physics

Lating et al., (2006) reveal that 86% of the few female students who qualify for Government scholarships for engineering training are largely from advanced level secondary schools located only in four educationally elite districts of Kampala, Mpigi, Mukono and Wakiso. Yet Uganda has about 80 districts, most of them poor and rural. Nearly eighty five percent of Uganda's population lives in the rural areas.

Since the admissions for Government scholarships are based on academic merit, it means that students in rural schools perform poorly, especially in Physics and Mathematics at Advanced-level (or A-level) examinations. Physics and Mathematics are the essential subjects required for admission for engineering training.

# 1.1.5. Enrollment by Gender for Science and Engineering training in other countries

Low participation of women in science, mathematics, engineering and technology is a world wide problem. Adeyemi and Akpotu (2004) report that the percentage of female students enrolled in Nigerian universities for engineering training was 9.25% (1988/89) academic year, 9.36% (1989/90), 9.88% (1990/91), 15.40% (1991/92), 7.02% (1992/93), 4.7% (1993/94), 13.87% (1995/96) and 9.79% (1996/97). The report highlights the fact that cultural and religious complications, especially in the northern part of Nigeria which is predominantly Moslem, inhibit education of the girl-child. Another drawback is that some laws in Nigeria prohibit women from pursuing some courses; and most of them are science-based courses. In the US, women make only 22% of those employed in science and engineering. Moskal (2000) recommends that "one manner in which to increase the overall pool of trained scientists and engineering majors in the next century is to increase the participation of women in these fields". Creativity, which is central to engineering,

is influenced by background. Women will bring to the engineering field a background which is different from that of the men. Experience has shown that women bring unique contributions in fields where they are deployed. Their underrepresentation in engineering is detrimental to the field. Mody and Brainard (2005) highlight both exemplary and promising practices in research, programs and policies in most regions of the world aimed at addressing the issue of low female participation of women in science and engineering disciplines. The report gives the approaches that the UN Gender Advisory Board has been following since 1995. It also gives success stories in the European Union. Sweden and US are specifically praised in the report for following up the issue of encouraging women in science and engineering more aggressively.

All these initiatives that are being implemented by the developed world may not work in the context of a poverty stricken community. The context of such countries should be taken into account.

# 1.1.6. Uganda Government's Strategies on Secondary Science Education

Uganda Government has been trying to improve science education in secondary schools. There was the In-Service Secondary Teacher Education Project (INSSTEP). This project was funded by the British Department of International Development, DFID, UK. It was aimed at increasing the efficiency and effectiveness of secondary science education by improving the quality of teaching Mathematics, English and Science Subjects like Physics, Chemistry and Biology. This was done through in-service training of teachers and establishment of a national network of teacher resource centers. The project was started in 1994 and ended in 1999.

The project was restricted to only lower ordinary secondary level, advanced secondary level did not benefit from it. Advanced-level science and mathematics subjects were excluded from the project. Furthermore, the project was not sustainable. As a result, the problem of secondary science education has persisted especially in rural schools where the majority of the students are. Many schools have no laboratories and libraries. Schools that have them can not buy equipment and chemicals, nor can they stock the libraries with relevant science and mathematics textbooks. Rural schools continue to have difficulties in attracting and retaining good, committed and qualified science teachers. The schools cannot afford to purchase science equipment and chemicals for ordinary practical work for students. They mainly buy science equipment and chemicals for national examinations only. The students see the equipment and chemicals for the first time during examinations.

#### 1.1.7. Science Subjects Made Compulsory in Ugandan Secondary Schools

From 2006, Government of Uganda has made science subjects compulsory in ordinary level from 2006. By the end of 2005, there were 1651 government aided secondary schools and 1898 private ones.

To address the issue of laboratories and libraries, the government intends to build 40 laboratory blocks annually. A laboratory block consisting of Physics, Chemistry and Biology laboratories is being constructed at 423 million Uganda shillings (about 228,650 USD, using a rate of 1USD to 1850 Uganda shillings). The 40 laboratory blocks per year

require 9,146,000 USD. This funding will be by the Ministry of Finance under the Mid Term Budget Framework expenditure. Government has budgeted for it.

Due to high costs of laboratory construction, private schools are unwilling to admit science students because they are not interested in building laboratories. Laboratories are expensive to build and equip.

The African Development Bank (ADB) will construct 54 science laboratories and 12 libraries. Japanese Government will fund training of teachers under the project entitled 'Secondary Science Teacher Development System, SSTDS'.

Government will also have a skewed recruitment of teachers towards science so that there will be adequate numbers of science teachers in secondary schools.

To improve the production of science and technical equipment for secondary schools, Government intends to strengthen the Science and Technical Equipment Production Unit, STEPU. STEPU is located at the National Curriculum Development Center (NCDC), in Kyambogo. NCDC is an autonomous body under the Ministry of Education and Sports, MOES. However, Tindimubona (2000) maintains that STEPU is a 'dead' unit yet it was built and equipped with human resources by British aid to produce educational materials for Ugandan schools. The unit failed to sustain itself. The main reason was the fact that no orders were received from Ministry of Education and Sports, as the Ministry's officials apparently preferred to import educational materials even though they could be produced at home using the facilities and human resources put in place by the British. STEPU is now in a sorry state, occupying an unfinished building which could have been completed with the proceeds of the orders.

Unfortunately, all these initiatives are aimed at lower secondary education, the O-Level. Again advanced level is not being catered for.

# 1.1.8. Universal Post-Primary Education and Training Policy in Uganda

The Universal Post Primary Education and Training (UPPT) Policy will be implemented from January, 2007. This policy will lead to more female students joining ordinary level secondary schools. But it will exasperate the problems of science education in secondary schools. Up to 7555 new secondary school teachers will have to be recruited and Government can only recruit 2000. The issues of science and mathematics infrastructure in secondary schools are not yet solved.

# 1.1.9. Expenditures on Education in Uganda

Expenditures on education (see table 1), where primary education takes up to 70% of the education budget, secondary level takes 15% and the balance is shared by tertiary institutions, Business, Technical and Vocational training institutes.

		2002/02	2002/04	2004/05	2005/06
		2002/03	2003/04	2004/03	2005/00
	Recurrent	255.127	279.182	285.718	325.661
Primary	Development	81.054	71.981	81.061	64.679
	Total	336.181	351.163	366.779	390.34
	Sector Share	66.7%	67.9%	66.1%	67.5%
	Recurrent	72.801	81.667	91.787	92.482
	Development	5.459	1.767	0.808	0
Secondary	Total	78.26	83.434	92.595	92.482
	Sector Share	15.5%	16.1%	16.7%	16.0%
	Recurrent	16.011	15.134	18.483	17.96
Business, Technical,	Development	4.17	1.422	4.407	3.826
Vocational Training (BTVET)	Total	20.181	16.556	22.89	21.786
	Sector Share	4.0%	3.2%	4.1%	3.8%
	Recurrent	47.481	49.048	55.821	61.328
	Development	3.15	1.608	1.875	2.06
Tertiary	Total	50.631	50.656	57.696	63.388
	Sector Share	10.0%	9.8%	10.4%	11.0%
	Recurrent	12.001	11.44	10.095	8.829
	Development	6.78	4.022	4.466	1.765
Other	Total	18.781	15.462	14.561	10.594
	Sector Share	3.7%	3.0%	2.6%	1.8%
Total Public Expenditure	Recurrent	403.421	436.471	461.904	506.26
on Education	Development	100.613	80.8	92.617	72.33
	Total	504.034	517.271	554.521	578.59

Table 1 : Public Expenditures on Education (Bi	Billions of Uganda Shilling	s)
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Recurrent expenditures are mainly expenditures on teachers' salaries and wages of school administrators.

From the table above, Capital development funds to secondary schools have been successively reduced from 5.459 billion UGX ( 2.8 million USD) in 2002/3 fiscal year, to 1.767 billion UGX (or 1 million USD) in the 2003/4 fiscal year, to 808 million UGX (440 USD) in 2004/5 to zero in 2005/6. Therefore, capital development funds were finally stopped in the 2005/6 fiscal year. Schools cannot construct new laboratories and libraries. Even if the funding of capital expenditures remained, the amount of money involved is insignificant for a school to use it meaningfully.

Government pays Capitation Grant of 65 Uganda shillings (0.035 USD at the same current exchange rate of 1 USD for 1850 Uganda shillings) per student per school day. In a year which consists of three terms each approximately 90 days long, the total amount paid per student per year equates to 17,550 Uganda shillings (9.5 USD). With this money, the school must keep the student for a year. It is worse if it is a boarding school where students must be accommodated and fed in the school. A typical boarding school with 700 students will receive 6650 USD for the upkeep of the students, that is where the problem is.

Most schools have created what is commonly called the Parents' and Teachers' Associations (PTA) with the aim of raising more money for the schools so that standards of education

do not drop. In such schools, the rich parents agree to pay substantial amount of money to cater for the welfare of teachers, students and capital development of the schools.

The best schools from the country have very strong PTAs. They are generally elite schools that produce the best students at national examinations. In rural communities, parents are poor and are unable to raise any more money for capital development of the schools.

While Government is making some efforts to improve science education in the country, the financial constraints are enormous. The building of physical laboratories, libraries and recruitment of qualified teachers for rural advanced level schools will take a long time. And emphasis is being put on ordinary secondary level of education, not advanced level. In the circumstances, another innovative way of delivering the curriculum using ICT should be sought.

# 1.2. ICT Projects in Some Secondary Schools in Uganda

There have been some attempts at introducing ICT in secondary schools in Uganda. The SchoolNet, Uconnect, CurriculumNet and NEPAD projects are worth describing in greater detail.

# 1.2.1. SchoolNet VSAT Pilot Project

When the World Links for Development Program, an initiative of the World Bank Institute started connecting schools in developing countries to the Internet, it started with Uganda in June 1996. One of the requirements for school selection was a telephone line (fixed or cellular mobile) in the computer lab. The schools were then connected to Internet using dial-up modems. Over time, lessons learnt included:

1. The recurrent telephone costs were so high that only "First World" urban schools could afford a maximum of one hour of Internet connectivity per day. Schools were typically spending between USD 200 – USD 300 per month on telephone bills accruing from Internet connectivity.

2. A number of schools had "noisy" or poor telephone lines, which could only support voice but not data.

3. Internet connectivity using telephone lines was too slow for educational use due to the low bandwidth of the telephone lines. Only e-mail facility was possible in most of the schools.

4. Due to poor or absence of communication infrastructure and high cost of connectivity, rural schools couldn't participate in the project. This had the potential danger of widening the already existing disparity in the academic performance between rural and urban schools.

Due to the challenges and high costs of connecting Uganda schools to theInternet over fixed/cellular telephone line infrastructure, World Links/SchoolNetUganda piloted wireless spread spectrum connectivity using microwave modems. This proved to be both technically and financially viable for schools in and around Kampala. All were using microwave wireless links to connect to the local Internet Service Providers (ISPs). Though this requires a high capital cost (about USD 2500), it has a fixed running cost of USD 200 per month with faster speeds and a 24 hr Internet access.

Rural schools however, could not go in for the Spread Spectrum microwave wireless connectivity because it requires a school to be in a 20-30 km radius from a VSAT (Very Small Aperture Terminal earth satellite) or a repeater of an ISP but there are no local ISPs in rural areas.

SchoolNet Uganda with its partners piloted connecting rural schools to the Internet using VSAT (earth -satellite) technology. This is the first ever satellite-based school connectivity in Africa. Under this project, 10 secondary schools, and one National Teacher Training College were connected to VSAT. Four other schools near Busoga College Mwiri were connected to Internet via spread spectrum microwave wireless links. These four schools were to link to the VSAT at Mwiri.

The project partners were:

• Links Organisation subsidised half the bandwidth cost for two years (USD 3,000 per month), training (technical and pedagogical), business and technology plan development.

• Bill and Melinda Gates Foundation – donated the earth-satellite dishes (VSATs)

• 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 for the four Jinja schools linked to Mwiri.

• Wilken AFSAT handled the school-based VSAT installation and commissioning.

•Verester, a global Communication Solution Provider provided the satellite bandwidth at a very competitive price (USD 6,000 per month for whole network).

• SchoolNet Uganda 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.

After the expiry of the two year project duration, SchoolNet continued to connect other educational institutions to Internet via VSAT. Up to 42 schools and institutions have been connected.

# 1.2.2. Uconnect Project

This is also an NGO based in the Ministry of Education and Sports. The object of Uconnect is the advancement of public education in Uganda by using Information and Communication Technology (ICT) for education to improve the quality and efficiency of communications. It started operating in Uganda in 1996. The NGO sources for cheap, refurbished computers from Europe and North America and sells them to schools at 170 to

220 USD. A school that has purchased at least 10 computers will be assisted in networking them if it can purchase an open source server from Uconnect. Training of both teachers and students is arranged. In some cases, Uconnect helps their clients to connect to Internet. By October 2006, 220 primary and secondary schools had purchased refurbished computers from Uconnect. Only four of those schools have had their computers networked into a LAN but have not been connected to Internet. Some schools like Mengo Secondary School that were connected to Internet via VSAT in the SchoolNet Project went to Uconnect and bought refurbished computers.

#### 1.2.3. CurriculumNet Project

This project was implemented by the National Curriculum Development Center, NCDC, with the assistance from International Development Research Center, IDRC, from 2001 to 2005. Total project cost was 446,800 CAD (Canadian Dollars). It was a pilot project to implement an ICT enhanced curriculum in selected subjects in a few schools in Uganda. The objectives of the project were:

- To test the technical and operational feasibility and economic viability of ICTs in the delivery of the curriculum in Uganda.
- Examine the 'value' added to the subject areas and extent of enhancing teaching and learning

The project focused on a few subjects: primary four and five Mathematics and Social Sciences, senior one and two Geography and Mathematics.

#### Project Successes:

• Improved the NCDC computer laboratory with additional equipment and facilities: 14 computers (one was made a server for the Internet, Intranet and LAN), a scanner, etc.

- Creating a web site for the institution (http://www.ncdc.go.ug)
- Training close to 40 individual teachers and curriculum specialists in ICT design and content development
- Developing initial content in selected subjects.
- CDs were made and the website was also used as additional content delivery medium.

The CD-ROMs were developed in a multimedia format that supports video, audio and text. They are useful for student-centered approach to learning. These training CD-ROMs were launched in March 2004.

After the expiry of the CurriculumNet Project, NCDC is trying to reach some schools and sell refurbished computers.

# 1.2.4. Newly Launched ICT in Education Projects

The NEPAD e-schools project was launched in Uganda in August, 2006. It will be piloted in 6 schools for 18 months. Kyambogo College in Kampala is the headquarters of the project.

Another SchoolNet project aimed at supporting secondary school female students of science subjects using ICT was launched in June, 2006. It is a partnership between Digital Links of UK and the Barclays' Bank in Uganda.

NEPAD e-schools project, just like the SchoolNet project for empowering the girl-child education through ICT are newly commissioned. The current SchoolNet project is particularly good since it focuses on the girl-child, unlike the previous one. It is anticipated that both projects, the NEPAD e-schools project and the new SchoolNet project, will roll out ICT to rural schools. It is feared that by partnering with Digital Links, the project may not be different from the Uconnect if the intention is to remove 10,000 used computers and dump them in Ugandan schools.

1.2.5. Some General Comments on the ICT in Secondary Education Projects in Uganda

The SchoolNet VSAT project targeted the well-established, elite secondary schools with good science infrastructures (laboratories, libraries and qualified and committed teachers). Yet the project was meant to be implemented in rural schools. Internet was connected to such schools that do not need them for purposes of improving their performances in sciences at national examinations. These are elite schools that dominate entry into tertiary institutions on government scholarships and private sponsorships. Entry into universities is based on strong academic performance at advanced level examinations. During the 2006/07 academic year, 215 undergraduate students were admitted for engineering training in the Faculty of Technology, Makerere University. The figure includes 140 on government scholarships students and 75 privately sponsored ones. Out of the 215 students admitted, 124 (58%) came from the elite schools that SchoolNet connected to Internet via VSAT. Yet internet in those schools is being used for administration purposes, not for learning. These schools have solid infrastructures for science education. SchoolNet selected the best performing schools in the country like Nabisunsa Girls' School, Trinity College, Nabbingo, Mt. St. Mary's, Namagunga, King's College, Budo, St. Mary's College Kisubi and Uganda Martyrs' College, Namugongo. These are schools that produce the best students at national examinations in the country. Mt. St. Mary's Namagunga is the only school that registered 100 percent first grade in the 2004 O-examinations . The same problem was repeated in piloting the CurriculumNet project. It was implemented in the four elite secondary schools and three primary schools. Again the elite secondary schools were King's College, Budo, Nabisunsa Girls' School, Ntare School and Bukoyo Senior Secondary School. All these schools were beneficiary of the SchoolNet project. All of them are top on the list of schools that send students for engineering training especially Budo, Nabisunsa and Ntare. They are not 'needy' schools. Both projects aimed at giving more to those schools that have more than enough. This fact should be looked at from the perspective that by the end of 2005 Uganda had 1651 government aided and 1898 private senior secondary schools, most of them rural.

Uconnect is basically an NGO that is distributing used, refurbished computers to educational institutions. Experience shows that, while these computers are cheap and schools are purchasing them, they offer a lot of maintenance and repair burden to schools. The total cost of ownership is quite high. There is also another thought that these NGOs are being used for dumping e-waste out of developed countries where environmental legislation is enforced.

It can be concluded that none of these ICT in Education projects have benefited rural secondary schools. Internet is not being introduced to solve educational problems that the schools have. The finding of SchoolNet that even the elite secondary schools have difficulty in affording Internet connectivity for 1 hour a day because of the costs involved should be noted. The experience of CurriculumNet that CD-ROMs are viable content delivery platforms in Ugandan secondary education context is also a very useful conclusion. Most crucial problems of rural schools are the absence of functional laboratories and libraries and qualified, committed teachers.

# Chapter two: Concept discussion

#### 2.1. E-learning

The only progressive ICT, whose extensive application in society led to the creation of the knowledge economy, is the Internet. Internet, when used to support education and training, is generally termed as e-learning or online training. Because of the benefits of e-learning, it is being applied extensively in the developed economies by government departments, businesses, universities and schools.

In the US, the government demands that all departments should train its employees online. In 2001, the US Department of Commerce, for example, had 1,800 employees in 85 countries. It was not possible to train all the employees in a classroom set-up. The costs of travel to training locations, instructor fees, facility rentals and employees allowances were substantial. According to Goodridge (2001) "by shifting career development and employee training online, training costs were cut in half".

Scottish Power, a company that provides electricity and/or gas services to around 6 million homes in UK and Western US, had problems with the traditional, tutor-led training of its employees due to increasing pressure on staff time, course cancellations and rising training costs. The company switched to e-learning (Waller, 2006).

However, in businesses, savings realized as a result of introducing e-learning differ. Pollitt (2005) reveals that Cable & Wireless Company, an international telecommunications company "estimates that using e-learning in critical business and information technology skills for its employees worldwide has cost about 80% less than the equivalent instructor-led training". Another business, which uses proprietary software for running its e-learning programme, did not realize any cost savings. Proprietary or commercial software license costs, as observed by Hoffman (2002), appear to be a major problem to franchises. He implies that proprietary software is one of the factors that negate the return on investment (ROI) of companies from e-learning.

Universities across the world are also embracing e-learning, though at different paces. Duan, Hosseini, Ling and Gay (2006) when developing architecture for an online laboratory

e-learning system for Nanyang Technological University, Singapore, found what is now popularly known as the e-learning equation:

LCMS =LMS + CMS,

where LCMS is the Learning Content Management System

LMS- Learning Management System. LMS is for managing students, communicating learning events and for collecting data on learner progress.

CMS- Content Management System. It is for creating and administering online content like articles, reports, pictures, etc. that are used in the publications on the web.

CMS can be taken to mean RLOs, Reusable Learning Objects. The interpretation of the equation is that in an e-learning environment, both contents and the learners are managed.

Universities are particularly concerned with the increasing number of people who want to work and study. To drastically increase enrollment, universities have to introduce e-learning. This is a move towards mass education. There are other students who are enrolled on the distance learning programmes who now feel e-learning can reduce the costs and improve efficiency of such distance studies. Many universities are now introducing e-learning in their curricula. For example, the University of Marburg, Germany, successfully applied an online course in nuclear medicine and radiotherapy for its third year students (Gottharrdt, Siegert, Schlieck, Schnieder, Kohnert, Groß, et al., 2006). Much of the course was online and self-directed with a lot of interactive content. The students were required to meet face-to face with experts three times a week in the campus for direct communications with their lecturers. Three interesting outcomes of this e-learning project are worth mentioning:

• a commercially available LMS (e-learning platform) was used despite the fact that proprietary software are usually expensive;

• the students in the study did not like the online forum, a means of

communication through e-mails. They considered receiving three to seven e-mails daily was too much. Yet in circumstances where bandwidth is low and is a scarce resource, communication through e-mail is very vital since it does not require a lot of bandwidth;

•the duration of the course reduced from 4 to 2 weeks without reducing the success rate of the students in examinations.

#### 2.2. Blended E-learning

The type of e-learning in the preceding section is termed as blended e-learning. Blending occurs when the traditional face-to-face meeting in classrooms is combined with training materials being posted on the websites for students to access. This is a preferred trend in the developed world. Tucker (2005) observes that "blended learning will continue to dominate the e-learning landscape because it allows companies to take advantage of the personal nature of the classroom and the cost savings of the web". This argument is very valid with respect to technical sciences. You cannot have everything done virtually. There is need for the students to physically do the experiment in a real classroom setting.

Pevac, Milanovic and Milosavljevic (2005) implemented the first e-learning project in Serbia in a Vocational School by employing a blend between lectures at the school and access to multimedia lessons via Internet either from home or school. However, their finding was that grade improvement in subjects where the blended e-learning was implemented was only by 8.87%, an insignificant improvement. In support of blended e-learning, Paechter (2004) asserts that there is no such thing like pure e-learning. Pure e-learning concept is outdated now, a view that Skill and Young (2002) also share. Skill and Young believe that learners should "spend one-third of their day at the computer, one-third with others and one-third making something". According to them a learner should share his/her time equally between computer, conversation with peers and teachers and constructing knowledge himself or herself. This hybrid approach to learning favors a combination of interactive and learning-by-doing. Although the traditional classroom is no longer a viable space for learner-centered activities, it must maintain it.

Past patterns suggest that the likely future will be neither solely online learning nor solely instructor-led classroom learning. It appears that the hybrid or blended models most frequently emerge as the most effective learning strategies. The creation of new learning environments should embrace both virtual and real spaces. The challenge is to design learning spaces that do not simply accommodate the need for diverse learning approaches but embrace, empower and sustain learners of differing capabilities and interests.

This distinction that Shill and Young raise is quite important. For communities that are capable in terms of Internet connectivity, bandwidth, webpage design and hosting, etc can use blended e-learning. Developed countries fall in this category. For the economically weaker countries, hybrid e-learning is the way to go. In such cases more space is given to the face-to-face interaction with limited space given to websites and Internet. Hybrid e-learning is the type of learning that can be applicable in poor, rural schools in developing countries, and in Uganda in particular.

### 2.3. Hybrid E-learning

E-learning environment essentially consists of:

a. The courseware.

b. The course platform used for delivering the courseware.

c. The tools and applications necessary for managing the e-learning environment. Common tools for managing the Virtual Learning Environment (VLE) were:

- Communication tools (e-mails, bulletin boards, chat, and white board).
- Student tools (calendars, check grades, submit assignments, glossary, search).

• Course information tools (course outline, syllabus, time table, assessment methods).

• Course administration tools (student tracking, archive for student grades).

• Interactive content delivery (activities, library and multimedia resources, assignments)

• Self assessment tools.

In this study students continued to attend normal classes in their respective schools. The traditional classroom system remained. This was because the students came from poor backgrounds where there were no computing facilities and broadband at home. The schools could afford to acquire and network a few refurbished computers that had to be upgraded to multimedia capabilities. Therefore, the main course delivery platform that could be achieved was the use of CD-ROMs.

Use of linux/Unix based open source platforms was encouraged. Proprietary/commercial Microsoft products were both not affordable and sustainable by poor, rural schools. They were also considered unreliable for rural educational purposes. In this study, the Mambo, an open source Course Management System, was used for managing the learning environment. It was hosted by B-one, an open source web-hosting provider. The website for the project was http://www.aruaeduc.com.

To enable the schools to access Internet and other resources from the website, Faculty of Technology set up an ICT Research Station with VSAT connectivity near the schools. Teachers and students were allowed to visit the Research Station. They were given e-mail accounts. Some content were sent as e-mail attachments to students. Assignments, tests and examinations will be done using the traditional methods. Course information like syllabuses, timetables were posted on the project website. Course administration tools like student tracking and archive of student grades continued to be done as it was by the schools. Assessment in the study remained in the hands of the national examination body, UNEB.

#### 2.4. Hybrid Digital Library

The combination of mixing traditional learning methods in classrooms while delivering content mainly by using interactive multimedia CDs was termed hybrid e-learning.

Using the same argument, the term hybrid digital library in the context of this study means a combination of the traditional methods of using the physical library textbooks in the school and getting library content in CDs. The idea of open source was also extended to library issues based on the Open Archive Initiative (OAI). The free and unrestricted online availability of literature materials is called open access. Freely accessible online books was downloaded on CDs and taken to the schools without paying for them. Each book was downloaded as a file on the computer.

# 2.5. Rural School Concept

The term 'rural' in the developed world means 'sparsely populated'. Within the context of this thesis, the term rural means 'poor'. Therefore, a rural school is to be understood as a poor school that cannot afford to build and equip science laboratories, it cannot afford to build libraries and stock them with relevant textbooks, it cannot attract and retain qualified and committed science teachers.

# Chapter three: Problem Statements and Research Question

#### 3.1. Problem Statements

Rural advanced secondary schools in Uganda perform poorly in Physics and Mathematics subjects due to a number of reasons. The most critical problems in this context are the following.

a) Lack of laboratories where experiments and demonstrations can be done (the rural schools cannot afford the construction of laboratories). A typical secondary school laboratory costs about 423 million Uganda shs (228,650 USD). Rural secondary schools cannot afford this financial expenditure.

b) Many rural schools have no libraries. Yet a library is a useful resource for learning and teaching. Those schools that have 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 US. In Uganda, a conservative estimate would be within the vicinity of 75,000 USD. This is extremely expensive for a rural school.

c) Rural schools do not attract good 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 semi-urban schools constantly upgrade their qualifications unlike their counterparts in rural areas who do not have such opportunities.

#### 3.2. Research Questions

The above scenario justifies research questions that need to be addressed as regards rural A-level secondary Physics and Mathematics education in Uganda:

The main research question is:

• Can hybrid e-learning be introduced in rural, advanced-level secondary schools to support the learning of Physics and Mathematics?

The research questions closely linked are:

• What kind of impacts can a hybrid e-learning project have in a complex context involving a number of vital stakeholders?

• Internet has been introduced in educationally elite secondary schools in Uganda but why is e-learning not being implemented in such schools?

• Why is it that ICT in education projects are mainly repeatedly implemented in established, elite, well-to-do secondary schools like Mt. St. Mary's College, Namagunga; Trinity College, Nabbingo; Kings College, Buddo; Kyambogo College; Teso College, Aloet; etc. and the poor rural schools, who are the majority in the country are ignored?

• What effects can be found when unserviceable and life-expired computers from the developed countries like UK are sold to secondary schools in Uganda?

• Why are educational software issues not being mentioned while introducing ICTs in schools?

• Why are schools being encouraged to purchase used computers yet most of the secondary school teachers and administrators have no basic ICT skills?

# Chapter four: Objectives of the Research

4.1. Overall Research Objective

The overall research objective is to improve performance of female students in Ugandan rural schools in Mathematics and Physics subjects and get female students from such rural disadvantaged schools enrolling for science and technology courses in tertiary institutions.

In order to achieve the objective the research project is divided into two parts. The objective of the first part is to develop appropriate tools and implement hybrid e-learning to support science education of female students in typical rural advanced-level secondary schools.

The objective of the second part is to study change in the mean Mathematics and Physics scores of the sampled female students from rural A-level secondary schools after applying hybrid e-learning in Mathematics and Physics subjects.

The purpose of the present study is to develop appropriate tools and implement hybrid e-learning to support science education of female students in typical rural advanced-level secondary schools.

# 4.2. Specific Research Objectives

The specific research objective of the whole research project is to find out the potential effect of hybrid e-learning on Mathematics and Physics scores of female students in rural Advanced-Level secondary schools and the factors that affect intra- and inter-individual change after introducing hybrid e-learning in the teaching and learning of the subjects.

The specific research objective of the first part is to introduce limited virtual course or hybrid e-learning in the rural girls' government-aided secondary schools. Therefore, the licentiate study will aim at achieving the following specific objectives:

1. To develop an online local content course material according to the current curriculum 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 a digital library for use by the A-level secondary students as a source of reference materials.

# The following aims will be included in the PhD Thesis.

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

# The plan for the first part:

secondary education.

1. Set up an ICT Research Station with VSAT Internet connectivity in a rural area using the triple helix methodology.

2. Identify suitable open source platform for managing the hybrid e-learning environment.

3. Design and develop interactive multimedia training CD-ROMs for advancedlevel Physics and Mathematics.

4. Develop sustainable digital libraries for use by advanced-level Physics and Mathematics students.

5. Identify appropriate research methodologies relevant for the implementation of hybrid e-learning in secondary schools.

6. Design, develop and maintain website for the hybrid e-learning project. Students and their subject teachers will be given e-mail accounts for easy communication during the project.

7. Train students and subject teachers in basic ICT skills, Internet use and working with e-mails.

8. Set up a content server at the ICT Research Station to support advanced level Physics and Mathematics students.

# Chapter five: Research Location

# 5.1. Arua District

Arua (see fig. 1) is remote, insecure and one of the poorest rural districts of Uganda. It is approximately 500 kms from Kampala, the capital of Uganda. It is situated in the North Western part of Uganda in the West Nile region. 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 spill over into Arua district.

There are two advanced-level girls' secondary schools in Arua that have failed to send any students on merit to Makerere University, Faculty of Technology, for engineering training. The two schools are Muni Girls' Senior Secondary School and Ediofe Girls' Senior Secondary School (here after referred to as Muni and Ediofe respetively).



Fig. 1 Map of Uganda showing the location of Arua district

# 5.2 The Two Cases

Field visits were made to Muni and Ediofe to determine the status of science infrastructure in both schools. Both schools have no senior laboratories for advanced-level science practicals. Both are boarding secondary schools. The students are accommodated at the schools. Ediofe is Catholic founded while Muni is protestant-based. The schools have a reliable supply of thermal electricicty from a local power generation and distribution company, the West Nile Rural Electrification Company Ltd (WENRECO).

Ediofe has an incomplete junior block of science laboratories built with the help of UNHCR. The condition for paying back the money is that every year the school admits about 20 refugee students who study free until the amount of money used for paying for the construction of the laboratory block is fully recovered. Plumbing, electrical installation and equipping of the laboratories was not done. Muni converted one of the classrooms to 'act' as a junior laboratory for ordinary-level science practicals. This improvised laboratory acts as Physics, Chemistry, Biology and Agriculture laboratories with one laboratory technician.

Both schools have libraries. Ediofe library was built using donations by Manos Unidas of Spain. The library in Muni was built in 1992 with the help of a group of Swedish students who supported the Protestant Church Projects at that time. Both libraries have no qualified librarians. Muni assigned a qualified teacher to take up the role of the missing librarian. Ediofe assigned a non-teaching staff to take care of the post.

There is shortage of qualified teachers in both schools. The Physics teacher in Muni is not qualified to teach at advanced-level. Muni's Mathematics teachers at advanced level are part-time teachers. They are not on government payroll. They are paid on piece-meal basis by the school. Their commitment is lacking since they do not have any contract with the Ministry of Education and Sports. They teach in a number of other schools, just for purposes of getting more remuneration. Ediofe has good, qualified advanced-level Physics and Mathematics teachers but they are the only ones for the whole school, both ordinary and advanced levels. Timetabling them is a big challenge in the school. The Mathematics teacher also does accounting work in the bursar's office.

Muni, which was started in 1983, stopped admitting students for sciences in late 1990s but resumed the exercise in 2003 when the government started emphasizing on science subjects. Now science subjects are compulsory in all secondary schools in Uganda. Both Muni and Ediofe admit very few students for sciences. Of all the science subjects, students of both schools try to avoid subject combinations that contain both Physics and Mathematics. There is only one student in Ediofe in advanced level taking a combination of Physics, Chemistry and Mathematics, PCM. This is the required combination for future engineering students. Muni does not have any student taking PCM combination.

Because students are not sure of passing science subjects, they take an additional principal arts subject at advanced level. Common arts subjects are Fine Art, Music, Languages (e.g. French). Results show that they do better in the arts subjects than the core science subjects in their combinations. This boosts the number of points the students get when being

considered for admission in tertiary institutions. It is not clear whether such students should be allowed to pursue further science education yet they passed arts subjects well. Though the schools have no functional computer laboratories, attempts are being made to acquire them. Ediofe is using a side store in the library as a computer laboratory and has 14 refurbished computers. Only 10 computers have been installed and networked in that small store. Space was not enough for all of them. The networking is peer o peer since there is no server. Muni has 10 refurbished computers all installed and similarly networked. They are in the laboratory preparation room. Since there is no laboratory technician sitting there, the room is being used as a computer room. The school intends to purchase 10 more refurbished computers, and that time space will be an issue. Fortunately, the school has provided for a proper computer laboratory in their three storied classroom block which is under construction now. It is being roofed.

# Chapter six: Research Methodology

#### 6.1. Research Modes

The traditional (western) academic research culture defines two types of research: basic (or fundamental or pure) research and applied research.

Basic research has as its primary objective in the advancement of knowledge and the theoretical understanding of the relations among variables. It is exploratory and often driven by the researcher'scuriosity, interest, or hunch. It is conducted without any practical end in mind, although it may have unexpected results pointing to practical applications. The terms "basic" or "fundamental" indicate that, through theory generation, basic research provides the foundation for further, sometimes applied research.

Applied research is done to solve specific, practical questions; its primary aim is not to gain knowledge for its own sake. It can be exploratory, but is usually descriptive. It is almost always done on the basis of basic research.

This licenciate thesis is more directed towards what is traditionally called applied research.

#### 6.2. Action Research

There are many research methods used by scholars. In this thesis, the Action Research method is more suitable.

Action research is a research method which has dual aims of action and research:

- Action to bring about change in some community or organisation or programme;
- Research to increase understanding on the part of the researcher or the client or both (and often some wider community).

Action Research is a process designed to empower all participants in the process (e.g students, teachers, and other parties) with the means to improve the practices conducted within the organization's experience. All participants are knowing, active members of the research process.

#### 6.2.1. Characteristics of Action Research

There are three main characteristics of an Action Research:

• Action research is cyclic (or spiral). The action research cycle consists of at least an intervention or planning before action and a review or critique after.

• It is primarily qualitative. Qualitative research can be more responsive to a situation. A need for responsiveness is one of the compelling reasons for choosing action research.

• Participation is another requirement. Participation can generate greater commitment and hence action. Since change is a desired outcome, it is more easily achieved if people are committed to the change.

#### 6.2.2. Action Research Design

The essentials of action research design consists of the following cycle:

• Initially an exploratory stance is adopted, where an understanding of a problem is developed and plans are made for some form of interventionary strategy. *(The Reconnaissance & General Plan.)* 

- Then the intervention is carried out. (The Action in Action Research)
- During and around the time of the intervention, pertinent observations are collected in various forms. (Monitoring the implementation by *Observation*.)
- The new interventional strategies are carried out, and the cyclic process repeats, continuing until a sufficient understanding of (or implement able solution for) the problem is achieved *(Reflection and Revision)*.

The protocol is iterative or cyclical in nature and is intended to foster deeper understanding of a given situation, starting with conceptualizing and particularizing the problem and moving through several interventions and evaluations.

## 6.2.3. Justification for the Action Research Approach

In the action research process, it is not possible to detach the researcher from the practitioners (the teachers, female students, district education officers, etc). The researcher is continuously involved in making small plans with the practitioners, implementing them and reviewing the outcomes. This is a cyclic process. It is repeated over and over during the research process. In this way, according to research and action are integrated (Fraser, 2000). Furthermore, action research, with its emphasis on diagnostic problems and initiating actions as collaborative process between the researcher and practitioners, has relevance to the research situation or context. Action research as a particular qualitative research method "is unique in the way it associates research and practice so research informs practice (and researchers and practitioners) through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework. Action research is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention and reflective learning. Action research encourages researchers to experiment through intervention and to reflect

on the effects of their intervention and the implication of their theories. In action research, the researcher wants to try out a theory with practitioners in real situations, gain feedback from this experience, modifying the theory as a result of this feedback, and trying it again. Each iteration of the action research process adds to the theory- so it is more likely to be appropriate for a variety of situations. In action research, the emphasis is more on what practitioners do than what they say they do.

#### 6.2.4. Critics of Action Research

Believers in the traditional conventional methods of conducting research are unleashing a lot of criticisms on action research methods. Some of the concerns according to (Dickens and Watkins, 1999) are that the action research is:

- Either producing research with little action or action with little research;
- Lacking the rigour of true scientific research;
- Lacking the internal and external control (or internal and external validity).

Other critics also add that action research is biased because the researcher is an 'insider' and not independent in the research. Other positivists argue that action research is a 'just little more than a consultancy'.

In a rebuttal Koch, McQueen and Scott (1997) maintain that

the progress through iterations allows the researcher to gradually broaden the research scope and in consequence add generality to the research findings. Effective application of the iterative approach to action research has the potential to bring research rigour up closer to standards acceptable by positivists and yet preserve the elements that characterize action research as such.

#### 6.2.5. Situating Action Research

The problem of situating action research in a research paradigm is well explained by O'Brien (2001) by identifying three research paradigms: Positivist Paradigm, Interpretive Paradigm and Paradigm of Praxis.

The dominant and most conventional research paradigm has always been the Logical Positivism. This paradigm strongly believes in objective reality, knowledge of which is only gained by sense data that can be experienced and verified between independent observers. Phenomena are subject to natural laws that humans discover in a logical manner through empirical testing, using inductive and deductive hypotheses derived from a body of scientific theory. The methods of Logical Positivism rely heavily on quantitative measures, with relationships among variables commonly shown by mathematical means. Positivism used in scientific and applied research has been considered anti action research.

Interpretive Paradigm emerged in the social sciences to break out the constraints imposed by positivism. With its emphasis on the relationship socially-engendered concept formation and language, it has been referred to as Interpretive Paradigm. Containing such qualitative methodological approaches like ethnography, phenomenology, etc. it is characterized by a belief in socially constructed, subjectively-based reality, one that is influenced by culture and history. Nonetheless, it still retains the ideals of researcher objectivity, and researcher as passive collector and expert interpreter of data.

There are people who feel neither the positivist nor interpretive paradigms are sufficient epistemological structures under which to take action research. Rather, a paradigm of praxis is seen as where the main affinities lie. Praxis is the art of acting upon the conditions one faces in order to change them. The word was used by Aristotle. Praxis deals with disciplines and activities predominant in the ethical and political lives of people. Aristotle contrasted this with Theoria- those sciences and activities that are concerned with knowing for its own sake. That knowledge is derived from practice, and practice is informed by knowledge, is an ongoing process. This is the cornerstone of action research. Action researchers also reject the notion of researcher neutrality, understanding that the most active researcher is often one who has most at stake in resolving a problematic situation.

This research adopts the Paradigm of Praxis approach. With action research consisting of two simultaneous cyclic activities (McKay and Marshall, 2001), two methodologies will be used: one for action process (practice) and one for research (generation of knowledge). These are the Participatory Methodologies and Multilevel Analysis Theory.

#### 6.3. Participatory Methodologies

According to Wikipedia, there are five major action research theories:

- 1. Chris Argyris' Action Science
- 2. John Heron and Peter Reason's Cooperative Inquiry
- 3. Paulo Freire's Participatory Action Research (PAR)
- 4. William Torbert's Development Action Inquiry
- 5. Robert Chambers' Participatory Rural Appraisal

Argyris' action science is useful for increasing professional effectiveness of organisations.

The Cooperative Inquiry brings peers (e.g. doctors, social workers, young women managers, etc) together in self-study groups. All the active subjets are fully involved as co-researchers and take part in all research decisions to be made. They do research 'with' people and not 'on' people. This is a higher level of doing research.

The Development Action Inquiry methodology was suggested by Professor William Rockwell Torbert. It is a methodology for simultaneously conducting action and inquiry as a disciplined leadership practice that increases the effectiveness of ones actions. The methodology is useful for developing leadership capacities of people.

The Participatory Action Research approach primarily in the southern hemisphere, concerns empowering the poorest and least educated members of society for literacy, for land reform analyses, and for community. Hence, this approach is primarily 3rd-person in the scope of its intended societal transformations.

Participatory Action Research (PAR) is a method of research where creating a positive social change is the predominant driving force. PAR grew out of social and educational research and exists today as one of the few research methods which embrace principles of participation and reflection, and empowerment and emancipation of groups seeking to improve their social situation. Kurt Lewin is credited with the creation of action research (AR) in the 1940's.

McKay and Marshall (2001) recommend that action research should be looked at as two complimentary cyclic processes: the action process which is a problem-solving process and the research process aimed at acquiring knowledge and answering the research question(s). This means that there must be two methodologies: one methodology for action or problem-solving (practice) and another for research. McKay and Marshall make this clarification to enlighten critics who say action research is 'just a little more than a consultancy'.

The biggest problem with action research is that the idea about it is not widely disseminated. Most of the literatures about action research are in textbooks. There are few articles in journals that deal with action research. However, its application in solving social problems is generally gaining ground.

#### 6.3.1. Conceptual Framework of PAR

There are quite a number of ways different authors use to represent the cyclic nature of action research. One such representation is shown in figure 1. It was developed by Kemmis. All the four stages of action research are shown graphically: plan, act, observe, and critically reflect before repeating the cycle.



Figure 2: Concept of an Action Research Cycle developed by Kemmis

The group undertaking PAR identifies a thematic concern through discussion and reflection. These concerns are integrated into a shared or common goal. The group agrees to collaborate and participate in a PAR project because of this integrated goal. The group and the members of the group are thus empowered to plan and act to create a social change. A change in practice is affected and observed using an appropriate research tool. The group critically examines the results and then the group has new knowledge from which theory may be developed. This knowledge and theory may be focused on the observed effects of the change affected or the processes which occurred, or both. These principles also form a cycle surrounding the inner Moments of PAR. These principles are espoused by the authors already cited. During the entire research cycle the group keeps individual journals in which they observe and reflect upon the processes going on. These journals can become a source of data for analysis.*6.3.2 Participatory Rural Appraisal (PRA)* 

In the context of this licentiate thesis, the Participatory Rural Appraisal methodology was found to be more appropriate to use.

Participatory rural appraisal (PRA) is a label given to a growing family of participatory approaches and methods that emphasize local knowledge and enable local people to make their own appraisal, analysis, and plans for action. The approach is based on the involvement of community members in research and analysis, the starting point being the knowledge of local people, with an emphasis on learning from each other. Locally adapted methods and techniques (or tools) are used. Although originally developed for use in rural areas, PRA has been employed successfully in a variety of settings. The purpose of PRA is to enable development practitioners, government officials, and local people to work together to plan context-appropriate programs.

Participatory Rural Appraisal evolved from Rapid Rural Appraisal (RRA) -a set of informal techniques used by development practitioners in rural areas to collect and analyze data. Rapid rural appraisal developed in the 1970s and 1980s in response to the perceived problems of outsiders missing or miscommunicating with local people in the context of development work. Participation of rural people in RRA was passive; they were only required to respond to requests for information. Under RRA, it is the outsiders who learn. Some authors call this type of behavior 'rural development tourism'. PRA is a solution to RRA. In PRA, data collection and analysis are undertaken by local people, with outsiders facilitating rather than controlling. PRA is an approach for shared learning between local people and outsiders.

Depending on the context, there are a number of PRA tools or techniques that can be used to facilitate data collection, analysis and discussions resulting in action plans being drawn. Common tools are:

• Meetings (initial open meetings, final meetings, follow up meetings, group meetings, discussion meetings)

- Semi-structured interviews
- Focus group discussions
- Preference ranking

- Mapping and modeling
- Seasonal and historical diagramming
- Venn diagrams
- Seasonal calendar
- Animation
- Drama and video-production
- Production of seasonal calendars and daily time use analysis

The tools rely heavily on visualization and diagramming for easy understanding by rural people. What distinguishes PRA from other methodologies is its emphasis on participation. PRA practitioners generally believe that when participants are in full control- of needs assessment, goal setting, planning policy-making, implementation and evaluation- can a process be considered fully participatory.

PRA can be applied in both rural and urban settings. Walker, Sinclair and Thapa (1995) used PRA methodology while advocating for the need to incorporate indigenous knowledge of rural people in agroforestry development. The indigenous knowledge of rural people could only be received when they were allowed to actively participate in the exercise. One of the conclusions of Walker et al is that "facilitating active partnerships between development professionals and local people in research can help to result in effective and well-targeted research". Maalim (2006) successfully used the PRA methodology to assess and plan the health needs of the nomadic Somali communities in the North Eastern part of Kenya. Rydhagen (2001) also successfully used PRA to study urban Swedish sanitation system from experiences in rural South Africa. It was found that there is no involvement of Swedish users in sanitary decision making by sanitary engineers and specialists. This prompted Rydhagen to start advocating for the introduction of participatory practices in Swedish sanitation technology development.

# 6.4. Theory of Multilevel Analysis/Hierarchical Linear Modeling

# 6.4.1. Brief Introductory Remarks

This section will be relevant for the PhD thesis. It is introduced here for purposes of depicting a complete understanding of the whole research process.

# 6.4.2. Conceptual Framework of the Research Methodology

When a variable is a sub-category of another variable, the former is considered being 'nested' with the latter and their relationship is termed as hierarchical. Hierarchical Linear Modeling (HLM) is the analysis of models with two or three levels of nesting (i.e., multilevel analysis). Such models may be used to analyze growth and change within individuals.

# 6.4.3. Definition of Multilevel Analysis

This definition is taken from Anderson (2003):

Multilevel analysis is a methodology for the analysis of data with complex patterns of variability, with a focus on nested sources of variability.

There are many sources of variability in educational research: measurement errors, variability between individuals, between classes in schools, between students, etc. Variabilities exist

within and between groups in clustered/multilevel/hierarchically structured data. These variabilities are called regressions. Many hierarchical (multilevel) data structures exist which are relevant to education in which more than one level may influence individual performance of a student.

# 6.4.4. A School as a Hierarchy

A school is a typical hierarchy as shown in Table 2 below and Figure 3 is depicted the conceptual framework of the multilevel (hierarchical) nature of a school. In a school, students are 'clustered' or grouped within classes.

Hierarchy	Levels	Terminology	Labels
Schools	Level 3	Population	Macro
Classes	Level 2	Sub-population, primary units, groups	Meso
Students	Level 1	Individuals, secondary units	Micro

#### Table 2: An Example of a School as a Hierarchy



#### Fig. 3 Conceptual framework of a school as a multilevel structure

#### Forms of Multilevel Analysis/ Hierarchical Linear Modeling

There are many forms of Multilevel Analysis/Hierarchical Linear Modeling, depending on the nature of the data collected. In this study, the data collected is longitudinal. This means, repeated data is collected from the same individual/student more than once. It would be a cross-sectional data if the data was going to be collected once without repetition. Furthermore, multivariate regression techniques are not applicable since it cannot handle the issue of missing data (possible drop outs from the study) and also requires that the data measurements be taken at fixed intervals. In other words, multivariate analysis is suitable for balanced data only.

Therefore, longitudinal data will be used to create a model which will be useful in getting precise estimates of regression parameters.

# 6.4.5. Conceptual framework for Longitudinal Data

Measurements taken on the same subject are usually 'more alike' than measurements taken from different subjects. Also measurements on a given subject are 'more alike' the closer together they are taken in time. In other words, measurements taken close in time on the same subject tend to be more similar than measurements taken far apart in time. Therefore, the values measured on the same subject show association i.e correlation. Such type of date is called longitudinal data. The longitudinal data should be used to propose a model which is used as a basis for statistical analysis. A longitudinal model describes patterns of change as trends e.g. a straight line. And the model acknowledges associations among observations or measurements on the same subject. The model allows observations from the same subject to be correlated.

#### 6.4.6. Multi-Stage Sampling Design

Multistage sampling, a complex form of cluster sampling, was done to identify the target group of female students who were participating in the hybrid e-learning research project.

Arua district was chosen as a case study area for two reasons. An earlier study by an undergraduate engineering student in 2001 had found that the ICT business in the District could be viable and sustainable. The Makerere University, Faculty of Technology, followed this up by later setting up an ICT Research Station in Arua town. Secondly, by the time of designing this research project on ICT in Education, Arua was the eighth poorest district in Uganda where the research could be done. The other poorer districts were either those without any advanced-level girls' senior secondary schools (like Nakapiripirit, and Pader) or they were in rebel-infested districts (like Kitgum, Gulu, etc) and could not be accessed easily.

During field visits to Arua district, it was found that there were 71 government-aided secondary schools and only Muni and Ediofe are advanced-level girls' schools. The girls who were admitted to Senior Five in 2005 and were taking Physics and Mathematics were identified as students who will be participating in the study.

#### 6.4.7. Collection of Longitudinal Data

This is a longitudinal study since repeated measurements will be done on the same individuals over a period of two years. There are two equal measurement occasions- when the students sit for national examinations set and centrally administered by UNEB.

Performance of the female students in Physics and Mathematics at national examinations will be recorded twice by getting results released by UNEB. The first results were collected when the Senior Four results were released in 2005. These results were collected from the schools. Then hybrid e-learning intervention was made and the students are expected to sit UNEB examinations again in November 2007. And their performance in Physics and Mathematics will be recorded again. The research design is as shown in table .3.

No.	Year	200 (Ba	5 se yea	r)	200	6		20	07		2008
1	School Terms	1	2	3	1	2	3	1	2	3	Analysis of data
2	Measurement Occasions or time			1						2	Writing dissertation Defense of Thesis
3	Class of female student	Seni UN (O1	Senior 4 UNEB results (O level)		Senior 5 (Admission)		Sei (A	Senior 6 (A level)		University admission, Year 1	

Table 3: The Research Design Plan

#### 6.4.8. Data analysis

Performance longitudinal data were collected from the same students twice: in 2005 (when the student completed Senior 4) and in 2007 (when the student completed Senior 6). Student's paired t-test was used to analyze the data because of the following reasons: 1. The sample size was small (less than 20). The only test that deals with problems associated with inferences based on 'small' samples is the t-test. 2. While two sets of data were measured, the sample was the same. The second 'sample' was not randomly selected; it was the same first sample. Unpaired t-test could not be applied to the data because the second sample was not randomly chosen.

In this study, the aim was to find out if introduction of hybrid e-learning led to improvement of the performance of advanced-level female students in Mathematics and Physics. The outcome variables were indicated bellow:

x- Performance scores of a student before the introduction of hybrid e-learning, and

y-Performance scores of a student after the introduction of hybrid e-learning.

To test the hypothesis that the true mean difference was zero, the following procedure was used:

The difference  $(d_i = y_i - x_i)$  between the two observations on each pair was calculated. Positive and negative differences were noted.

The mean difference,  $\overline{d}$  was calculated.

The standard deviation of the differences,  $s_d$  and the standard error of the mean difference were calculated  $SE(\bar{d}) = \frac{s_d}{\sqrt{n}}$ .

The *t*-statistic, *T*, was calculated using the expression  $T = \frac{d}{SE(d)}$ . Under the null hypothesis, the *t*-statistic follows a *t*-distribution with *n*-*I* degrees of treedom.

The tables of the t-distribution were used to compare the value for T and the distribution  $t_{n-1}$ . That gave the *p*-value of the paired *t*-test.

The 95% confidence interval for the mean difference was calculated. The aim was to determine the limits within which the true difference was likely to lie. A 95% confidence interval for the true mean difference was determined from the expression:  $\bar{d} \pm t^*$ .  $\frac{s_d}{\sqrt{n}}$  or

equivalently  $\bar{d} \pm t^*.SE(\bar{d})$ , where  $t^*$  was the 2.5% point of the *t*-distribution on *n*-*I* degrees of freedom.

STATA and SPSS software were used for carrying out the calculations.

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# Part II

## Introduction to the Papers

This licentiate thesis deals with applied research activities when implementing hybrid elearning to support Physics and Mathematics education of advanced-level secondary school girls in the remote, poor and insecure District of Arua, Uganda. The thesis includes an extensive literature survey on the concept of e-learning in general and hybrid e-learning in particular. 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 Digital Libraries for Advanced-Level Rural Secondary Schools in Uganda, by Peter Okidi-Lating, Samuel Baker Kucel and Lena Trojer. Unpublished report.

# Paper I

# Strategies for Implementing Hybrid E-learning in 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

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, 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.

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

Table 1. Graduations of Undergraduate Students by Gender from Faculty of Technology, Makerere University, March 2000 to March 2003

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 other 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 5. This is so low if you compare with a country like Sweden that had 516.3 in the same report.

# 4.0. Internet Connectivity 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 web 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-ROM.

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.

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# 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 80 Districts, it means secondary schools in 76 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 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 2007 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 80 Districts in Uganda. Therefore, 76 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. Elearning 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 Mamboand 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 240 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 of 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.

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%

#### Table 1: 2003 Enrolment by gender in Ugandan educational institutions

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 80 districts, and secondary schools in 76 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 the buildings, burglarproofing them and converting the main buildning 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. 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 2007. 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 governmentaided 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 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: Componenets 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 dialup 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 buildings 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.

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# 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 Development Procedure for 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 only 4 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 Productions 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<sup>®</sup> 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

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 photoquality results of 2400dpi and 48-bit colour. This made the exercise of digitalization very tedious.

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	

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

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 handwritten, 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.

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#### Paper IV

# Development of Sustainable Digital Libraries for Advanced-Level 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

This paper shows how digital libraries were implemented in disadvantaged, poor, rural advanced level girls' secondary schools to support Physics and Mathematics education. 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 have very low computer literacy skills. Hybrid digital libraries were introduced in the schools. Local contents were collected from several sources, digitized (by scanning or typing handwritten notes into the PCs.) before saving them on CD-ROMs and delivered to the schools. All the teachers and students were trained in ICT skills. CD-ROMs were found to be the only effective media for delivering content to students and teachers in the schools. After that, additional interactive training CD-ROMs were purchased and given to the schools. The students and their teachers were allowed access to the Faculty of Technology ICT Research Station with VSAT Internet connectivity for content they may need from the Internet or from some Websites. This Research Station is within 5 km radius from each of the schools.

Keywords: Rural Education; Digital Libraries; Electronic Libraries; Virtual Libraries; Uganda; Libraries

#### Introduction

Currently in Uganda, engineering courses are predominantly offered by only two Universities: Makerere and Kyambogo Universities in the Faculties of Technology and Engineering respectively. However, there is a serious gender disparity in the enrolment of students for engineering training in the country. Makerere University in Kampala was started in 1922 and it was only in 1970 when it created the Faculty of Technology and admitted the first engineering students. Kyambogo University, located also in Kampala, is a new University which was created by an act of parliament in 2003.

According to Turygyenda, Kibira and Lugujjo (2005) for the last 35 years of the existence of the Faculty of Technology, 2040 students were graduated of which only 420 were females. This means that only 20.5% of the graduates were females during the said period. During the 2004/5 academic year, the Faculty of Technology had a total enrolment of 1094 undergraduate students of which only 208 were females giving a female enrolment ratio of 19%. Turyagyenda *et al* further note that there is equally low female students' participation in engineering training in Kyambogo University. In 2004/5 academic year, Kyambogo University, Faculty of Engineering, had 1011 undergraduate students of which 99 (or 11%) were female students.

Admission into Universities in Uganda is based mainly on the performance of the advanced level secondary students at the Uganda Advanced Certificate of Education (UACE), a national examination that is set and centrally administered through out the country by the Uganda National Examinations Board (UNEB). The essential subjects required for engineering training are Physics and Mathematics. These subjects are weighted highest during consideration of applicants for entry into the engineering faculties.

The few female students who qualify for engineering education are mainly those who studied in urban, elite schools. The majority of the rural girls' secondary schools performs poorly in Physics and Mathematics and consequently cannot be admitted into engineering faculties.

According to Lating, Kucel and Trojer (2006b), one of the causes of low rural female participation in engineering training in Uganda is the lack of libraries in advanced level secondary schools. Absence of functional physical libraries makes students perform poorly at Uganda Advanced Certificate of Education examinations by UNEB. These are University entry examinations.

This article starts by looking at the situation in two typical rural advanced level girls' secondary schools in Arua District in the West Nile region of Uganda. This is one of the poorest districts in Uganda and is 500 kms from the Kampala, the capital city of Uganda. In the circumstances of non-functional conventional libraries in the two girls schools the paper then attempts to introduce a digital library for the benefit of the female students of Mathematics and Physics.

A study of literature on digital libraries was done and the article describes how a dual approach was used to introduce hybrid libraries in the schools. The viability of using CD-ROMs as a main content delivery method in poor schools is discussed.

The paper concludes by recommending that CD-ROMs are effective content delivery

media when introducing digital libraries in disadvantaged schools.

# **Status of Libraries**

There are two rural advanced-level girls' secondary schools in the District of Arua. Arua is in the North Western part of Uganda popularly known as West Nile region of Uganda. The two advanced-level girls' secondary schools in Arua are 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.

Muni and Ediofe have physical/conventional libraries that were built and furnished through donations from abroad. The library in Ediofe was built and furnished by Manos Unidas of Spain at approximately 60 million Uganda shillings while the library in Muni Girls was built in 1992 using funds provided by the Swedish students' organization.

The 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.

# Textbook Resources

There are very few copies of the relevant textbooks in both libraries. The number of relevant text books for Advanced-Level Mathematics and Physics are shown in the table 1. In most cases the numbers of the available textbooks are not enough for the subject teachers in the school.

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 3 <sup>rd</sup> edition	Mathematics	7	20
5	Pure Mathematics Book1 (1985).J.K. Backhouse 3 <sup>rd</sup> Edition.	Mathematics	7	13
6	Advanced Mathematics by L.K. Turner	Mathematics	0	20

Table 1: List of Physics and Mathematics Textbooks in Ediofe and Muni Girls' Secondary Schools, Arua

It must be mentioned that there are many irrelevant titles of textbooks in the libraries of both schools. These books get into the libraries as donations from interested organizations or individuals. Sometimes the schools themselves buy such books on recommendation by the subject teachers. Neither the Ministry of Education and Sports nor the National Curriculum Development Center provide a list of recommended textbooks to schools. The subject teachers check previous UNEB examination past papers and determines the topics where examination questions are frequently set. Then they advice the school administration to buy the books they think are useful. In rare circumstances, the Ministry of Education and Sports gives books to schools but they are generally Ordinary Level text books, not for Advanced Level students. Table 2 shows the number of book titles available in both libraries.

No	Subject	Numbe Titles in Library	Number of Titles in the Library		Number of Titles with only one or two copies only		Percentage of book titles with only one or two copies in the library	
		Ediofe Girls' SS	Muni Girls' SS	Ediofe Girls' SS	Muni Girls' SS	Ediofe Girls' SS	Muni Girts' SS	
1	Physics	46	53	36	43	78.3%	81.1%	
2	Mathematics	74	97	49	60	66.2%	61.9%	

Table 2: Numbers of book titles in Muni and Ediofe libraries

Most of the textbooks are one or two copies only in the libraries.

The schools try to stock Science and Mathematics textbooks but claim that such textbooks are very expensive. Expenditures of the schools on textbooks from 2003 to 2005 are shown in table 3:

			/				
School	2003		2004		2005		
	UGX	USD	UGX	USD	UGX	USD	
Muni Girls' SS	3,154,400	1,615	4,408,000	2,543	0	0	
Ediofe Girls' SS	9,065,000	4,640	9,265,000	5,344	8,650,000	4,696	

Table 3: Expenditures of Muni and Ediofe on text books, 2003-2005

NB: 1. USD- United States Dollars; UGX- Uganda Shillings.

2. The exchange rates used for December 2003, 2004 and 2005were obtained from the Uganda Revenue Authority website: http://www.ugrevenue.com/exchange\_rates/

With the above budget for textbooks, schools find it difficult to buy textbooks for Physics and Mathematics. In September, 2006 a survey of the prices of relevant advanced-level textbooks for Physics and Mathematics was done. The prices are depicted in table 4. This explains why schools buy only one or two copies of the Physics and Mathematics textbooks.

No.	Author(s)	Title of Book	Edition	Year of	Price	
				Publication	UGX	USD
A	Physics Textbook	8				
1	Micheal Nelkon,	Advanced Level	7 <sup>th</sup> Edition	2001	65,000	35
	Philip Parker	Physics				
2	Roger Muncaster	A-Level Physics	4 <sup>th</sup> Edition	1993	89,000	48
3	Tom Duncan	Advanced	5 <sup>th</sup> Edition	2005	65,500	35
		Physics				
4	Steve Adams,	Advanced	1 <sup>st</sup>	2000	69,500	38
	Jonathan Allday	Physics	Publication			
5	Michael Nelkon	Principles of	8 <sup>th</sup> Edition	1996	45,800	25
		Physics				
6	Keith Gibbs	Advanced	2 <sup>nd</sup> Edition	2005	17,000	9
		Physics				
B	Mathematics Textbooks					
1	J.K. Backhouse,	Pure	4 <sup>th</sup> Edition	1985	32,000	17
	S.P.T.	Mathematics I				
	Houldsworth					
2	J.K. Backhouse,	Pure	3 <sup>rd</sup> Edition	1985	32,000	17
1	S.P.T.	Mathematics II				
	Houldsworth,					
	B.E.D. Cooper					
3	C.J. Tranter	Advanced Level	4 <sup>™</sup> Edition	1975	18,900	10
		Pure				
		Mathematics			68.000	
4	A.J.Sadler,	Understanding	2 <sup>nd</sup> Edition		62,000	34
	D.W.S Thorning	Mechanics	445 27 27.1	2001	60.000	
5	C. Crawshawn, J.	A Consise Course	4 <sup>th</sup> Edition	2001	68,000	31
	Chambers	in Advanced				
L		Level Statistics		1005	44.500	24
6	J.F. Jaibert, H.H.	Additional	6th Edition	1995	44,500	24
L	Heng	Mathematics	1	1000	55.000	
7	L. Bostock, S.	Mechanics for		1996	75,000	41
1	L Chondlar	Advanced Level	L Publication	1	1	1

Table 4: Prices of Physics and Mathematics textbooks from Aristock bookshop, Kampala NB: 1USD= 1,848 UGX as in September 2006

#### Computer Resources

Both schools 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. In case of power outage, Muni Girls has a standby generator. There is solar electricity for lighting in some classrooms in Ediofe Girls.

Both schools are located in an area where the two national mobile telecommunications operators have a mobile telephone network coverage based on the GPRS technology. The two competing companies are the MTN and Celtel Uganda.

Though both schools have no computer laboratories, each created a computer laboratory from the existing structures. For example, Ediofe girls converted a store in its library into

a computer laboratory and installed 11 of the 15 computers they have in it. They have no space to install the remaining four computers. Muni girls converted the preparation room in the laboratory into a computer laboratory and installed ten computers in it. All the computers are refurbished and the schools bought them cheaply from the National Curriculum Development Center (NCDC). Each of these computers was bought at 175 USD (303,380 UGX) in 2004. Unfortunately, the computers hardly have any multimedia capability. The results of technical inspection of the computers in Ediofe Girls are depicted in table 5.

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.

Table 5: Results of technical inspection of Ediofe refurbished computers purchased from NCDC

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.

Muni Girls intends to purchase ten more refurbished computers from Uconnect, an NGO which is located in the Ministry of Education and Sports headquarters in Kampala. Muni Girls is soon completing a modern storied classroom block in which a computer laboratory has been provided for.

The computers in both schools have been networked (peer to peer) to avoid the cost of purchasing servers. The networking ensures that the computers can share resources (e.g. files). Furthermore, both schools are not connected to the Internet. Teachers and students at both schools have no basic computer literacy skills.

A question that needs to be answered is: Since the schools cannot afford to stock libraries with relevant Physics and Mathematics textbooks, can a sustainable digital library be introduced in the schools for the benefit of the disadvantaged female Physics and Mathematics students?

#### **Concept Discussion**

The term 'digital library' is usually defined differently depending on the author. This complicates the understanding of the concept. According to Cleveland (1998), the idea of easy, finger-tip access to information-what is conceptualized as digital libraries todaybegan in 1945 with Vannenar Bush's Memex machine. The concept has continued to evolve with each advance in information technology. With the arrival of computers, the concept centered on large bibliographic databases, the now familiar online retrieval and public access systems that are part of any contemporary library. When computers were connected into large networks forming the Internet, the concept evolved again, and research turned to creating libraries of digital information that could be accessed by anyone from anywhere in the world. Phrases like "virtual library," "electronic library," "library without walls", "library without books", "electronic library", and, most recently, "digital library," all have been used interchangeably to describe this broad concept. Zhou (2005) reports that the concept of digital libraries was first proposed by scholars from the United States of America as late as in the beginning of 1990s. This was the period when many libraries and museums (cousins of libraries) started to aggressively digitize content as a means of preserving culture and artifacts. Magara (2002) defines digital libraries in the context of Uganda as "those libraries that are greatly aided by networks, have and can access electronic databases, have an online public access catalogue and to some extent provide e-mail and Internet services to its users, and at least a certain percentage of their information resources are in electronic format". This paper adopts the view point of the American Library Federation which in 1998 defined digital libraries as (Ke & Hwang, 2000):

Digital libraries are organizations that provide the resources, including the specialized staff, to select, structure, offer intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of collections of digital works so that they are readily and economically available for use by a defined community or set of communities.

With the assumption that digital libraries are libraries first and foremost, we can list some characteristics. These characteristics have been gleaned from various discussions about digital libraries, both online and in print (see Cleaveland, 1998).

- Digital libraries are the digital face of traditional libraries that include both digital collections and traditional, fixed media collections. So they encompass both electronic and paper materials.
- Digital libraries will also include digital materials that exist outside the physical and administrative bounds of any one digital library.
- Digital libraries will include all the processes and services that are the backbone and nervous system of libraries. However, such traditional

processes, though forming the basis of digital library work, will have to be revised and enhanced to accommodate the differences between new digital media and traditional fixed media.

• Digital libraries ideally provide a coherent view of all of the information contained within a library, no matter its form or format

• Digital libraries will serve particular communities or constituencies, as traditional libraries do now, though those communities may be widely dispersed throughout the network.

• Digital libraries will require both the skills of librarians as well as those of computer scientists to be viable.

From the above characteristics, it can be concluded that digital libraries are hybrid libraries since they include the electronic (digital) as well as print and other (e.g. film, sound)

materials. The challenge is how to introduce hybrid libraries in poor, rural schools like Muni and Ediofe to support advanced-level Physics and Mathematics training.

# Methods

The methodology is inspired by action research (Argyris, Putnam, & Smith ,1985).

The research approach is process oriented but with a clear vision. Neither the process nor the activity plan can be known in detail before hand in a context where a number of stakeholders are cooperating. In order to make use of all the potentials in this research approach the grounding in an explicit epistemological base is essential. The latter is embedded in the understanding of knowledge production to be distributed and focused on being socially robust (Nowotny, Scott, & Gibbons, 2001).

A continuous learning process with double looping (Smith, 2001) is also subject for practice in the research activities, which is an important dimension of what is called PRA, participatory Rural Appraisal (Rydhagen, 2002; Chambers 1997).

# Results

To facilitate deeper understanding of the methods used in creating digital libraries, some literatures were reviewed. Zhou (2005) emphasizes that in creating digital libraries in China, digital librarians were trained first. Sources of content and its digitization, copyright issues, storage, retrieval and dissemination in digital library development are covered in the works of Jeeven (2003). Lin and Simske (2004) give the specifications for scanning digital content with subsequent re-mastering to eliminate any errors engendered during the creation of the digital library. Re-mastering produces a high quality digital content after scanning the materials.

When creating sustainable digital libraries for advanced level Physics and Mathematics students in Ediofe and Muni, two approaches were followed. Some aspects of the digital library were implemented in the schools by delivering content in CD-ROMs. Within a 5-km radius from both schools, the Faculty of Technology set up an ICT Research Station with VSAT Internet connectivity. Students and teachers have access to this facility for additional resources and receiving content through project website and e-mails.

# A: The Girls Schools

# Upgrading Pentium I, II omputers in the Girls' Schools

The refurbished computers in the schools were upgraded to the following specifications: 40GB of hard disk drive capacity, 128 RAM and the following software were installed: WinXP serv. II, Win2000 ser.II, MS Office 2003 2<sup>nd</sup> Edition, McAfee (2006) for antivirus, Acrobat Reader ver.7.0, Macromedia Flash ver. 8, and Fire works ver. 8. The total cost of upgrading these computers was approximately 2,240,000 Ugandan Shillings (UGX). The upgrade and repairs would have been enough to purchase eight more such refurbished computers. The purpose of upgrading them was to let them have multimedia capabilities. The upgrade of the computers was done using funds from the research project supported by Sida/SAREC.

# Skills Training

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.

# Sources of Local Content

Local content was collected from the following sources:

Hand written notes were collected from current students of Faculty of Technology who were successful and were admitted based on their good academic performance at national examinations set by UNEB. These are mainly students from advantaged, elite schools in Uganda.

Past examination papers from Muni and Ediofe. The schools administer three examinations every term. In a year, there are three school terms. All the past papers are continuously collected and form part of the local content.

Past examination papers are also continuously collected from other advantaged schools in the country like Trinity College, Nabbingo.

UNEB publishes booklets of past examination papers for sale to the public. Such past papers also formed an invaluable source of content.

A group of experienced senior teachers contribute typical examination questions for Alevel students in Uganda. These questions are published as pull outs in the two national daily newspapers as 'Pass A-Level' pull-outs. They are published every Thursdays in the *The New Vision* and *The Daily Monitor*.

Recommended textbooks were purchased. Some of them are published locally in Uganda.

# Digitization of Local Content

Hand written notes were typed into computers to produce soft (digital) copies. This was the most difficult part of the exercise. The secretaries who were doing the digitization were not able to use applications for technical and engineering audience. All of them were unable to use the Equation Editor software. They had to be trained first. When some proficiency was gained, the speed of digitization was slow. Later, the subject teachers from the schools themselves were encouraged to use computers to digitize their own notes, now that they also have computer skills.

Other locally available training materials like textbooks, "Pass A-Level" pull-outs, examination past papers, etc. were scanned/digitized.

# Delivery of Local Content

The materials locally collected were digitized and published in CD-ROMs (Compact Disc-Read Only Memory) and delivered to the students. The contents of the CD-ROMs were downloaded into the computers in the schools.

# Additional Outsourcing of Content

The Ugandan A-level syllabus differs very little from the one in UK. At WSIS conference in Tunisia in November 2005, contact was made with content developers from the UK. With assistance from them, additional interactive training CD-ROMs for A-level students, especially in Pure Mathematics, Mechanics, Statistics and Physics were acquired. These CD-ROMs were copied and given to the female students. The contents were also downloaded into the computers in the schools.

# **B:** Internet Connectivity

# ICT Research Station

The Faculty of Technology, Makerere University, set up an ICT Research Station in Arua town with funds provided by Sida/SAREC. The building were provided by the District Local Council. The Research Station has VSAT Internet connectivity. Head teachers, subject teachers and the female students from Muni and Ediofe have access to the Internet resources from the Research Station. On the Internet, there are free digital resources: electronic books, online journals, audio files (wav, MP3), images (tiff, gif), movies (mpeg, quicktime) and reference texts (dictionaries and directories). The teachers and their students are able to access these educational websites. Some of the links were provided by the subject teachers from advantaged schools like St. Henry's College, Kitovu.

Table 6 shows the cost of setting up the ICT Research Station with VSAT Internet connectivity and a website for education project in the rural District of Arua.

No.	Item	Cost, USD
1	21 new IBM computers, 1 IMB Server with 21UPS, 21 Monitors and networking and power cabling accessories.	35,944.29
2	Internet connectivity (VSAT equipment, installation fees, annual maintenance fees, annual access fees and 18% VAT)	10,822.50
3	Renovation of the Research Station (repairs of the floor, roof; burglar proofing windows and doors; partitioning; painting; installing lightening arrestors; installing gate and upgrading the perimeter fence)	14,000.00
4	Website design, development and hosting for two years, http://www.ictsrd.ac.ug. This is the main project website for the ICT in Sustainable Rural Development Project	3,000.00
	Total	63,766.79

Table 6: The cost of setting up the ICT Research Station in Arua

# Collaboration with SchoolNet Uganda

Collaboratively with subject teachers of the schools and SchoolNet Uganda, a science content server was created. The initial content was copied by SchoolNet on a 200 GB Hard Disk Drive. These are materials that SchoolNet Africa uses to improve science education in disadvantaged African secondary schools. This content was uploaded into the content server at the ICT Research Station. Subsequent content were added by the subject teachers. They can add content but have no permission to delete it.

Relevant content from the Internet and the content server is transferred to the schools using memory sticks or CDs.

# Website for the Project

A website was created for the Arua ICT in Education Project and the URL is http:// www.aruaeduc.com. Under this project, the Mambo, and open source e-learning platform, was introduced for managing the e-learning environment. The open source web hosting company is in Denmark. All the female science and Mathematics students and their subject teachers were given e-mail addresses. Some educational content were sent to the students as e-mail attachments.

# ICT Skills Training

From June 2006, the ICT Research Station was opened for public use. Ten Faculty of Technology, second year Telecommunication Engineering students were used for carrying out extensive training of the District civil servants, teachers, students and the general public in ICT basic skills, Internet use and working with e-mails. The total number of people trained is depicted in the table 7.

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

Table 7: Records of training done in Arua during the recess semester by Faculty of Technology engineering students

The inferior Pentium I, II in the Girls schools were upgraded so that they could have multimedia capabilities. Interactive CD-ROMs for science and Mathematics were given to the teachers and students in the schools. The schools have the following software: Advanced level Physics, Pure Mathematics, Statistics, Mechanics, Biology and Chemistry. O-level Science and Mathematics were also delivered to the schools. All these software were uploaded into the computers in the schools.

The female students and their teachers access Internet resources and other content through e-mails from the ICT Research Station. Since the schools cannot afford Internet connectivity, they are timetabled to have some of there lessons at the Research Station; 5 kms from each of the schools. E-mails can be received when they are at the Research Station. The content server developed jointly with the SchoolNet Uganda also has additional Science and Mathematics content. And the subject teachers keep adding more content into the available database.

#### Discussion

There are a number of requirements that must be considered when introducing hybrid digital libraries in poor, rural schools like Ediofe and Muni. These are computer hardware and software requirements, electricity supply, telecommunications, Internet connectivity, bandwidth, human resources requirements, website design and hosting.

#### Computers

The supply of used, obsolete computers to both Muni and Ediofe is a clear sign of using a Government department like NCDC for dumping e-waste in Uganda. This is a manifestation of 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 cost of these computers was used to repair and upgrade them so that they can have multimedia capabilities.

#### Internet Costs

A more serious obstacle to the creation of hybrid digital libraries is the Internet connectivity to the poor rural schools. 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 Station 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. This includes the 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.

Another problem related to Internet is the bandwidth. 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 500USD 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 Faculty of Technology ICT Research Station in Arua with VSAT Internet connectivity, 450USD per month is charged for a bandwidth of only 256kbps. 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 was 265,265,557 UGX (135,774USD), 363,849,268UGX (209,881USD) in 2004 and 474,626,127 UGX (257,642 USD) in 2005.

There are five commercial Internet cafes in Arua town and they charge a minimum of 50

UGX for surfing for a minute. If a student surfs for 10 hours in a day, the total monthly amount of money required is 900,000 UGX (about 485USD at an exchange rate of 1USD=1857UGX). This is equivalent to a gross salary of an average civil servant who earns 140,000UGX per month for nearly seven months. No student can afford commercial surfing on the Internet for purposes of enhancing her education.

Internet connectivity and bandwidth costs remain a challenge to secondary schools in Uganda.

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 per 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.

#### Open Source Web Platform

Another expensive technology in developing digital libraries is the cost of website design, development, hosting and maintenance. Web hosting companies provide this service. The service includes domain name registration, allocation of storage space and bandwidth, e-mail accounts, and technical support. It is important to know the operating system the

server that the web hosting service provider uses. It is either Unix (or Linux) platform which is open source or Microsoft Windows platform. Experience shows that Unix or Linux server is very reliable and fast under heavy traffic. Up to 3,000 USD was spent on designing, developing and hosting for two years the main project website for 'ICT in Sustainable Rural Development Project. The URL for the site is: http://www.ictsrd.ac.ug. This is a very big amount. It is because the web-hosting commercial company uses a proprietary/commercial server based on Windows Operating System. Later, when hosting the site for the ICT in Education Project, which is a small component of the main research project, open source web hosting provider was used. Only 47 USD is used for hosting for a year, including set up costs with unlimited e-mail accounts. The website is http://www.aruaeduc.com.

#### 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 and website hosting are prohibitively high.

When creating hybrid digital libraries in poor rural secondary schools like Muni and Ediofe, CD-ROMs were found to be the main media for delivering content and uploading it in the standalone computers in the schools. The female students together with their teachers were allowed to visit the Makerere University, Faculty of Technology ICT Research station and get Internet resources, attend advanced ICT training and open some educational websites. They could also access training materials from the 'ICT in Education website', http://www.aruaeduc.com. The hybrid e-learning website was hosted by an open source provider and the learning environment was managed by the Mambo platform, also open source software. Open source platforms are suitable for application in poor schools since they are cheap and reliable.

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.

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# Part III

# 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 be 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 can not 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. CD-ROMs are very practical format for areas with little Internet access.

# Concluding Discussion

The aim of this on-going study is to investigate the effects of hybrid e-learning application in rural advanced secondary education on the performance of female students in Physics and Mathematics. The study is being done in Arua district. There are two advanced level boarding senior secondary girls' schools in Arua district: Muni and Ediofe. There are no records in both schools to show that they have ever sent any students for engineering training. Both schools have non functional libraries and science laboratories. There is shortage of science and mathematics teachers at advanced level in both schools. There are 660 students in Muni and Ediofe has a total enrolment of 630 girls.

The purpose of the licentiate thesis is to encounter this situation by developing tools and implementing hybrid e-learning in these two rural advanced level secondary schools.

There is a severe financial constraint in both schools. For example, the total annual expenditures (both capital and recurrent expenditures) of Muni were a mere 135,775 USD in 2003, 209,881 USD in 2004 and 257, 642 USD in 2005. With such a budget, capital investment in science laboratories, libraries, ICT infrastructure, etc. is not possible. Capital development is only limited to maintenance of the existing old structures like buildings, classrooms, dormitories, administration blocks, fences, furniture repairs.

The Ministry of Education and Sports (MOES) in Uganda is encouraging secondary schools to introduce ICT in their curriculum. The poor rural schools, like Muni and Ediofe, look for 'cheap' old computers that are being sold at about 165USD. Non-Governmental Organisations based in MOES are responsible for the sale of such computers to schools. The main NGOs are SchoolNet Uganda and Uconnect. Some schools, including both Muni and Ediofe, purchased the old computers through the National Curriculum Development Center (NCDC), an autonomous body under the MOES. Muni has 10 such computers while Ediofe acquired 15. Technical inspection of the computers in Ediofe showed that they are not suitable for educational purposes. One had a defective mother board (it is scrap), two had power problems and only one computer had hard disk drive capacity of 40GB. Most of the computers have hard disk drive capacity of less than 1.3GB. The RAM is also low with most of them having a Ram of 8MB. Only two of the computers have CD-ROM drives. Software installed had no multimedia capability. Ediofe paid 2,475 USD for those computers and 1,081USD was used to repair and upgrade them to multimedia

capabilities. The computers breakdown frequently yet the schools have no laboratory technicians. The total cost of ownership of these computers is going to be very high. It would appear that these computers are just being damped in schools in Uganda.

*i-network Uganda* raised the issue of damping 'digital waste' in Africa recently. It is a problem that should be looked at from the wider perspective of the relationship between the developed and developing countries. Generally, Africa has become the 'digital dump' for obsolete computers, mobile phones, television screens, and other electronics often labeled as 'refurbished' or 'recycled'. Toxic e-waste from developed countries labeled as assistance in 'bridging the digital divide' is concealed by including several genuinely refurbished equipment to escape stringent European health and environmental regulations. When these electronic devices are broken up, burned or degraded, they release toxic materials that include lead, cadmium, barium, mercury and chromium. Plastic components contain brominated flame retardants that accumulate in human blood and fat tissues and can disrupt the body's hormonal balance. When burned, some of these plastics release dioxins and furans, persistent pollutants linked to a host of health problems, including cancer (*i-network Uganda, Discussion Forum, June 30, 2006*).

To support the hybrid e-learning in Arua district, the Faculty of Technology, Makerere University, set up the ICT Research Station with VSAT Internet connectivity in Arua town. The Research Station is within 5 kms from either Muni or Ediofe. Sida/SAREC provided funding while Arua District Local Government provided the buildings. The Research Station has three ICT training classrooms in the main building (for beginners, intermediate and advanced lessons). The smaller building houses the server and a specialized classroom for more advanced categories of students.

This is the first time when Makerere University, Faculty of Technology, teamed up with the Local Government in Arua and the business community there to set up a research station for the benefit of the rural community. It is a successful application of the Triple Helix Methodology.

Of concern are the high costs of Internet connectivity in Uganda. AFSAT connected the VSAT facility in Arua Research station at 11,000 USD. This includes the cost of the Satellite Disk, 2,500USD. At a monthly access fee of 450USD, the recurrent expenditure including VAT of 18% and maintenance of the Ku band comes to a total of 6,795USD. No rural school can afford such recurrent costs. It is equivalent to the total capitation grant that the government gives the school for its operation. Government pays 0.035USD per school day per student. Since there are 270 school days in a year, this comes to 9.45USD per student per year. A school like Muni with about 700 students gets a capitation grant of 6,615USD. With this level of funding, the school cannot afford Internet connectivity. Rural secondary schools do not have any other sources of raising money. Their Parents' and Teachers' Associations (PTSs) are consisting of poor parents who cannot afford to raise enough money to support the schools.

There are elite schools that were connected to Internet under the SchoolNet VSAT project. Such schools have not introduced e-learning. They have problems with the recurrent

operating costs of the Internet connectivity. None of the schools would like to purchase bandwidth for educational purposes. Nor are they willing to pay for the commercial Course Management System (q.v.) or platform that is being suggested.

Bandwidth in Uganda is still a very expensive resource. Uganda does not have its own Internet backbone. The highest institution of higher learning, Makerere University, has problems paying for bandwidth. Makerere pays 20,000USD per month for a T1 bandwidth (1,544 kbps). The university has budgeted 480,000USD for bandwidth for 2007. Not even a group of secondary schools can combine to purchase enough bandwidth for educational purposes. The price of Internet in Uganda is still very high to everyday users at 50 UGX in Arua (28 cents) per minute limiting Internet use and growth basically affected by expensive bandwidth sold by a few Internet Service Providers (ISPs). The ISPs also say they too are buying bandwidth via satellite very expensively.

With Internet connectivity and bandwidths not affordable by rural secondary schools, CD-ROMs remain the only viable ICT for delivering training materials to such disadvantaged schools. CD-ROMs are particularly useful because of their clear advantages: big memory capacity, multimedia capability, high data transfer rate and their widespread standardization.

Interactive CD-ROMs for advanced level Mathematics and Physics were produced for use by the female students. A Local Content Creation Workshop was organized in Arua district. Thirty three teachers of A-level Mathematics and Physics were invited from Arua and Koboko districts. They developed content with guidance from curriculum experts from NCDC, an autonomous institution in the MOES. Since nearly all the teachers were computer illiterate, the content was handwritten. It took time for the handwritten content to be digitized. Then the CD-ROMs were produced with a lot of 'trade-offs'. Since the schools have inferior and refurbished computers, it made no sense putting in the content what would require a lot of bandwidth like video clips and animations. These were excluded from the CD-ROMs.

All the students and their teachers were found without basic ICT skills. Most of the teachers are graduates from Makerere University. It would appear that even Makerere University, School of Education, has not introduced ICT in its curriculum. That is why most graduate teachers are computer illiterate. Our key stakeholders in the local government lack ICT skills. There are public officers in the local government who are graduates but have no exposure to computers. From June 2006, the ICT Research Station was opened to the public. Ten Faculty of Technology engineering students were taken to Arua to do massive training of teachers, students, civil servants, and interested members of the public. Training was arranged at the Research Station and in four secondary schools that have computers (Mvara, Muni, Ediofe and Logiri). By the end of August, up to 1,253 people were trained in basic ICT skills, Internet use and working with e-mails. Internet training was done at the Research Station only. All the participating female students with their teachers were trained and they had free access to Internet resources from the Research Station.

Digital libraries for the schools were created. Local content materials were collected from many sources: advantaged schools like Trinity College, Nabbingo; former notes of engineering students in the Faculty of Technology; 'Pass A-level' pull-outs from daily newspapers, UNEB past examination papers; past examination papers from the participating schools; etc. These materials were digitized by scanning and copied in CDs before delivering them to the schools. Some A-level training CDs were purchased from UK as additional library resources. From the ICT Research Station, the students and their teachers can access additional library resources: links, e-books. Any relevant materials that they get from the Internet are transferred to the computers in the schools using portable devices like CD-ROMs or memory sticks (flash discs).

Collaboratively with SchoolNet, an advanced level content server was started at the ICT Research station. The initial content was uploaded by SchoolNet. Subsequently, the subject teachers from the advanced level schools were encouraged to develop materials for uploading on the content server. These materials were reviewed first by senior subject teachers before deciding to upload them on the server. The teachers had permission only to upload material but not to delete it. Advanced level students were advised to look at relevant materials from the content server.

A project website was created http://www.aruaeduc.com. Website development and hosting in Uganda is also quite expensive. The cheapest quotation was 2,000USD for designing a webpage and hosting it for two years. These are commercial web hosting companies. With support from Blekinge Technical Institute, only 45USD is being paid annually for hosting the project website on a *cascade* open source server by *B.one* in Denmark. The amount includes even set-up costs.

An open source platform, the *Mambo*, is being used for managing the hybrid e-learning environment. The Mambo is an open source Content Management System (CMS) freely available on the Internet and continuously being improved by contributors around the world. It was selected because of its strong e-learning capability at low cost and has a vibrant development community. It is also a low cost hosting. When resources are scarce, open source software cannot be avoided. Rural communities cannot afford commercial platforms. Their cost of acquisition is high and maintaining the platforms also requires a lot of funds. Commercial platforms are unreliable and prone to virus attacks. The website is going to be more intensively used as the students together with their teachers gain more proficiency in Internet use and working with e-mails.

Software is linked to sustainability of projects. They offer the biggest operational costs, not hardware. Most projects fail because they use commercial software. Makerere University, with all the bandwidth constraints it has, introduced the *Blackboard*, a very expensive e-learning platform not only to acquire but to maintain. Acquisition of an inferior version was done at 30,000USD, with monthly fee of 300USD. Later, the vendor started charging per student. Eventually, for every upgrade of the platform, a new license had to be bought. Using the Blackboard turned out to be unsustainable. Now Makerere University is piloting the *Kewl.NextGen*, an open source software.

#### **Ending Remarks**

Rural secondary schools in Uganda are usually very poor and financially constrained schools. Generally, such schools have non-functional science laboratories and libraries. They also have difficulty in attracting and retaining qualified science and mathematics teachers, especially at advanced level of secondary education. The financial situation of rural schools is so bad that capital investments in science infrastructures like laboratories and libraries are not possible. Fortunately, such schools can afford to acquire computers preferably with multimedia capabilities. Hybrid e-learning can be introduced in such rural secondary schools to support science and mathematics education. The main delivery tools under hybrid e-learning are the CD-ROMs due to their superior advantages over other portable storage devices: big memory capacity, high data transfer rate, multimedia capability and widespread standardization. Used computers with inferior capabilities that are being sold to rural schools cheaply are not useful for educational purposes. The cost of acquisition is low but the total cost of ownership is extremely high. It would appear that such computers are just being dumped in rural schools as e-waste. The costs of Internet installation, bandwidth, commercial platforms and web-hosting make introduction of pure e-learning in Ugandan schools not viable, even in educationally elite secondary schools. That is why most ICT in education projects in Uganda are repeatedly being implemented in advantaged schools with the thinking that they will be able to introduce pure e-learning. It is not possible. Hybrid e-learning is the only realistic option in the complex financial situation of Ugandan schools. Experience has shown that where there is Internet presence for use in education, open source web-hosting providers and open source platforms must be used. They are cheap and affordable, even by poor rural secondary schools.

# Statement of Scientific Contribution and Originality

## **Scientific Contribution**

The scientific contribution, that is my deliveries of results from the research project to different beneficiaries, are the following:

# 1. Makerere University

I produced three conference papers that were published as proceedings of the international conferences:

At the First International Conference on Advances in Engineering and Technology, Entebbe, Uganda, July 2006, I presented two papers. They were: *"Strategies for implementing hybrid e-learning in rural secondary schools in Uganda"* and *"Design and development of interactive multimedia CD-ROMs for rural secondary schools in Uganda"*. Both papers were published in the conference proceedings by Elsevier Ltd, UK. ISBN- 13: 978-0-08-045312-5 and ISBN- 10: 0-08-045312-0, pgs. 538-545 and 546-553 respectively.

At the E-learning Africa International Conference in May 2006, Addis Abbaba, Ethiopia, I presented a paper on the *"Implementation of hybrid e-learning model for advanced secondary school Physics and Mathematics education of female students in Uganda: Arua case study"*. The abstract was published in the Book of Abstracts, ISBN 3-9810562-2-1. The full paper was published in the conference CD.

# 2. Advanced-Level Secondary Schools in Arua

In the rural district of Arua, hybrid e-learning tools were developed for the benefit of disadvantaged advanced level female students. CD-ROMs for A-level Mathematics and Physics were locally collectively developed and were produced before releasing them for use. Digital libraries in CD-ROMs formats were also produced and deployed for use by the female students. This led to empowerment of the rural female students. It put the disadvantaged students on an equal level with the rest of the advantaged students in elite, urban schools. The unique contribution addressed the rural-urban divide in Uganda.

#### 3. Uganda

According to the 2005 Human Development Report published by UNDP, Uganda had 5 Internet users for every 1,000 population or (0.5% Internet usage). Furthermore, Internet use in Uganda is mainly an urban affair with most users concentrated in Kampala, the capital city. Rural Internet use is extremely low. By setting up an ICT Research station with VSAT Internet connectivity for public use in the rural district of Arua, Internet use in the area is expected to increase. The Research Station should be viewed as a facility for helping Uganda achieve the requirements of the following national and international documents: MDG goal no. 3, WSIS Gender Caucus recommendation for action no.6, NEPAD e-schools project, and PEAP pillar no.5 of the Ugandan Government.

#### Originality

During the course of the study, the following contributions were found to be new in the Ugandan context:

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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 center for A-level students in the district. This concept is also new in Uganda.

# **Future Work**

In order to establish the effect of the hybrid e-learning intervention in advanced level secondary schools for the benefit of the female students, the hybrid e-learning implementation will continue in 2007. The female students will continue to use the interactive training CD-ROMs, hybrid library resources, the Mambo Course Management System from the ICT Research Station where there is VSAT Internet connectivity. Then an assessment will be done in November 2007 when the students will sit for the national examinations set by the Uganda National Examinations Board, UNEB. It is expected that UNEB will release the results in March 2008. A longitudinal analysis of these results will be done to determine the impact of the intervention on performance of the students. This will be included in the Doctoral Thesis.

The ICT Research Station with VSAT Internet connectivity has been opened for public use. The Station has trained teachers, students, district heads of departments and the general public. There are requests to extend the services to Southern Sudan and Eastern DRC. The benefit is that the local communities are using it, thus narrowing the digital divide including the gender divide. Between June and August, 2006 up to 1,253 people were trained by the center using Faculty of Technology Telecommunications Engineering students as trainers. The Research Station is a concrete example of the role Makerere University, Faculty of Technology, is playing in sustainable rural development.

This finding may be useful to help and re-direct Uganda Government's policies, particularly in secondary schools. Government has made science (and mathematics) subjects compulsory in all secondary schools (both private and government-aided schools). To implement this policy, government intends to build 40 science laboratories every year in all government-aided schools and there are no plans to build libraries. A secondary school requires at least three laboratories for Physics, Chemistry and Biology. By 2005, there were 1,651 government-aided and 1,898 secondary schools in Uganda; most of them are rural schools. It will take the government many years to complete building physical laboratories in all its schools. A total 228,650 USD (423 million shillings) is being used to build and equip a block of Physics, Chemistry and Biology laboratories per school. Private schools have not much money to invest in additional science infrastructures because of the costs involved. And the government needs many years to come before completing the expensive exercise of building science laboratories in all its schools.