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An Investigation into Using Current Information Technologies to Provide Engineering Education to Sub-Saharan Africa

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Abstract
Engineering education is one of the key factors for the development of any nation. Nowhere is this more true than in Sub-Saharan Africa, where a dearth of engineers has contributed to the lowest regional standard of living of anywhere in the world. The need in this region is so vast and immediate that it could only be met by the use of ICT-based education. This paper presents the findings of an investigation into the feasibility of providing tertiary level engineering education through current information and communication technologies in Sub-Saharan Africa. Data collected includes an extensive review of the available literature, contact with current providers of ICT-based engineering education, and a survey of 250 engineering firms in Sub-Saharan Africa, the end-users of engineering education in that region. The findings indicate that it is indeed feasible to deliver tertiary level engineering education to Sub-Saharan Africa, assuming that resources could be found for course development and to enhance the technological capacity of local institutions. This paper complements the picture of a 'flat world' draw by Thomas L. Friedman [43] who in his recent book focused on well developed countries only.

I Introduction and Background
Engineering is widely recognized as a vital prerequisite for economic development, especially for Least Developed countries (LDCs). Studies have shown a strong correlation between a society's capacity to provide engineering education and improved economic performance, and the number of engineers per capita is very positively associated with its economic growth [1]. This is evidenced by the fact that in 1993 there were 166 times more engineers in developed countries than in Sub-Saharan Africa [2].

Sub-Saharan Africa is one of the world's least developed and poorest regions where many countries have annual per capita incomes of less than US $200. Both contributing to and resulting from this impoverishment is a sustained severe shortage of available human capital, as well as the indigenous capacity to substantially increase the human resource base. Countries in the region can only provide tertiary education to a small fraction of their populations, and resource constraints make it difficult for institutions to remain up-to-date. This is particularly the case for the field of engineering.

Engineering education in Sub-Saharan Africa is extremely limited. In some countries it is non-existent while in others it is offered almost entirely by private institutions. Even where the discipline is offered, there are "concerns about declining quality of science and engineering education" and about "the loss of leading science and technology expertise to other regions of the world" [3]. Most Africans studying engineering already do so abroad and many do not return home, depriving their indigenous countries of much needed skills. The dearth of trained engineers in Sub-Saharan Africa results in their importation from outside the region, often at considerable expense, in order to fill the gap. This costly reliance upon external sources for engineers is neither desirable nor sustainable.

Since all indicators point to the improbability of a significant increase in the resource base for most Sub-Saharan African countries is unlikely to significantly increase in the foreseeable future, the region's economic development will require both an appropriate and an affordable means by which to dramatically increase the human capital base, particularly the number of trained engineers.

In the last three decades the advent and rapid expansion of the internet, the World Wide Web (WWW) and associated Information and Communications Technologies (ICTs) have had a dramatic effect on globalization and a leveling result on the commercial playing field, especially for developing countries. They have also offered the first very real possibility of providing education at a reasonable cost to populations residing in the most remote areas of the world. ICTs have been adapted and increasingly widely used for distance learning outside the traditional education setting. While most of this has taken place in developed countries, evidence has shown that where ICT-based courses have been implemented, both at regional and local levels, governments and residents alike have witnessed vast improvements in access to education [4,5]. Evidence also indicates that the quality of learning is comparable to that provided through traditional means [6].

At present there is no evidence that engineering education, at any level, is currently being provided in Sub-Saharan Africa using only ICT, although related technologies are being widely used to provide other types of education and training. While Sub-Saharan African countries are faced with considerable constraints and, in many cases, have very different needs than developed countries, the potential of ICT to both expand and strengthen engineering education while making it more appropriate for the local context appears undeniable. The key question is whether or not it would be feasible to pursue development of ICT-based engineering education given the current development of the technologies and the socio-economic situation of Sub-Saharan Africa.

The purpose of this paper is to present an answer to the key question posed above. This, however, requires a thorough understanding not only of the technical requirements for viable ICT-based educational programs, but also of the Sub-Saharan African context in which these programs would have to operate. Since the focus is on engineering education at the tertiary level, it was also necessary to determine basic academic and skill requirements of the region and if the current state of engineers are adequately equipped for their market.

Due to the very limited information available on the use of ICT-based education programs in Sub-Saharan Africa, it was necessary to draw heavily upon the extensive literature regarding ICT distance learning in developed countries. The ready availability of the UK's Open University (OU) afforded the opportunity to obtain data first hand on its experience of providing ICT-based education, especially so in the case of engineering, in which the OU provides a full degree course. The dearth of available information on engineering education in Sub-Saharan Africa, and especially the total lack of information on ICT-based engineering education in this region, necessitated the use of a survey to collect primary data from the local end-users of engineers – the firms and organizations that employ them. This survey was conducted primarily to ascertain if ICT-based engineering education would be acceptable to local employers and thus appropriate for the local context, whether they would be willing to support such a program, including contributing to its development, and to determine if they felt such a program would be appropriate from the standpoint of skills development.

II Use of ICT to Deliver Tertiary Level Education

Information and communication technologies encapsulate all hardware and software that are used to share any data, whether it is vocal or written, digital or analogue. Fax machines, copiers, and the telephone are all included in this, although the focus of this paper is on the computing and internet aspects. These technologies have had a massive effect on the world over the past 30 years. The amount of instant communication many people take for granted today was beyond the scope of even the most futuristic thinkers less than half a century ago. People are no longer limited to local resources, and the advent of the World Wide Web has made it even easier to instantly access a virtually limitless tome of information on practically any subject.

This has lead to an exponential increase in the use of ICT in the education sector. It is an integral part of all universities in developed countries, used for both communication, such as emails and chat rooms, and the day-to-day running of many vital functions including finance and coursework grading. Higher education has always led the way in the development and usage of such technologies, as the internet itself was designed in part as a quick way to communicate and share scientific data between educational institutions [7].

More recently, these technologies have been used to expand the reach of higher education, entering the realm of distance education. The original offerings of single, one-off modules and lessons have evolved into full courses making it possible to earn an entire degree online. In the last decade this has expanded enormously and in 2005 there were 1,680 institutions that offered over 54,000 online courses [8]. The number of universities that have embraced learning through ICT is growing dramatically, from the Anadolu University in Turkey with over 500,000 students to the distance learning only Open University in the United Kingdom. However, it is important to note that the bulk of these courses do not exceed national boundaries. The vast majority offered are based solely in the United States of America and only available to US citizens.

III Future of ICT in Higher Education

Eighty-five percent of public universities in the US consider online education critical to their long-term academic strategies [9]. Its benefits have long been publicized and discussed in the academic community, but only recently has this recognition become widespread [10]. While information technologies are still progressing at a fast rate, the core tools for distance learning, such as video conferencing, are readily available now. At the same time, considerable resistance still exists to the adoption of e-learning, stemming largely from the misconception that the lack of face-to-face interaction results in poorer quality teaching than that provided in a traditional setting [11, 12]. There is little evidence to support this view. According to 248 studies compiled by North Carolina State University, no significant difference could be found between distance learning and traditional classroom learning, and a review of this study concluded that "Distance learning (can be) considered as effective as face-to-face learning" [13, 6]. In addition to this, The Open University in the United Kingdom, the country's premier distance learning institution, was recently ranked among the top five institutions in the United Kingdom for quality of teaching [14].

IV ICT-based Tertiary Education in Sub-Saharan Africa

While ICT has already made major inroads into tertiary education in most developed and middle income countries, due to a range of obstacles it has not become a standard feature in Sub-Saharan Africa. Although there is certainly some mistrust attached to using and expanding ICT-based education in this region, the major obstacles relate more closely to the scarcity of economic and technical resources than to any educational bias [15].

In a recent report, the Association of African Universities has acknowledged that the quality of African tertiary education is declining as a result of dwindling resources [16]. This is especially problematic for a region which already has so few technical resources. For example, there is an average of one computer per 250-400 people in Sub-Saharan Africa, well below the international quotient of one computer per 15 people, or the North American and European ratio of one computer for every two people [17]. While in Sub-Saharan Africa this number drops to one for every 55 tertiary students, this ratio would only support light browsing and printing. It would be far from sufficient to support the implementation of a full ICT-based degree level course. Since computing technology is readily available worldwide, the viable solution to this problem would be one of increasing available financial resources to purchase and maintain additional computers.

Simply the provision of a greater number of computers however would not solve the access problem with respect to engineering education, as the computer requirements for engineering are generally higher than those for other courses. This is due to the extra power which is often needed to run important analysis programs like CAD packages. The Engineering Department of the UK's Open University considered the following (see Table 1) to be the minimum requirements for a student to be able to undertake their engineering course compared with a normal OU course [18].

A recent study, commissioned by the World Bank Institute, which researched the internet capabilities of over 80 higher education institutions in 40 African countries, found the average available bandwidth to be 537 Kbps download and 769 kbps upload, but this varied widely from 7 Mbps to just 28 Kbps. The study also found that 68% of the total bandwidth available to universities was already being utilized full time. While the upper range of these bandwidths would be sufficient to run an ICT facilitated course, many institutions would not be able to run a course without upgrading their current connection and dramatically increasing their available bandwidth. From the standpoint of more effectively and widely utilizing ICT, universities in Sub-Saharan Africa would require *ten times* the bandwidth that is currently available to them. An idea of the overall bandwidth situation in Africa can be characterized by comparing it with developed countries where, for example, the average North American user has 570 times more international bandwidth than the average African citizen [19].

Table 1: Minimum PC spec for engineering students at Open University (UK)

<table>
<tr><th colspan="2">Component</th><th colspan="2">Typical Requirement</th><th colspan="2">Engineering Requirement</th></tr>
<tr><td colspan="2">Processor</td><td colspan="2">Pentium 700MHz</td><td colspan="2">Pentium 1GHz</td></tr>
<tr><td colspan="2">Memory(RAM)</td><td colspan="2">64MB</td><td colspan="2">128MB</td></tr>
<tr><td colspan="2">Operating System</td><td colspan="2">Windows XP/2000</td><td colspan="2">Windows XP/2000</td></tr>
<tr><td colspan="2">Hard Drive</td><td colspan="2">10 GB</td><td colspan="2">20 GB</td></tr>
<tr><th colspan="6">Other</th></tr>
<tr><td colspan="3">Color Monitor</td><td colspan="3">Sound/Video Card</td></tr>
<tr><td colspan="3">Keyboard/Mouse</td><td colspan="3">Microphone/Webcam</td></tr>
<tr><td colspan="3">Modem</td><td colspan="3">Office Software</td></tr>
</table>

This limited availability of internet bandwidth would place the greatest constraints on the more capacity-intensive aspects common to many ICT facilitated courses - the use of live video and audio [20]. A connection of 128 kbps to 256 kbps is normally required to run smooth video and audio over the internet [21, 22]. Given the average of one computer per 55 students, and an average bandwidth of 3.36 kbps per computer, a video conference at these speeds would take the equivalent bandwidth that is normally allocated for 2000 to 4000 people. This is obviously unrealistic, with the easier solution being to increase the bandwidth first and then the number of computers.

V Socio-Economic Obstacles

Many Sub-Saharan African countries still heavily regulate their telecommunications sectors, allowing only a state-run monopoly to offer internet. This, in turn, results in higher costs for access and generally a poorer service. One method of control commonly used is to regulate the market by requiring licenses to operate an Internet Service Provider (ISP) or to obtain internet from another source. While this is better than no competition in a closed market, it still limits the usage to larger institutions. For example, a VSAT license in Zimbabwe costs an average of US $72,000, which is prohibitive for virtually all institutions operating in the country [19].

For ICT distance education courses, it has been estimated that around 25% of the total costs of a course come entirely from the cost of hardware [23]. The cost of the course development generally requires the largest investment. For example, it can cost from US $10,000 upwards to develop each course hour. Given that the average course comprises around 30 lectures, each approximately one hour in length, course development costs would be at least US $300,000, depending on the country of development [24]. This is a substantial amount given the low level of public expenditure on tertiary education per student in Sub-Saharan Africa. Considering these costs and the low gross domestic income per capita of most countries in the Sub-Saharan region, it is almost certain that outside aid would be needed handle the development costs for these courses.

Once the development phase of a course has been completed and the hardware secured, there are still other costs that must be met. These include outlays such as teacher salaries, facilities maintenance, and running costs. The average cost per year of a computer per student in tertiary education ranges from US $18 to US $104, depending upon its usage [25, 26]. However, these estimated costs are based on usage levels that would be far less than that for a student taking an entire course using ICT. Taking this into account, a more realistic rate that has been suggested would be an average of US $1.70 per lecture hour [27]. Assuming that an educational program consists of six modules, each 30 hours in length, this would result in about US $300 per student, per year in computer and electricity costs. For an individual, these costs, combined with that of an internet connection of approximately US $60 a month, present a considerable expenditure [28]. For most students in Sub-Saharan Africa, if paid on an individual basis such costs would be prohibitive.

Traditionally, open universities operate at 13-73% of the per-student costs of conventional programs [28]. This is generally due to fewer recurrent costs, such as reduced face-to-face time. However, only a few cost studies and even fewer studies of cost effectiveness have been done on ICT programs in Africa, so although it can be assumed that the percentages would probably be similar it is not currently certain if the above costs would be valid for this region.

VI Overcoming Problems

Even with the above constraints, ICT is increasingly being utilized throughout the African continent to provide education at all levels. Its uses range from providing materials and training to teachers in primary education to providing the basis for university campus networks, which are used by 97% of universities [29, 19].

A study of 21 Sub-Saharan countries, not including South Africa, found that all were actively participating in ICT distance education courses. In 10 of these countries the courses were supplied by a local university, while in 19 they were supported by donor projects. In 11 countries Non Governmental Organizations (NGOs) were directly involved in the provision of technology-based education through ICT [30].

The international donor community has been very supportive of the use of ICT for educational purposes. The World Bank, for example, has initiated over 27 new education projects in the past 4 years, of which 22 have had technology supported components [28]. It also created, on a pilot basis, the African Virtual University (AVU) to serve as a technology based distance education network [31]. Created in 1997, the

AVU has grown to enroll over 23,000 students all over Sub-Saharan Africa. Working with 32 universities, it provides education and facilities as well as a Digital Library for journals and resources.

The African Tertiary Institutions Connectivity (ATIC) survey found that, in general, the situation for ICT in the Sub-Saharan Africa region is certainly improving. Obstacles and licenses are being lifted and governments are adopting official ICT policies to spur its development and growth within their countries. These ICT policies are designed to guide each country's technical development and the employment of digital technologies. Many are along the lines of those of developed countries, such as the UK's National Grid for Learning (NGfL). A sign of this positive development was shown by the fact that 58% of universities contacted in the ATIC survey which had VSAT had also obtained a fee waiver, allowing them to bypass licensing laws [19]. There are also four major infrastructure projects currently being implemented in Sub-Saharan Africa. These are spending over $400 million on connections which will have the combined potential of providing an extra 400 GBps of bandwidth in the region [32].

VII Dearth of Institutions Providing Engineering Education

There is very little information accessible on the availability of engineering education offered in Sub-Saharan Africa. No comprehensive database could be found, and most available articles and journals on the subject only addressed specific aspects of engineering education. One paper by the World Bank, however, did state that of 27 of the largest universities in 13 Sub-Saharan African countries only three offered engineering related degrees [28]. Although this is only a small sample of universities, this situation is probably a fair representation of the universe of African institutions. For example, Ghana, with a population of 14 million, has only one engineering school and a total stock of about 7000 engineers. They represent about 0.5% of Ghana's workforce. Engineers in the US constitute about 2% [33].

Technical colleges help in some ways to fill this gap. They are able to provide some engineering-related training, although generally in specific technical skill areas, such as air conditioning or basic electronics. The majority of these colleges are private, however, and rarely monitored by the government or outside quality assurance agencies [34]. There is also little to no accreditation for the courses they offer.

It was possible to gain an idea about the current status of engineering education in Sub-Saharan Africa from an extrapolation of information that was available on related subjects. For example, of 528,000 scientific articles produced worldwide in 1999, only 3,600 were from Sub-Saharan Africa, of which almost all were South African [3]. Of these papers, less than 5% were related to engineering and technology. Also, in the first half of the 1990s about 56,000 of 192,000 Sub-Saharan Africa students known to be undertaking tertiary-level studies, not including those in South Africa, were studying abroad because educational opportunities were unavailable in their own countries [31]. The indications demonstrate that a good portion was undertaking courses in engineering or related fields. For example, 22% of all Sub-Saharan African students studying in the US are enrolled in engineering, while overall only 4.7% of all tertiary students in the US are enrolled in engineering or computer science [31, 35].

Even where engineering education is offered in Sub-Saharan Africa there is concern about the quality and relevance of the education. For example, a study of universities that provide engineering education in the region found that over 40% of staff posts were empty [36]. It also found that due to the vast need for engineering skills, businesses often offered relatively large salaries in comparison to academic wages, drawing many teachers into the private sector.

It is important to note that much of the engineering education that *is* available in Sub-Saharan Africa may not even be completely relevant to the local business economy. This seems to have been the case for a long time, as a study in 1970 concluded that "*African engineering education does not concentrate on aspects which are readily applicable within African communities.*", while a report from 2005 found the situation much unchanged, stating there were "*large problems with the relevance of the curricula*" which needs to be "*re-examined for relevance, rationalization and efficient utilization of the resources*" [37, 36]. This latter report also found that, on average, the Sub-Saharan institutions only updated their curriculum every 10.4 years. This means that many engineers enter the market with the wrong set of "tools", requiring retraining.

This question of relevance is extremely important, as it directly relates to the value of the education which engineers receive. It appears logical that the education and skills provided to the students in their own countries should be adapted to their local conditions so that they would have a greater positive impact. It is also rational that if this were the case there would be a greater tendency for these persons to remain and work in their home countries. General Obasanjo, the president of Nigeria, alluded to this need to adapt such education to local needs when he stated, "*In education and in industrialization, we have used borrowed ideas, utilized borrowed experiences and funds and engaged borrowed hands. In our development programs and strategies, not much, if anything is ours.*" [38]. This overdependence on outside support, at least in the way it has been provided to date, may have even contributed to the lack of adaptability of education to Africa's local needs.

At the same time, there are few universities or research institutes in Sub-Saharan Africa that "*have proven capable to date of undertaking the long term research and producing the results needed to develop or adapt locally usable, productivity-enhancing technologies*" This indicates a strong need for the development of linkages between these universities and institutes and universities in the developed countries. A recent study reinforced this view when it concluded that "*The amount of engineering education and training required by engineers in Africa is so huge that it cannot be provided using resources within the region alone. This can be done only through international cooperation involving academic institutions and other organizations in the developed world and those in Africa.*" [39].

VIII ICT-based Engineering Education

The amount of engineering and engineering-related education available through ICT varies greatly based on the specific definition of "education". The number of universities and institutions offering basic engineering training are too many to count. Much, if not most, of this training is meant simply to refresh the skill set of a professional in the relevant field, or to provide basic training for someone wishing to enter a new area of engineering. There are very few universities that offer a full engineering degree through ICT. From an internet survey of 10 institutions in the U.S.

offering engineering degrees online it was found that only one offered a Bachelors degree in engineering, although all 10 offered various Masters degree courses, with the most common subjects being electrical and software engineering. In all, there were 26 ICT-based engineering degrees offered. A possible reason for this emphasis on short courses or graduate-level programs is that more specialized courses would be far easier to implement than a basic degree course that spans three to four years. Very few core engineering subjects such as mechanical and civil engineering were found to be offered through ICT.

By far the most advanced offering of engineering degrees online was available from the Open University of the United Kingdom. Established in 1970, the OU has been offering ICT-based distance education for much longer than virtually any other institution. It offers a range of degrees with varying amounts of engineering detail, from Bachelor of Science (BSc), BSc (Honours) in Technology, Bachelor of Engineering, Masters of Engineering, and Postgraduate Diploma in Engineering. The Bachelor of Engineering degree is offered in a number of specialized engineering fields. The cost of an OU engineering degree ranges from the equivalent of US$8,000 to US$10,000 [14].

With the exception of the semi ICT-based engineering courses being provided from the University of South Africa, no information could be found on any other ICT-based engineering education taking place in Sub-Saharan Africa today. Information on the African Virtual University indicated that it was considering offering courses in engineering. Whether this has been done could not be determined, as it was not possible to access the AVU web site.

IX Engineering Firms Survey

As noted above, previous studies have shown that it is extremely important that engineering education be appropriate for the local context, especially in developing countries. For this to occur it would have to be acceptable to the end-users of the engineers, i.e., to those firms that employ engineers. Therefore, in order to make a determination of the feasibility of ICT-based engineering education in Sub-Saharan Africa, it was first necessary to ascertain: (a) if these end-users of engineering education felt that the skills required by their engineers were already being provided and, if not, could be provided through an ICT-based course; (b) if there was a willingness on behalf of these firms to utilize and pay for engineering education provided through the non-traditional means of ICT; and, (c) if they would be willing to help develop courses appropriate to the local context. Since this study was focused on tertiary-level education it was also necessary to know how important employers viewed university level accreditation, and if continuing education to keep skills up-to-date was needed.

IX.A Survey Research Methodology

To collect this information, a web-based survey of engineering firms in Sub-Saharan Africa was developed and conducted between November, 2006 and January, 2007. Due to distances, costs and times involved it was not possible to include firms that did not have an active email address. While it might have been useful to obtain the input of these firms, it was assumed that those that do not use electronic mail would also be those with the least interest in an ICT-based engineering course. In all, email addresses were obtained for a total of 385 companies. However, when emails were sent to these companies, 135 or 35% of the email addresses were found to no longer exist. This left a survey universe of 250 firms, out of which 51 responded. It was not possible to ascertain if those firms with invalid email addresses had simply changed or stopped using their addresses, or had ceased to exist.

It should be noted that while the respondents represented 13 countries in Sub-Saharan Africa, 56% were based in South Africa. This is almost certainly due to the fact that, in comparison with other Sub-Saharan African countries, it is far more developed, has a much greater technical base, and has a per capita gross domestic product (GDP) which is 50 times higher than most other Sub-Saharan countries [40]. However, since the questionnaire found no discernable divergence between the views expressed by South African companies and those of the other countries, it was not considered necessary to treat data from these respondents separately.

In formulating the survey questionnaire, the program outcomes of several universities were contacted to determine the key skills that engineers are expected to obtain from their education. The bulk of the questions were then divided into two main areas; skill sets, and ICT course interest.

IX.B Analytical Approach

The approach to data analysis was two pronged. First, simple distributions of responses were examined as were listings of open responses, which were then grouped into categories based on similarities. These were used to make general statements regarding issues such as whether or not the employers believe that the engineers they have employed have received adequate and appropriate education for the jobs they are currently doing. Second, partial-correlation and cross-tabulations were used to determine if relationships exist between particular responses, especially those related to accreditation, willingness to help develop ICT-based engineering courses and to pay for ICT-based education. Considering the limitations of the survey and the fact that the sample of respondents could not be considered completely random, these relatively unsophisticated techniques were considered appropriate for the kinds of data collected and very useful in displaying the level of association between important factors. The levels of association between particular variables in the data were determined by using a professional statistics program, SPSS, to find their Pearson's correlation value [41, 42]. This correlation was specifically employed in this case because of the ratio-based nature of the results. It should be noted that, as there were no comparable data available from other surveys, there was no predefined level of correlation used to serve as a threshold of importance or relevance. Consequently, for this analysis a Pearson's value of 0.2 was chosen as the minimum significant correlation. Although lower than the more accepted value of 0.5, this value was considered reasonable as it discarded the majority of the un-correlated data while providing a wealth of interesting and significant relationships.

Cross tabulation, a process in which two sets of data are compared against each other based on how the percentage of responses to one question is related to those of another, was then used to help display and fully quantify the important correlations found using Pearson's.

IX.C Survey Results

The survey found that Sub-Saharan engineering firms felt that the most vital professional skills or qualifications needed for their engineers were their understanding of engineering principals and computer literacy (Figure 1). Three quarters also felt that a degree in engineering and work experience were essential. The criterion relating to understanding engineering principals, which 94% of the respondents rated as vital, could be considered obvious, as no engineering company would want to employ engineers who do not know at least the basics of their trade. However, this criterion was included in the questionnaire in order to gauge the importance of later questions relating to the quality of training these companies believe their engineers have received.

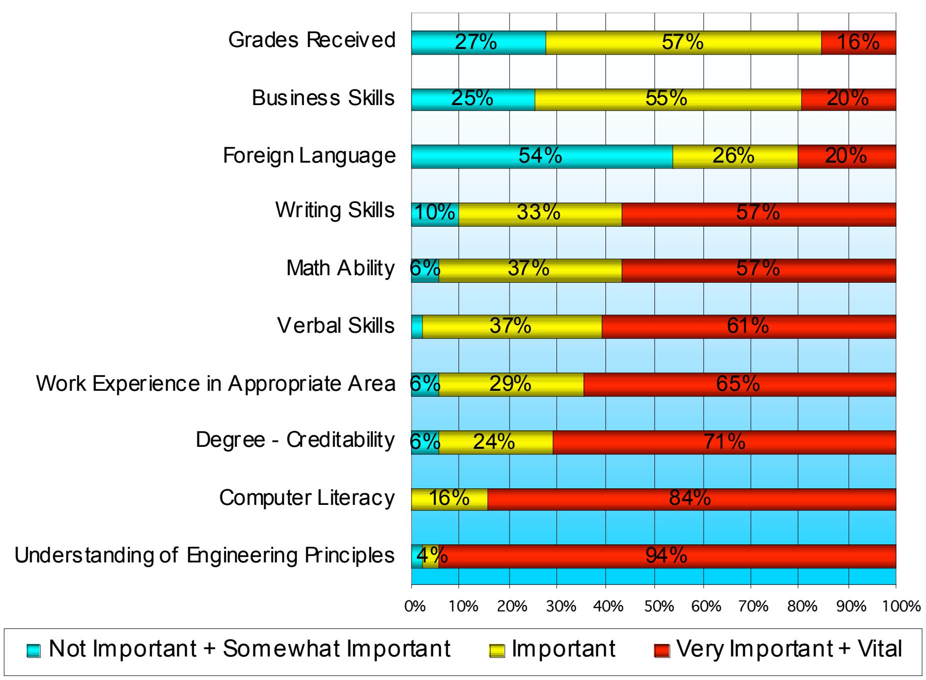

Figure 1: Professional Skills / Achievements

The importance placed on managerial and soft skills was also examined. As shown in Figure 2, 90% of the respondents felt that problem solving/creativity was by far the most important skill, followed by time management and teamwork. Only a quarter of the firms felt that business management skills were very important or essential although over three quarters felt these skills were at least important.

In addition to the specific skills listed in the questionnaire, companies were asked to comment on any other skills they felt were important for an engineer to possess. Of these, people skills and initiative were the most commonly mentioned, representing 34% of the responses. Business awareness and practical engineering ability were the two other most mentioned skills. It is interesting to note that business awareness was considered important while business management skills were not. One can only conjecture that the respondents were those who actually managed the firms, and while they felt that their engineers needed to be aware of the business side, they did not think they needed to have the skills required to manage the business.

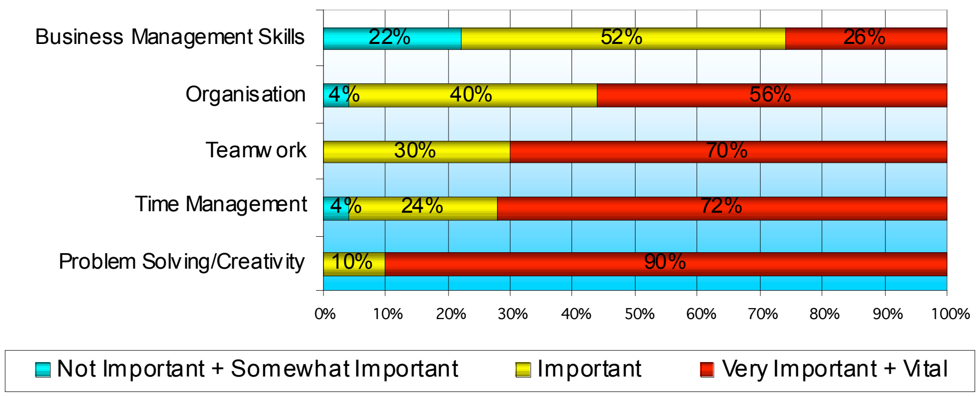

Figure 2: Managerial / "Soft" Skills

The survey also obtained information on the qualities these companies felt were most lacking in their engineers. As shown in Figure 3, almost one third of the respondents felt that practical engineering experience and skills were the qualities most lacking, followed by communications skills.

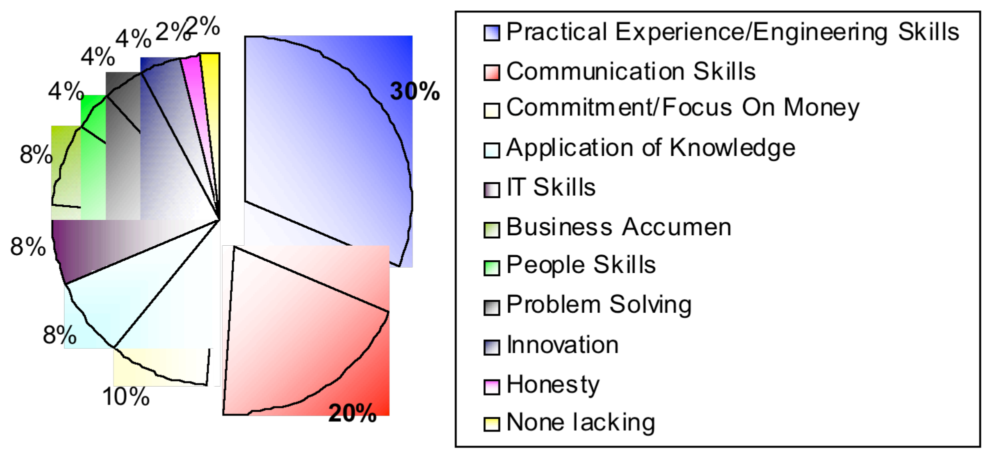

Figure 3: Skills Most Lacking in Engineers

When asked about the primary criteria used in selecting new engineers, the largest number (42%) stated that experience and qualifications were the most vital, while 70 % felt an internationally certified degree in engineering was either important or vital. Only around half (51%) of the respondents felt that the education and training their engineers had received was really relevant for the job, while a further 31% felt it was only semi-relevant. Eighteen percent did not feel the training their engineers had received was appropriate at all. The largest number (39%) felt that the lack of relevance of the education received stemmed largely from a lack of practical experience (39%) and a lack of soft skills (38%). It is interesting to note that project management/practical skills (40%) and business experience (24%) topped the list of skills training which they feel would have been most beneficial for their graduate engineers. These responses relate closely to the principal kinds of jobs these companies said they would most likely hire engineers for, i.e., project engineers and business analysts. Two thirds of the respondents indicated it was important for their engineers to be trained to work in the business side of engineering in order to be able to gain and keep clients, while 84% thought training in marketing and business was either important or essential for their engineers.

In attempting to ascertain how interested Sub-Saharan African companies would be in ICT-based education, including some form of continuing education in engineering, the survey found that 58% indicated they would find a continuing education course in engineering very useful and 73% were especially interested in participating in such a course if offered over the internet by an accredited university. Only 10% felt it would not be useful. The principal skills they would seek to upgrade using such a program were engineering management (34%) followed by technical and IT skills (18% each).

The survey sought to determine if companies in Sub-Saharan Africa would have an interest in working with local universities to both improve engineering education and make it more relevant to their needs. The response was very positive, with 78% indicating they would be interested in having ties to local universities, not only to help the companies themselves find future employees (31%), but also to help them gain knowledge on the latest engineering developments (29%) and improve the training their engineers receive (26%). Almost two thirds said they would be interested in helping develop engineering education with local institutions, and that this link would make them more willing to hire engineers from these institutions. Three fourths of the respondents stated they were even willing to host placements (engineering interns) for periods of two weeks to six months. Quite obviously, these companies see the importance to themselves of helping to improve and strengthen engineering education locally and in making it more relevant for their needs.

This analysis produced a number of interesting correlations, particularly with respect to the importance respondents placed on formal qualifications (degrees) and their willingness to help develop or improve engineering education in local institutions or to participate in ICT-based education. Basically, all of those who considered a reputable degree in engineering to be an important qualification were interested to some degree in ICT-based engineering education. Two thirds (65%) indicated they were even willing to pay for this kind of education. Most of the companies (85%) who felt an internationally recognized degree was important also saw value both for themselves and for improving local engineering education in having links with an educational institution. Over four fifths (82%) of this same group were willing to host placements of engineers as part of their education.

X Conclusions

There is obviously a critical need both for more engineers in Sub-Saharan Africa and a greater capacity to produce engineers on a broader scale. Given the very limited resource base of all countries in the region, with the exception of South Africa, it will be impossible to increase the pool of available engineers using traditional education methods. The only possible means for doing this is an ICT-based engineering education program. The current technological development of ICT is fully capable of supporting such a program.

The situation in Sub-Saharan Africa with regard to its technological capacity to support an ICT-based engineering education program is not favorable, although it is improving on all fronts. Sub-Saharan African governments, universities and donor partners have all embraced ICT as a viable means for increasing access to education at all levels, and barriers to expanding its reach are coming down. However, major constraints relating primarily to bandwidth and computer resources remain, but there are also attempts underway to address them. There are also good models which can be drawn upon to develop a viable tertiary-level engineering education program for this region. In particular, the Open University in the UK and the distance learning program of the University of South Africa both have extensive experience which would prove invaluable in developing such a program.

The need for engineering education to be appropriate for the local context has been highlighted. The Engineering Firms Survey showed this concern could be addressed by involving local universities and local end-users of engineering education in the development of ICT-based programs. The interest is there and, once developed, indications are that these local organizations would be willing to pay for this education, thus making the continuation of these programs sustainable. This approach would also build local ownership for the program.

Developing an ICT-based engineering education program for Sub-Saharan Africa which leads to a degree would almost certainly require the involvement of a university or institute in a developed country. The most appropriate scenario would be linking it with a local university or with a number of universities. Initially, the most viable approach might be for a developed country university to link with the University of South Africa, as it has the most mature distance learning program in the region.

Course development would obviously entail substantial upfront costs, although once developed and rolled out the per-student cost would be expected to decrease dramatically. Besides being the only way to significantly increase the capacity to produce engineers in the region, in the long term it should prove extremely cost effective.

The overall conclusion that can be reached from this study is that it is definitely feasible to deliver ICT-based engineering education in Sub-Saharan Africa, given the resources needed to develop the course in conjunction with local counterparts and to sufficiently upgrade their technological capacity with increased bandwidth and computers. Donor assistance would almost certainly be required for these development and start-up costs. The most acceptable approach initially might be to implement such a program on a pilot basis in order to demonstrate locally that it is a viable, cost effective means of producing appropriately trained engineers. Once this is proven, it could be expected that the resources required to expand this program would be forthcoming from many sources, not least of which would be from within the countries themselves.

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