# ON NEW CURRICULA FOR CREATING HUMAN CAPITAL NEEDED FOR ICT-LED ECONOMIC GROWTH: CASE OF FACULTY OF COMPUTING AND IT, MAKERERE UNIVERSITY

By

Venansius Baryamureeba,
Dean, Faculty of Computing and IT, Makerere University,
P.O. Box 7062, Kampala, Uganda, barya@cit.mak.ac.ug, www.cit.ac.ug

**FRONTIERS OF KNOWLEDGE FOR AFRICA**

**UNIVERSITY LEADERS' FORUM**
**UNIVERSITY OF CAPE TOWN**
**November 18-21, 2006**

# On curricula for creating human capital needed for ICT-led economic growth: Case of Faculty of Computing and IT, Makerere University

Venansius Baryamureeba,
Department of Computer Science
Faculty of Computing and IT, Makerere University,
P.O. Box 7062, Kampala, Uganda, barya@cit.mak.ac.ug, www.cit.ac.ug

## Abstract

This paper focuses on programs and curricula being developed by Makerere University in the area of Computing and ICT to meet the needs of employers in Africa and around the world. We also share experiences, highlight lessons learned and make recommendations on areas of future improvement.

## 1. INTRODUCTION

For any meaningful development to take place or be sustained in any country a critical mass of Science and Technology (S&T) human capital is mandatory. In the same vain it can be said that for any meaningful ICT-led economic development to take place, a critical mass of ICT human capital is mandatory. This is the case in countries like China, India, and Finland. For example, in 2005 China accelerated S&T expenditure by 25% increase compared to 2004, at the same time Research and Development (R&D) expenditure alone grew by 20% and R&D workforce surpassed a million. Also in 2005 China had 1200 Institutes of Technology, and 53 High-Tech parks. S&T human capital is a prerequisite for the attainment of the Millennium Development Goals (MDGs).

## 2. ABOUT MAKERERE UNIVERSITY FACULTY OF COMPUTING AND IT

The Faculty of Computing and IT (CIT) is one of the many Faculties at Makerere University. CIT is the main computing and ICT training, research and consultancy centre in Uganda and is ranked high in Sub-Saharan Africa. With competent, qualified and motivated staff the Faculty is positioned as the fastest growing Faculty in the region. Currently CIT has a total of 5560 students (5000 undergraduate and 560 postgraduate students including 54 PhD students) distributed in four academic departments i.e. Computer Science, Information Technology, Information Systems and Networks. CIT in addition runs several professional/ international certification programs. By all standards, CIT is one of the largest computing faculties on the African continent. Plans are underway to have CIT transformed into a College by 2008 with a projected student population of 12,000.

The vision of CIT is to be a leader in Computing and ICT training, research and consultancy services on the African continent. The Faculty of Computing and Information Technology is an innovative and market-oriented institution, pursuing inquiry, discovery and application through excellence in teaching and learning, value-added research, cutting edge consultancy and vibrant student life.

The mission of CIT is to provide first class (i) teaching and research in Computing and ICT and other related areas to students and working professionals from the African region and beyond; and (ii) consultancy services, through ICT Consults Ltd, to the African region and beyond.

The Faculty offers expert teaching and research in many areas of Computing and ICT through its academic programmes. These include:

### 2.1. Doctoral Program in Computing of Makerere University

The doctoral program at Makerere University (V Baryamureeba and D Williams, 2006) [2] is a coursework and research program intended to inform investigators and build the academic field of computing with a comprehensive multidisciplinary, interdisciplinary and integrative view. Indeed, computing and engineering offer a new design approach, which calls for an interdisciplinary approach to research. A study was conducted (V Baryamureeba and D Williams, 2006) [2] and the findings of the study showed that PhD students lack research skills and methodologies in computing. Coursework and dissertation was recommended as opposed to thesis for future improvements. The coursework is aimed at demonstrating an understanding and detailed philosophy and methodology of computing, data representation and processing, which is directly related to the quality of results. The doctoral program is intended to catalyze this approach as an academic discipline. The PhD curriculum consists of one year of coursework and two years of research. The curriculum is structured in such a way that by the end of the first semester the student has an approved research proposal and by the end of the first year each student has published at least a review paper in his/ her area of research. The main advantage of this curriculum is that students are able to work independently after the first year and as a result; they can finish their 2nd and/ or 3rd year at another university.

This program approach is aimed at producing highly qualified PhD holders in environments where sufficient PhD supervisors are lacking. This PhD program in computing with a focus on Computer Science, information technology, information systems and software engineering forms a framework that could be adopted and customized in any discipline where PhD supervisors are scarce and yet the demand for PhD training is high.

### 2.2. Programs under the Department of Computer Science

The programs include a PhD in Computer Science, M.Sc. in Computer Science, Postgraduate Diploma (PGD) in Computer Science, B.Sc. in Computer Science, Diploma in Computer Science and Information Technology, and Computer Science as a sub-programme (as part of the B.Sc. Degree Programme) in collaboration with Faculty of Science.

### 2.3. Programs under the Department of Information Technology

The programs include a PhD in Information Technology; Master of Information Technology with options in Information Technology Management, Information Security, Internet and Service Delivery, and Internet and Web Computing; PGD in Information Technology; and Bachelor of Information Technology.

### 2.4. Programs under the Department of Information Systems

The programs include a PhD in Information Systems; M.Sc. in Information Systems with options in Computer Information Systems, Management Information Systems, Information Systems Management, and Internet and Database Systems; PGD in Information Systems; Bachelor of Information Systems (*proposed*) to begin in 2007/2008 academic year.

### 2.5. Programs under the Department of Networks

The programs include a PhD in Software Engineering; M.Sc. in Data Communications & Software Engineering with options in Data Communications Engineering, Network and System Administration, and Software Engineering; PGD in Data Communications & Software Engineering; PGD in ICT Policy and

Regulation; is run under Nettel@Africa program [6]; B.Sc. in Computer Engineering (*proposed*) to begin in 2007/2008 academic year; and B.Sc. in Software Engineering (*proposed*) to begin in 2007/2008 academic year. The Department of Networks will soon be split into three departments: Department of Software Engineering, Department of Computer Engineering and Department of Data Communications and Computer Networks.

### 2.6. Short Courses

The Faculty of Computing and IT runs several short courses of duration 1-8 months which include Certificate in Computer Applications (CCA); International Computer Driving License (ICDL); Oracle Certified Associate (OCA); Oracle Certified Professional (OCP); Cisco Certified Network Professional (CCNP); Cisco Certified Network Associate (CCNA); IT Essentials I & II; and Microsoft Certification: MOS, MCDBA, MCSE, MCSA, and MCSD.

## 3. COMPUTING DISCIPLINES

In a general way, we can define computing to mean any goal-oriented activity requiring, benefiting from, or creating computers. Thus, computing includes designing and building hardware and software systems for a wide range of purposes; processing, structuring, and managing various kinds of information; doing scientific studies using computers; making computer systems behave intelligently; creating and using communications and entertainment media; and finding and gathering information relevant to any particular purpose (Computing Curricula 2005, 2005) [1].

There are currently five major kinds of undergraduate degree programs in computing (*computer engineering, computer science, information systems, information technology,* and *software engineering)*, and each one provides a different focus and perspective on the discipline of computing (Computing Curricula 2005, 2005) [1]. A student typically earns a bachelors degree in one of the computing disciplines to prepare for entry into the computing profession. Because computing provides such a wide range of choices, it is impossible for anyone to become proficient at all of them. Hence, an individual who wishes to become a computing professional requires some focus for his or her professional life.

### 3.1. Computer Engineering

Computer engineering is concerned with the design and construction of computers and computer-based systems. Its curriculum focuses on the theories, principles, and practices of traditional electrical engineering and mathematics and applies them to the problems of designing computers and computer-based devices. *CE has a strong engineering flavor*. It involves the study of hardware, software, communications, and the interaction among them. Computer engineering students study the design of digital hardware systems including communications systems, computers, and devices that contain computers. They study software development, focusing on software for digital devices and their interfaces with users and other devices. Currently, a dominant area within computer engineering is embedded systems, the development of devices that have software and hardware embedded in them. For example, devices such as cell phones, digital audio players, digital video recorders, alarm systems, x-ray machines, and laser surgical tools all require integration of hardware and embedded software and all are the result of computer engineering.

### 3.2. Computer Science

Computer science spans a wide range, from its theoretical and algorithmic foundations to cutting-edge developments in robotics, computer vision, intelligent systems, bioinformatics, and other exciting areas.
We can think of the work of computer scientists as falling into three categories:

- They design and implement software. Computer scientists take on challenging programming jobs. They also supervise other programmers, keeping them aware of new approaches.

- They devise new ways to use computers. Progress in the CS areas of networking, database, and human-computer-interface enabled the development of the World Wide Web. Now CS researchers are working with scientists from other fields to make robots become practical and intelligent aides, to use databases to create new knowledge, and to use computers to help decipher the secrets of our DNA.
- They develop effective ways to solve computing problems. For example, computer scientists develop the best possible ways to store information in databases, send data over networks, and display complex images. Their theoretical background allows them to determine the best performance possible, and their study of algorithms helps them to develop new approaches that provide better performance.

Computer science spans the range from theory through programming. Curricula that reflect this breadth are sometimes criticized for failing to prepare graduates for specific jobs. While other disciplines may produce graduates with more immediately relevant job-related skills, computer science offers a comprehensive foundation that permits graduates to adapt to new technologies and new ideas.

### 3.3. Software Engineering

Software engineering is the discipline of developing and maintaining software systems that behave reliably and efficiently, are affordable to develop and maintain, and satisfy all the requirements that customers have defined for them. It has evolved in response to factors such as the growing impact of large and expensive software systems in a wide range of situations and the increased importance of software in safety-critical applications.

Software engineering seeks to integrate the principles of mathematics and computer science with the engineering practices developed for tangible, physical artifacts. Prospective students can expect to see software engineering presented in two contexts:

- Degree programs in computer science or computer engineering offer one or more software engineering courses as elements of the CS or CE curriculum. Some offer a multi-course concentration in software engineering within CS or CE.
- A number of institutions offer a software engineering degree program.

Degree programs in computer science and in software engineering have many courses in common. Software engineering students learn more about software reliability and maintenance and focus more on techniques for developing and maintaining software that is correct from its inception. While CS students are likely to have heard of the importance of such techniques, the engineering knowledge and experience provided in SE programs go beyond what CS programs can provide. SE students learn how to assess customer needs and develop usable software that meets those needs. Knowing how to provide genuinely useful and usable software is of paramount importance.

### 3.4. Information Systems

Information systems specialists focus on integrating information technology solutions and business processes to meet the information needs of businesses and other enterprises, enabling them to achieve their objectives in an effective, efficient way. This discipline's perspective on information technology emphasizes information, and views technology as an instrument for generating, processing, and distributing information. Professionals in the discipline are primarily concerned with the information that computer systems can provide to aid an enterprise in defining and achieving its goals, and the processes that an enterprise can implement or improve using information technology. They must understand both technical and organizational factors, and they must be able to help an organization determine how information and technology-enabled business processes can provide a competitive advantage.

The information systems specialist plays a key role in determining the requirements for an organization's information systems and is active in their specification, design, and implementation. As a result, such professionals require a sound understanding of organizational principles and practices so that they can serve as an effective bridge between the technical and management communities within an organization, enabling them to work in harmony to ensure that the organization has the information and the systems it needs to

support its operations. Information systems professionals are also involved in designing technology-based organizational communication and collaboration systems.
All IS degrees combine business and computing coursework. A variety of IS programs exist under various labels which often reflect the nature of the program. For example, programs in Computer Information Systems usually have the strongest technology focus, while programs in Management Information Systems emphasize the organizational and behavioral aspects of IS.

### 3.5. Information Technology

Information technology is a label that has two meanings. In the broadest sense, the term information technology is often used to refer to all of computing. In academia, it refers to undergraduate degree programs that prepare students to meet the computer technology needs of business, government, healthcare, schools, and other kinds of organizations. In some nations, other names are used for such degree programs.
In the previous section, we said that Information Systems focuses on the information aspects of information technology. Information Technology is the complement of that perspective: its emphasis is on the technology itself more than on the information it conveys. IT is a new and rapidly growing field that started as a grassroots response to the practical, everyday needs of business and other organizations.
Today, organizations of every kind are dependent on information technology. They need to have appropriate systems in place. These systems must work properly, be secure, and upgraded, maintained, and replaced as appropriate. Employees throughout an organization require support from IT staff who understand computer systems and their software and are committed to solving whatever computer-related problems they might have. Graduates of information technology programs address these needs.
Degree programs in information technology arose because degree programs in the other computing disciplines were not producing an adequate supply of graduates capable of handling these very real needs.
IT programs exist to produce graduates who possess the right combination of knowledge and practical, hands-on expertise to take care of both an organization's information technology infrastructure and the people who use it. IT specialists assume responsibility for selecting hardware and software products appropriate for an organization, integrating those products with organizational needs and infrastructure, and installing, customizing, and maintaining those applications for the organization's computer users.
Examples of these responsibilities include the installation of networks; network administration and security; the design of web pages; the development of multimedia resources; the installation of communication components; the oversight of email systems; and the planning and management of the technology lifecycle by which an organization's technology is maintained, upgraded, and replaced.

## 4. MEETING INTERNATIONAL STANDARDS

### 4.1. Curriculum

The Institute of Electrical and Electronic Engineers (IEEE)[7] is the world's leading professional association for the advancement of technology. IEEE Computer Society is a technical society within the IEEE that is focused on computing and its membership includes computer engineers, software engineers, computer technologists, and computer scientists. Association of Computing Machinery (ACM) [8] is the world's first educational and scientific computing society. *In recent years there has been a large overlap in membership between ACM and IEEE Computer Society and as a result the two societies cooperate in creating curriculum standards, and, in this way, send a single message to the computing community.* Today many researchers and lecturers (teachers) belong to both organizations. Association of Information Systems (AIS) [9] is a professional organization whose purpose is to serve as the premier global organization for academicians specializing in Information Systems. IEEE Computer Society, ACM and AIS commissioned a joint task force that produced Computing Curricula 2005 (Computing Curricula 2005, 2005) [1] covering 5 undergraduate degree programmes in computing i.e. Computer Engineering (CE), Computer Science (CS), Information Systems (IS), Information Technology (IT) and Software Engineering (SE). Softcopies of Computing Curricula 2005 are available at http://www.acm.org/education/curricula.html and http://computer.org/curriculum.

In order to keep pace with international standards and also make the graduates from the programs match international standards, the Faculty of Computing and IT when either designing new curricula or revising existing curricula follows curricula guides from internationally recognized professional bodies such as ACM, IEEE Computer Society and AIS and Quality Assurance Agencies such as the International Network for Quality Assurance Agencies in Higher Education (INQAAHE) [10] and Quality Assurance Agency (QAA) for Higher Education in the UK [11].

For example computing curricula guide as proposed by ACM, IEEE and AIS is summarized in Table 1 and 2 below, where:

- Min value represents the minimum emphasis typically placed on that topic as specified in the curriculum report for that computing discipline. The Min value also indicates a discipline's minimum requirement relative to the minimum requirements of the other disciplines.
- Max value represents the greatest emphasis that can typically occur within the latitude provided by the curriculum report of that degree. Each discipline permits students some latitude in choosing an area of specialization and requires that a student's program of study goes beyond the minimums defined in the curriculum report.

| *Knowledge Area* | *CE* | | *CS* | | *IS* | | *IT* | | *SE* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Min* | *Max* | *Min* | *Max* | *Min* | *Max* | *Min* | *Max* | *Min* | *Max* |
| Programming Fundamentals | 4 | 4 | 4 | 5 | 2 | 4 | 2 | 4 | 5 | 5 |
| Integrative Programming | 0 | 2 | 1 | 3 | 2 | 4 | 3 | 5 | 1 | 3 |
| Algorithms and Complexity | 2 | 4 | 4 | 5 | 1 | 2 | 1 | 2 | 3 | 4 |
| Computer Architecture and Organization | 5 | 5 | 2 | 4 | 1 | 2 | 1 | 2 | 2 | 4 |
| Operating Systems Principles & Design | 2 | 5 | 3 | 5 | 1 | 1 | 1 | 2 | 3 | 4 |
| Operating Systems Configuration & Use | 2 | 3 | 2 | 4 | 2 | 3 | 3 | 5 | 2 | 4 |
| Net Centric Principles and Design | 1 | 3 | 2 | 4 | 1 | 3 | 3 | 4 | 2 | 4 |
| Net Centric Use and configuration | 1 | 2 | 2 | 3 | 2 | 4 | 4 | 5 | 2 | 3 |
| Platform technologies | 0 | 1 | 0 | 2 | 1 | 3 | 2 | 4 | 0 | 3 |
| Theory of Programming Languages | 1 | 2 | 3 | 5 | 0 | 1 | 0 | 1 | 2 | 4 |
| Human-Computer Interaction | 2 | 5 | 2 | 4 | 2 | 5 | 4 | 5 | 3 | 5 |
| Graphics and Visualization | 1 | 3 | 1 | 5 | 1 | 1 | 0 | 1 | 1 | 3 |
| Intelligent Systems (AI) | 1 | 3 | 2 | 5 | 1 | 1 | 0 | 0 | 0 | 0 |
| Information Management (DB) Theory | 1 | 3 | 2 | 5 | 1 | 3 | 1 | 1 | 2 | 5 |
| Information Management (DB) Practice | 1 | 2 | 1 | 4 | 4 | 5 | 3 | 4 | 1 | 4 |
| Scientific computing (Numerical mthds) | 0 | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Legal / Professional / Ethics / Society | 2 | 5 | 2 | 4 | 2 | 5 | 2 | 4 | 2 | 5 |
| Information Systems Development | 0 | 2 | 0 | 2 | 5 | 5 | 1 | 3 | 2 | 4 |
| Analysis of Business Requirements | 0 | 1 | 0 | 1 | 5 | 5 | 1 | 2 | 1 | 3 |
| E-business | 0 | 0 | 0 | 0 | 4 | 5 | 1 | 2 | 0 | 3 |
| Analysis of Technical Requirements | 2 | 5 | 2 | 4 | 2 | 4 | 3 | 5 | 3 | 5 |
| Engineering Foundations for SW | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 0 | 2 | 5 |
| Engineering Economics for SW | 1 | 3 | 0 | 1 | 1 | 2 | 0 | 1 | 2 | 3 |
| Software Modeling and Analysis | 1 | 3 | 2 | 3 | 3 | 3 | 1 | 3 | 4 | 5 |
| Software Design | 2 | 4 | 3 | 5 | 1 | 3 | 1 | 2 | 5 | 5 |
| Software Verification and Validation | 1 | 3 | 1 | 2 | 1 | 2 | 1 | 2 | 4 | 5 |
| Software Evolution (maintenance) | 1 | 3 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 4 |
| Software Process | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 5 |
| Software Quality | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 4 |
| Comp Systems Engineering | 5 | 5 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 3 |
| Digital logic | 5 | 5 | 2 | 3 | 1 | 1 | 1 | 1 | 0 | 3 |
| Embedded Systems | 2 | 5 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 4 |
| Distributed Systems | 3 | 5 | 1 | 3 | 2 | 4 | 1 | 3 | 2 | 4 |
| Security: issues and principles | 2 | 3 | 1 | 4 | 2 | 3 | 1 | 3 | 1 | 3 |
| Security: implementation and mgt | 1 | 2 | 1 | 3 | 1 | 3 | 3 | 5 | 1 | 3 |
| Systems administration | 1 | 2 | 1 | 1 | 1 | 3 | 3 | 5 | 1 | 2 |
| Management of Info Systems Org. | 0 | 0 | 0 | 0 | 3 | 5 | 0 | 0 | 0 | 0 |

| | CE | | CS | | IS | | IT | | SE | |
|---|---|---|---|---|---|---|---|---|---|---|
| Systems integration | 1 | 4 | 1 | 2 | 1 | 4 | 4 | 5 | 1 | 4 |
| Digital media development | 0 | 2 | 0 | 1 | 1 | 2 | 3 | 5 | 0 | 1 |
| Technical support | 0 | 1 | 0 | 1 | 1 | 3 | 5 | 5 | 0 | 1 |

Table 1: Comparative weight of computing topics across the five kinds of degree programs [adopted from Computing Curricula 2005, (Computing Curricula 2005,2005) [1]]

| *Knowledge Area* | *CE* | | *CS* | | *IS* | | *IT* | | *SE* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Min* | *Max* | *Min* | *Max* | *Min* | *Max* | *Min* | *Max* | *Min* | *Max* |
| Organizational Theory | 0 | 0 | 0 | 0 | 1 | 4 | 1 | 2 | 0 | 0 |
| Decision Theory | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 1 | 0 | 0 |
| Organizational Behavior | 0 | 0 | 0 | 0 | 3 | 5 | 1 | 2 | 0 | 0 |
| Organizational Change Management | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 0 | 0 |
| General Systems Theory | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 0 | 0 |
| Risk Management (Project, safety risk) | 2 | 4 | 1 | 1 | 2 | 3 | 1 | 4 | 2 | 4 |
| Project Management | 2 | 4 | 1 | 2 | 3 | 5 | 2 | 3 | 4 | 5 |
| Business Models | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 0 | 0 |
| Functional Business Areas | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 0 | 0 |
| Evaluation of Business Performance | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 0 | 0 | 0 |
| Circuits and Systems | 5 | 5 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| Electronics | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Digital Signal Processing | 3 | 5 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| VLSI design | 2 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| HW testing and fault tolerance | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Mathematical foundations | 4 | 5 | 4 | 5 | 2 | 4 | 2 | 4 | 3 | 5 |
| Interpersonal communication | 3 | 4 | 1 | 4 | 3 | 5 | 3 | 4 | 3 | 4 |

Table 2: Comparative weight of non-computing topics across the five kinds of degree programs [adopted from Computing Curricula 2005, (Computing Curricula 2005,2005) [1]]

### 4.2. Degree outcomes

This section provides a comparative view of the performance capabilities expected of the graduates of each degree program i.e. summarizes the expectation of the student after graduation. Table 3 lists nearly 60 performance capabilities across 11 categories. For each capability, each discipline is assigned a value from 0 to 5. The value 0 represents no expectation whatsoever, while 5 represents the highest relative expectation. Table 3 shows that:

- Computer engineers should be able to design and implement systems that involve the integration of software and hardware devices;
- Computer scientists should be prepared to work in a broad range of positions involving tasks from theoretical work to software development;
- Information systems specialists should be able to analyze information requirements and business processes and be able to specify and design systems that are aligned with organizational goals;
- Information technology professionals should be able to work effectively at planning, implementation, configuration, and maintenance of an organization's computing infrastructure; and
- Software engineers should be able to properly perform and manage activities at every stage of the life cycle of large-scale software systems.

| Area | Performance Capability | CE | CS | IS | IT | SE |
|---|---|---|---|---|---|---|
| Algorithms | Prove theoretical results | 3 | 5 | 1 | 0 | 3 |
| | Develop solutions to programming problems | 3 | 5 | 1 | 1 | 3 |
| | Develop proof-of-concept programs | 3 | 5 | 3 | 1 | 3 |
| | Determine if faster solutions possible | 3 | 5 | 1 | 1 | 3 |
| Application programs | Design a word processor program | 3 | 4 | 1 | 0 | 4 |
| | Use word processor features well | 3 | 3 | 5 | 5 | 3 |
| | Train and support word processor users | 2 | 2 | 4 | 5 | 2 |
| | Design a spreadsheet program (e.g., Excel) | 3 | 4 | 1 | 0 | 4 |
| | Use spreadsheet features well | 2 | 2 | 5 | 5 | 3 |
| | Train and support spreadsheet users | 2 | 2 | 4 | 5 | 2 |
| Computer programming | Do small-scale programming | 5 | 5 | 3 | 3 | 5 |
| | Do large-scale programming | 3 | 4 | 2 | 2 | 5 |
| | Do systems programming | 4 | 4 | 1 | 1 | 4 |
| | Develop new software systems | 3 | 4 | 3 | 1 | 5 |
| | Create safety-critical systems | 4 | 3 | 0 | 0 | 5 |
| | Manage safety-critical projects | 3 | 2 | 0 | 0 | 5 |
| Hardware and devices | Design embedded systems | 5 | 1 | 0 | 0 | 1 |
| | Implement embedded systems | 5 | 2 | 1 | 1 | 3 |
| | Design computer peripherals | 5 | 1 | 0 | 0 | 1 |
| | Design complex sensor systems | 5 | 1 | 0 | 0 | 1 |
| | Design a chip | 5 | 1 | 0 | 0 | 1 |
| | Program a chip | 5 | 1 | 0 | 0 | 1 |
| | Design a computer | 5 | 1 | 0 | 0 | 1 |
| Human-computer interface | Create a software user interface | 3 | 4 | 4 | 5 | 4 |
| | Produce graphics or game software | 2 | 5 | 0 | 0 | 5 |
| | Design a human-friendly device | 4 | 2 | 0 | 1 | 3 |
| Information systems | Define information system requirements | 2 | 2 | 5 | 3 | 4 |
| | Design information systems | 2 | 3 | 5 | 3 | 3 |
| | Implement information systems | 3 | 3 | 4 | 3 | 5 |
| | Train users to use information systems | 1 | 1 | 4 | 5 | 1 |
| | Maintain and modify information systems | 3 | 3 | 5 | 4 | 3 |
| Information management (Database) | Design a database mgt system (e.g., Oracle) | 2 | 5 | 1 | 0 | 4 |
| | Model and design a database | 2 | 2 | 5 | 5 | 2 |
| | Implement information retrieval software | 1 | 5 | 3 | 3 | 4 |
| | Select database products | 1 | 3 | 5 | 5 | 3 |
| | Configure database products | 1 | 2 | 5 | 5 | 2 |
| | Manage databases | 1 | 2 | 5 | 5 | 2 |
| | Train and support database users | 2 | 2 | 5 | 5 | 2 |
| IT resource planning | Develop corporate information plan | 0 | 0 | 5 | 3 | 0 |
| | Develop computer resource plan | 2 | 2 | 5 | 5 | 2 |
| | Schedule/budget resource upgrades | 2 | 2 | 5 | 5 | 2 |
| | Install/upgrade computers | 4 | 3 | 3 | 5 | 3 |
| | Install/upgrade computer software | 3 | 3 | 3 | 5 | 3 |
| Intelligent systems | Design auto-reasoning systems | 2 | 4 | 0 | 0 | 2 |
| | Implement intelligent systems | 2 | 4 | 0 | 0 | 4 |
| Networking and communications | Design network configuration | 3 | 3 | 3 | 4 | 2 |
| | Select network components | 2 | 2 | 4 | 5 | 2 |
| | Install computer network | 2 | 1 | 3 | 5 | 2 |
| | Manage computer networks | 3 | 3 | 3 | 5 | 3 |
| | Implement communication software | 5 | 4 | 1 | 1 | 4 |
| | Manage communication resources | 1 | 0 | 3 | 5 | 0 |
| | Implement mobile computing system | 5 | 3 | 0 | 1 | 3 |
| | Manage mobile computing resources | 3 | 2 | 2 | 4 | 2 |
| Systems Development T through Integration | Manage an organization's web presence | 2 | 2 | 4 | 5 | 2 |
| | Configure & integrate e-commerce software | 2 | 3 | 4 | 5 | 4 |
| | Develop multimedia solutions | 2 | 3 | 4 | 5 | 3 |
| | Configure & integrate e-learning systems | 1 | 2 | 5 | 5 | 3 |
| | Develop business solutions | 1 | 2 | 5 | 3 | 2 |
| | Evaluate new forms of search engine | 2 | 4 | 4 | 4 | 4 |

Table 3: Relative performance capabilities of computing graduates by discipline [adopted from Computing Curricula 2005, (Computing Curricula 2005,2005) [1]]

## 5. ADDRESSING PRIVATE SECTOR NEEDS IN THE PROGRAMS AND CURRICULA

In as much as we follow internationally recognized curricula guides, the graduates from the computing programs (computer engineering, computer science, information systems, information technology, and software engineering) still lack some skills required by the employers. These skills are mainly professional and vocational. In order to address the above the Faculty of Computing and IT has integrated Cisco Certified Network Associate (CCNA), Cisco Certified Network Professional (CCNP), and IT Essentials in the computing degree programs. In addition to CCNA/CNNP and IT Essentials all the other professional programs like Microsoft Certified System Engineer (MCSE), Oracle Certified Network Associate (OCA), Oracle Certified Network Professional (OCP), Security Plus, IP Telephony and IT Essentials I & II are offered during the semester breaks and students are free to take them as optional courses. Students are also free to take skills based courses in for example entrepreneurship, negotiation, strategic planning and management. Also While teaching the main curricula we try as much as possible to use both commercial and free software, operating systems and other teaching aids like routers so that the students are not limited to skills of products from a few companies like Microsoft and Cisco Systems. Students interested in software development have an additional opportunity of working in the Department of Software Development and Innovations at the Faculty of Computing and IT on development/ customization of commercial software and prototypes. This ensures that by graduation time, the graduates have gone through academic and professional/vocational training and are acquainted with both commercial and open source software and as a result have acquired most of the skills needed in the workplace.

## 6. IMPLEMENTATION STRATEGY

### 6.1. Human Resources

The creation of human capital starts with the design of curricula. The curricula must address the skills set required of the graduate and at the end of each course the students must have acquired the required skills that will contribute to the overall skills set of the program. For the students to acquire the skills set out for each course the lecturer himself/ herself must possess the same skills before he or she can lecture a given course.

Computing is a new discipline and universities in Uganda in particular and Africa in general have very few PhD holders in any of the computing subfields. At Makerere University, the undergraduate programs in computing are run by fulltime local staff (mainly M.Sc. holders) that use both online (e-learning) and face to face classroom instruction. Due to lack of sufficient local PhD holders and masters holders with several years of experience in the area of computing, the postgraduate programs depend on local staff, African Diaspora especially Ugandan Diaspora, PhD holders on projects supported by the development partners, occasional (short visits) Professors and visiting fellows on sabbatical leave. Most of the postgraduate students are supervised online by academic staff from institutions around the world. In the long term the faculty expects to mainly depend on the over 80 PhD students currently training at Makerere University and at Universities abroad. In the short and medium term, the Faculty of Computing and IT has devised strategies to boost the programs which need to be singled out for example:

#### 6.1.1. Organizing The Annual International Conference on Computing and ICT Research

This annual event [3] brings together scholars from all over the world every August of every year. This series of conferences started in 2005. Most scholars who come to the conference stay much longer at Makerere University working with local researchers and postgraduate students on several research projects. Some scholars give a series of seminars on different topics in computing. There is always a PhD colloquium that gives the PhD students an opportunity to get advice on their research from several experienced researchers. Postgraduate students especially PhD students have been able to get a 2$^{nd}$ or 3$^{rd}$ supervisor from either the scholars at the conference or scholars at the home institutions of the conference participants as a result of networking with the scholars at the conference. Also this conference gives an opportunity to young scholars especially PhD students to have their research peer reviewed.

#### 6.1.2. Hosting the International Journal of Computing and ICT Research (IJCIR)

This is a peer reviewed International journal [4] with an objective of providing a medium for academics to publish original cutting edge research in the field of computing and ICT. IJCIR publishes two issues per year. The Journal publishes papers in computing and ICT and other related areas. This journal is hosted by Makerere University in the Faculty of Computing and IT. It has encouraged local researchers and postgraduate students especially PhD students to send in their papers for peer reviews. This journal not only publishes papers that meet its high standards but also receives papers from young researchers, which may not necessarily be published but taken through the review process so that students can gain from the reviews to improve their papers and resubmit or submit to other journals. In a way it acts as an incubation facility for young researchers. On a good note most of these younger researchers who submit papers in this journal have in the process gained confidence and are now submitting good papers to this journal and other international journals for possible publication.

#### 6.1.3. Establishing a Program for Visiting Scholars and African Diaspora.

The Netherlands organization for cooperation in higher education (Nuffic) and Makerere University put in place a modest fund to support visiting staff on sabbatical leave to spend 3-12 months at Makerere University. This offer was also extended to African Diaspora of which the Ugandan Diaspora tremendously responded. Of all these categories the Ugandan Diaspora tends to stay much longer and even on return to their home institutions, they continue to dedicate a substantial amount of their time to the activities at Makerere University such as supervision, research, and online instruction with the help of ICT and digital learning environments like blackboard.

#### 6.1.4. Department of Software Development & Innovations

In an effort to impart programming and software development skills to the students, the Department of Software Development and Innovations was established in the Faculty of Computing and IT, Makerere University. The Department has 6 fulltime software developers and are linked to staff in the academic departments and students. The core function of the department is to develop new commercial software and customize existing software. It also engages students to develop software prototypes. More than 1000 students at any time are working on different software prototypes being supervised by academic staff in close consultation with the staff of this department. Most of the research done in software engineering is utilized in this department to develop commercial products. Some products developed using open source software are availed freely and the department only benefits from training the end users at a fee.

#### 6.1.5. ICT Consults Ltd

In an effort to impart continuous consultancy and practical skills to the lecturers, the Faculty of Computing and IT set up a private consultancy firm [12] whose consultants are mainly staff and students of the faculty. The students are able to gain consultancy skills before graduation and ICT Consults Ltd has led to so many spin off ICT companies. The staff of the faculty are always lead consultants on the projects and a result gain new skills as they undertake different projects and this feeds into curricula review. The company also generates income, which is used to supplement the salaries of the consultants, and this is one of the staff retention mechanisms being employed by the faculty.

#### 6.1.6. Private Sector Dimension

Makerere University appoints distinguished fellows from the private sector who hold at least a master's degree and several years of experience either as honorary lecturers or honorary professors or honorary research fellows. These fellows participate in teaching, research and joint supervision of projects. The experience of the private sector in training and curricula development is very important and these fellows act as a link between the faculty and their organizations. Some companies have set up fully funded research chairs at the departments in the faculty and more companies are promising to do.

Both private and public companies in Uganda accept students from the faculty for internship or field attachment. Again the staff from both the Faculty of Computing and IT and the private sector jointly supervise the students on the projects. The projects mainly come from the private sector, the Non Governmental Organizations (NGOs) and the community at large. The projects are solicited through an open process through advertisements in the newspapers, on the website and other communication media and the clients normally provide a co-supervisor or contact person to validate the outputs.

## 6.2. Physical Resources

In addition to adequate human resources, the sufficient physical resources are preliquisite for quality training of the students. In this modern day and age, the faculty is focusing on putting in place modern laboratories that are suitable for computer assisted learning and assessment.

### 6.2.1. Existing space

The Faculty of computing and IT is currently housed in a 2,400 square metres building donated by The Royal Kingdom of Norway. This space is supplemented by space from other places in the University for teaching purposes. The Faculty also uses 1000 sq metres of space in the former Institute of Computer Science building located in the Faculty of Science (old site).

### 6.2.2. New building

In February 2006, exactly one year after transition from Institute to a faculty, the Faculty of Computing and IT embarked on construction of 12,000 square metres complex as extension of the current building, so as to cater for the growing demand for computing and ICT training in the region. The centre once completed will be the largest computing and ICT training and research centre in the whole of Africa. It will have six floors comprised of: 6 computer laboratories each of 800 square metres (1000 seat capacity); 6 lecture theatres each of 400 square metres (600seat capacity); 6 small laboratories of total area 1200 square metres; 6 small lecture theatres of total area 1200 square metres; One canteen of total area 300square metres; 300 square metres of office space and 1800 square metres of circulation space. This facility is expected to boost e-learning (online learning and assessment) especially for big classes in the University. The facility will also be used in implementing crosscutting university-wide computing courses.

## 6.3. Computing Resources

CIT recently procured an IBM power clustered server, the first one of its kind in any University in Eastern Africa, with high availability functionality to ensure reliability and access at all times. The Faculty has also 10 more powerful servers at least 1,500 desktop computers. In addition, the Faculty encourages the students to use their own computers and so far more than half of our graduate students and more than a third of undergraduate programs have their own laptops. More so, students who are working use computers at their places of work. In Uganda it is common to have some hours of the day without electricity. So the Faculty has acquired three powerful generators to ensure 24/7 power supply.

## 6.4. E-learning/ online learning

E-learning is learning that is facilitated by the use of digital tools and content, i.e. any technologically mediated learning using computers whether from a distance or in face to face classroom setting (computer assisted learning). E-learning covers a wide set of applications and processes such as web-based learning, computer-based learning, virtual classrooms, and digital collaboration. Typically, it involves some form of interactivity, which may include online interaction between the learner and their teacher or peers. E-learning can cover a spectrum of activities from supported learning, to blended learning (the combination of traditional and e-learning practices), to learning that is entirely online. It is offered over a network (internet, intranet/extranet, LAN, WAN) or using electronic delivery methods such as personal computers, CD-ROMs, audio and videotape, video conferencing, P.D.A.s, Mobile Phones interactive/Digital Television, satellite broadcast, websites and e-mail. Communications technology enables the use of the Internet, email, discussion forums, and collaborative software. Learners are able to learn any time and any place [5].

The Faculty of Computing and IT has implemented computer-based learning and is now piloting fully-fledged e-learning for both on campus and off campus students. Problem based learning is being adopted in many courses on the programs and as a result learning is more and more becoming student centered.

## 7. LESSONS LEARNED/ RECOMMENDATIONS

### 7.1. Establishing/ Strengthening Faculties/Schools of Computing

The human capital in ICT/ Computing is still low in African countries, Uganda inclusive. There is need to prioritize the establishment of the School/ Faculty of Computing that will run the major computing programs (computer engineering, computer science, information systems, information technology and software engineering) in every University and create human capital that meets the needs of the employers in Africa and around the world.

### 7.2. Cross fertilization of Computing/ ICT Programs

In an effort to optimally utilize the scare resources, due to under funding of most public Universities in Africa both public and private Universities must be encouraged to house the computing programs under one faculty/ school. This will also put the core lecturers required on computing programs under one faculty/school. Students on all computing programs are required to take some non-computing courses as indicated in Table 2. These non-computing courses must be outsourced from outside the computing faculties/schools.

No single student can have all the computing skills set but students from different computing programs can undertake joint projects. It has turned out that most employers require computer science, computer engineering, software engineering, information systems, information technology and electrical/ electronic engineering graduates to work on joint projects so that they can put their multiple skills to good use. So joint projects before graduation prepares them with teamwork skills that are crucial in today's workplace. This converged and multidisciplinary approach is considered as better alternative to the traditional curricula where separate computing subjects are taught in different faculties of science (for CS), engineering (for CE) and of business (for IS).

### 7.3. Quality of Graduates

The National Council for Higher Education in Uganda is in the process of putting in place a quality assurance framework and subject benchmarks. Makerere University is in the process of putting in place a quality assurance framework. So within Uganda there are no quality assurance frameworks/ subject benchmarks at both national and University level to guide the process of establishing academic programs. Quite often there are rifts between faculties on which faculty should host a program and at times faculties have put in place programs, which can not measure up to international benchmarks. This in the end renders graduates from such programs unacceptable internationally as a result of following curricula that does not provide the relevant skills or being taught by staff that lack the necessary skills.

However, new programs at Makerere University do not have such problems and Makerere University has embarked on the revision of old curricula to ensure that international standards are adhered to.

Therefore it is necessary that all countries in Africa be required to put in place Quality Assurance Agencies, quality assurance frameworks and subject benchmarks to guide higher education.

### 7.4. ICT and Gender

The Faculty of Computing and IT has systematically identified and recruited female academic staff into the different academic departments and currently constitute approximately 51%. The female students' population on computing programs has dramatically increased and now stands at 46% of the total student population in the faculty. There seems to be a positive correlation between the number of female lecturers and the number of students in the faculty. So computing departments need to improve on the number of female lecturers if the enrollment of female students on the computing programs is to improve.

### 7.5. African Diaspora

All efforts should be put in place to involve the African Diaspora in Science and Technology and Innovations on the African continent. With ICT it is possible for them to still contribute from wherever they are based. Also centres of excellence with good terms and conditions of service must be put in place to attract skilled African Diaspora especially in the area of Science and Technology/ ICT to return home. African Diaspora have gained knowledge and if tapped by African Universities and Governments could boost Research and Development and innovations on the Africa continent. All in all African governments must ensure that the brain drain turns into brain gain or brain circulation.

### 7.6. Sensitization about the Computing Discipline

The discipline is undergoing tremendous developments day by day as a result of technological advances and most scholars have not yet understood what computing is all about. It is common for many academicians to imagine that software engineering is part of computer science and that computer engineering is not a subfield of computing. As much as there has been sensitization about Information and Communication Technology (ICT) there is also need to sensitize University leaders and Quality Assurance Agencies about the computing discipline and its importance in ICT-led economic development.

### 7.7. Impact on socio-economic development

Many African countries (e.g. South Africa, Ghana, Rwanda, Uganda, Kenya) have developed ICT-led socio-economic development strategies. However, without a critical mass of ICT professionals in these countries these strategies will only remain on paper. It is the critical mass that will lead to several innovations and patents that are a preliquisite for development. Also the critical mass will ensure stable workforce, easy retention of staff and generally affordable skilled human capital. This in the long term will lead to low costs of production, which will attract multi-national companies and lead to high tax collections, as is the case in China and India.

## 8. CONCLUDING REMARKS

Computing is still a new discipline that should be prioritized by all Universities in Africa if the crucial ICT human resource for an ICT-lead economic development is to be developed and sustained.

In this paper we have explained the need for using curricula/ subject benchmarks from professional bodies and quality assurance agencies both at national, regional and international levels so as to ensure easy mobility of workforce and comparability of skills across the globe. The role of the private sector in curricula design and implementation has been emphasized. We have also described strategies employed by the Faculty of Computing and IT at Makerere University to run both undergraduate and postgraduate programs in a resource constrained environment. Lastly we have highlighted lessons learned and made recommendations for future improvements.

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Professor Venansius Baryamureeba holds a PhD in Computer Science and is a Professor of Computer Science. He currently serves as the Dean of the Faculty of Computing and IT at Makerere University, Uganda. He is a member of Senate and Council at Makerere University. In addition to administrative and teaching duties, he currently supervisors master's and PhD students in computing disciplines and has published extensively in international journals. He has a track record as a consultant on ICT research, training, advisory services and policy and a recognised expert on e-governance and higher education planning and management, and he has been involved in the design and implementation of computing curricula at both undergraduate and postgraduate levels. He is the Chairman and Managing Director of ICT Consults Ltd, one of the prestigious ICT consultancy firms in Africa. He is also currently involved in initiatives of growing and sustaining ICT/ Computing human capital in Sub-Saharan Africa region.