ICT EDUCATION IN SWAZILAND SECONDARY SCHOOLS: OPPORTUNITIES AND CHALLENGES

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Abstract

Swaziland, like most developing countries, faces challenges in achieving the millennium development goals and education for all initiatives. In order to widen access to quality education, Swaziland has tried to come up with policies and strategies in a bid to harness the role of technology towards building a knowledge-based economy. The application of Information and Communication Technology (ICT) in schools is perceived as a means for transforming teaching and learning processes, and has been met with significant enthusiasm. Swaziland as a country also perceives ICT as a tool that will promote socioeconomic, political, and sustainable development. Hakkarainen et. al. (2000) points out that ICT is a transformative tool and its full integration into the school systems is necessary to prepare students for the information society they will inherit [9].However, research has shown that the ICT revolution has had an impact on curriculum development and delivery and continues to pose new challenges for education and training systems around the world [4]. Lack of adequate planning for the introduction of ICTs in schools, inadequate teacher training or lack of expertise in using ICTs on the part of teachers, inequalities in ICT distribution, lack of technical support and inadequate infrastructure are usually some of the key factors affecting the introduction, adoption and integration of ICTs in schools. In this paper we discuss enabling conditions or opportunities and challenges in the implementation of ICTs in education as well as shed some light on the critical need for establishing a policy framework that will guide the implementation of ICT throughout secondary schools in Swaziland. The importance of putting in place a well- structured policy to guide the introduction of ICTs in the schools and to recognize all the ICT related costs is highlighted.

INTRODUCTION

The major goal of ICT in education in Swaziland is to craft an educational system in which learners leave schools confident, innovative and industrious users of new technologies, including information and communication technologies, and understand the impact of those technologies on society [10]. ICTs (*information and communication technologies)* are defined, for the purposes of this paper, as a "diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and manage information." These technologies include *computers, the Internet, broadcasting technologies (radio and television), and telephony (fixed and mobile)*. ICTs now offer major opportunities to advance human development – from providing basic access to education or health information to making cash payments and stimulating citizen involvement in the democratic process.

The school curriculum, in Swaziland, offers ICT education as an optional subject in secondary schools while it is compulsory in tertiary education. This is interrogated in order to establish that the ICT policy framework for the introduction of ICTs in education must ensure consistent nurturing at all education levels. ICT education cannot be optional if the country needs to be in the forefront of ICT development to establish a foothold in a knowledge driven economy, reduce the digital divide, and grow the economy, social fabric and administrative efficiency of the country.

Education is seen as the natural platform for equipping the nation with ICT skills. Information and Communication Technology has a direct role to play in education and if appropriately used, ICT, can bring many benefits to the classroom as well as education and training processes in general[8].In 1984, Seymour Papert, when he was at the MIT Technology Lab, predicted that, "*there won't be schools in the future….I think the Computer will blow up the school...*"*(Trying to predict the Future," Popular Computing 3(13), pp.30 – 44)*[18]. This shows that ICTs have, for a long time, been seen as potentially powerful enabling tools for educational change and reform. The experience of introducing different ICTs in the classroom and other educational settings all over the world seems to indicate that the full realization of the potential educational benefits of ICTs is not automatic. The effective integration of ICTs into the educational system is a complex, multifaceted process that involves not just technology because, given enough initial capital, acquiring the technology is the easiest part, but curriculum and pedagogy, institutional readiness, teacher competencies, and long-term financing, among others, are the most crucial aspects to consider [17]. While there is no conclusive research to prove that student achievement is higher when using ICTs in the education space, either in the developed or developing countries, there is a general consensus among practitioners and academics that integration of ICTs in education has a positive impact on the learning environment. [7].ICTs also offer possibilities in facilitating skill formation, sustaining lifelong learning, and advancing community linkages. Planning for effective use of ICTs in education necessitates an understanding of the potential of technologies to meet different educational objectives and, consequently, to decide which of these objectives is pursued [6].

For the developing countries, like Swaziland, ICTs have the potential for increasing access to and improving the relevance and quality of education. Improving the quality of education and training is a critical issue, particularly at a time of educational expansion. ICTs are also transformational tools which, when used appropriately, can promote the shift to a learner-centered environment [1]. ICTs, by their nature, can help expand access to education. One defining feature of ICTs is their ability to transcend time and space. Online course materials can be accessed at any time and distance is not an issue. Teachers and students no longer have to rely solely on printed books and other materials in physical media housed in libraries and available in limited quantities for their educational needs. With the Internet and the WWW, a wealth of learning resources in every subject and in a variety of media can be accesses from anywhere at any time of the day and by an unlimited number of people. ICTs also facilitate access to resource persons, mentors, experts, researchers, professionals, business leaders, and peers all over the world. Professional isolation from which many teachers suffer can also be broken by ICT use [18].

This paper examines the opportunities and challenges in the implementation of ICTs in secondary schools in Swaziland. The discussions in this paper are based review of literature on ICT, review of Ministry of Education and Training documents, National ICT policy documents, review of NGO like Computer Education Trust and others and International organizations like UNDP country reports, our experiences as academics at the University of Swaziland and informal conversations and discussions with people from the private sector and educators, including headmasters and teachers.

Education System in Swaziland

Education and training in Swaziland is divided into four main sub-sectors: early childhood care and development (ECCD), primary education, secondary and high school education, post-secondary or tertiary education. In 2010 there were 780 public schools in

Swaziland: 564 primary and 216 secondary (according to the EMIS, 2010). Swaziland has one national university as well as teacher-training and nurse-training colleges and a few skills-training institutes. Swaziland's adult literacy rate for 2008 stood at 89%. The net primary school enrolment was 89% during the same period [16].

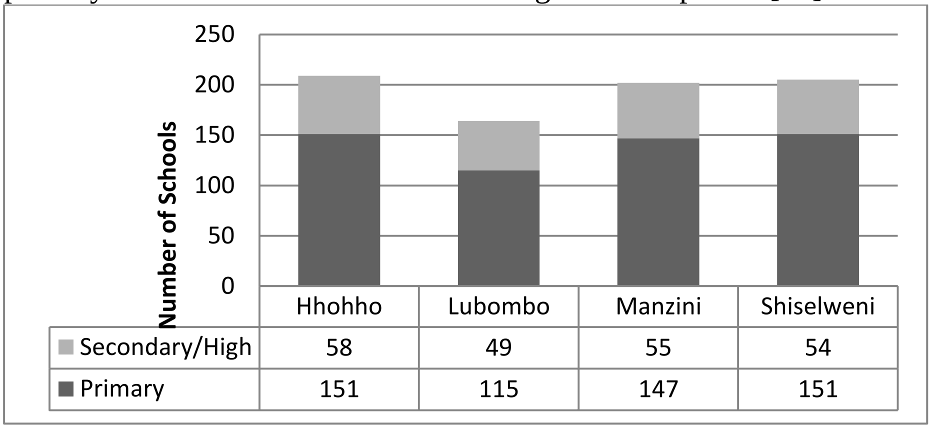

Figure 1. Public Schools Per Region (EMIS 2010)

Primary education in Swaziland covers seven years with the age range from 6 to 13 years. Secondary education is divided into two sub-systems: three years of junior secondary and two years of senior secondary. Post- secondary education consists of tertiary education and vocational education[15].There is a total of 230public and private, secondary schools and all have electricity. An estimated 10% of the secondary schools are based within 5km radius of the urban cities of Mbabane and Manzini, and these schools could potentially tap into the ICT infrastructure within these cities. Through the initiative of Government, Computer Education Trust (CET) and other organizations, at least 70% of the government schools now have a minimum of 20 personal computers per school. CET hopes to achieve 100% coverage by the end of 2013. ICT is not yet offered as a main stream subject in secondary schools and there is no official curriculum for the subject.

Current situation of ICT services in Swazi Urban and Rural Communities

An estimated 78% of the population lives in rural areas and the remaining 22% on urban areas. Mainly the urban residents of the capital city of Mbabane and the city of Manzini, estimated at 75,000 and 110,000 respectively, remain the major beneficiaries of limited information and communication technology infrastructure provided by only 1 fixed phone operator (SPTC) and one mobile operator (MTN). These communities enjoy the services of about seven (7) internet services providers (ISPs). Access to internet is possible through internet cafes, ASDL, mobile telephone, wireless dongles. Access to radio and television is also well developed.

The ICT infrastructure in rural communities is relatively poor. With the exception of radio, mobile telephony, with an estimated 72% subscription and 95% coverage of the population, remains the only infrastructure that could be used by rural communities to access the internet. The fixed phone coverage, estimated at only 4.38 coverage of the population, hardly covered rural communities. Television signals and wireless connections are either very poor or not present at all in some of the rural communities.

In Swaziland almost every secondary school is connected to electricity. More than half of the 230 high schools (both Rural and Urban) have on average about 20 PCs stand alone. Most of these are re-furbished computers donated by the Computer Education Trust (CET), with the help of ComputerAid International and SchoolNetSA. Very few have internet access. Amongst the schools that have computers, there is a problem of which curriculum to follow because there is no single recommended curriculum. So some schools use the

Cambridge IGCSE, others follow the Institute of Computer Education South Africa (ICESA), others use Future Kids which teaches the ‘Skills Pro’ curriculum and a few others offer City & Guilds. This makes curriculum monitoring & coordination and collaboration amongst the schools and teachers to be very difficult. Fig. 2shows the numbers of urban and rural schools that are currently offering computer studies for each of the four regions in Swaziland.

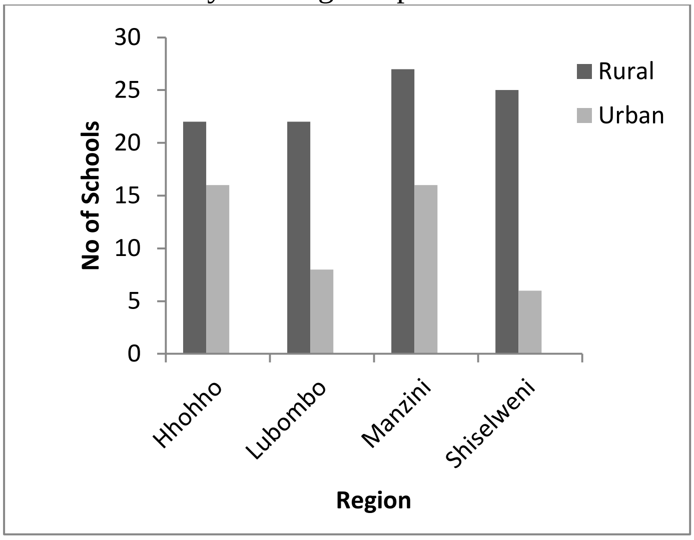

Figure 2. Schools Offering Computer Studies

Current Initiatives

Most secondary schools, especially in rural areas, had no proper rooms that could house the computers. With the assistance of Micro Projects, some of the schools are currently constructing computer labs. In some cases vacant classrooms are being converted into computer labs. The Ministry of Education is also currently pushing for the creation of ICT teaching posts since currently there are very few allocated posts for ICT teachers from Teaching Service Commission (TSC) and the Ministry of Public Service.

The Ministry of Education has entered into partnerships with JICA (Japan International Cooperation Agency) to get help in assessing the situation on the ground and come up with recommendations to influence ICT staffing policy, curriculum development and resource allocation. The Ministry is also in the process of creating a new section within its administrative structure to deal with the development of ICT education. Already there is a Senior Inspector for ICT. The creation of the unit will require new staffing and additional financial and material resources. In the years ahead, ICT teachers would have to be trained, recruited and posted to schools with adequate resources. Without this, it would be very difficult, if not impossible, for the existing staff and resources to stretch themselves further to accommodate this initiative effectively in an already tightly packed curriculum and possibly highly congested classroom time and space.

Swaziland ICT Policy Framework

Technologies have a great potential for knowledge dissemination, effective learning, and efficient education services. Yet, if the educational policies and strategies are not right, if ICT in education policies are not well thought out, and if the prerequisite conditions for using these technologies are not met concurrently, this potential will not be realized [18]. The challenges facing education in Swaziland are increasing and the struggle between needs and resources is deepening. The quest for radical solutions is intensifying and the pressure on decision makers to do something is growing. However, in deciding the introduction of ICTs in education, decision makers need to be bold but not reckless, cautious but not slow, and calculating but not procrastinating.

The Government of the Kingdom of Swaziland, through the Ministry of ICT, has developed the National Information and Communication Technology Infrastructure policy. This was done under the auspices of the African Information Society Initiative (AISI) and with financial assistance from the Government of Finland and technical assistance of the United Nations Economic Commission for Africa (ECA). The policy was adopted by parliament in August 2006. The development of an implementation has been very slow. A draft implementation plan 2012-2016 has been developed, by the Ministry of ICT, but is yet to be adopted and implemented. The Implementation plan accommodates sector policies from all the Ministries, the Ministry of Education included. The Swazi Government is also now keen on and committed to exploring the uses of ICTs in schools. The Ministry of Education has developed a draft policy on ICTs in Education. The fact that the Government is working on establishing an Education sector ICT policy is a reflection of the Government's realization of the importance of integrating ICT use and the promotion of quality education enabled through ICTs.

Key Difficulties and challenges

There are many challenges in implementing ICTs effectively in existing schools. Budgetary allocations for deploying ICTs in school education are typically limited, and given the high initial costs of setting up ICT systems, the cost factor works as a further deterrent. Shifting the existing focus from traditional educational models to an ICT-based education system is bound to be met with constraints and roadblocks. Below we discuss some key issues or problems that need to be addressed in order to create an ICT friendly environment in schools.

1. **Availability of infrastructure to support ICT**

The whole prerequisite hardware infrastructure needs to be in place with the supporting elements such as electricity, maintenance, and technical services. It is not realistic to expect teachers, who will be struggling with a new role and pedagogy, to assume technical responsibility for the hardware [18]. A basic requirement is whether appropriate rooms or buildings available to house the technology? In schools where there are some vacant classrooms and or old school buildings, extensive renovation to ensure proper electrical wiring, heating/cooling and ventilation, and safety and security would be needed. Another basic requirement is the availability of electricity and telephony. In the case of Swaziland availability of electricity at secondary schools is not a problem because all secondary school have electricity. The problem is that of the telephone network and access to Internet.

2. **Cost of implementing and using ICTs**

One of the greatest challenges in ICT use in education is balancing educational goals with economic realities. ICTs in education programs require large capital investments and developing countries need to be prudent in making decisions about what models of ICT use will be introduced and to be conscious of maintaining economies of scale [17]. The introduction of computers represents additional costs for schools. Categorical assessments of cost-effectiveness are difficult to make because of lack of data, differences in programs, problems of generalization, and problems of quantification of educational outcomes and opportunity costs [1]. A common mistake in estimating the cost of a particular ICT educational application is to focus too much on initial fixed costs—purchase of equipment, construction or retrofitting of physical facilities, initial materials production, and the like [3]. The Total cost of ownership is spread out over time. The total cost of ownership may therefore be considered to include the following:

Fixed costs	Variable or Recurrent costs
Renovation of physical facilities	Professional development
Hardware and networking	Connectivity, including Internet access and telephone time
Software	Maintenance and support
Upgrades and replacement	

Table 1: Cost of Ownership

Another dimension of cost is location, or who will pay for what. In projects that involve computers connected to the Internet, either the school or student or both bear the variable costs related to operations such as maintenance, Internet service charges, and telephone line charges [17].Given the current budgetary and resource constraints of the Government, a widespread investment in ICTs in education is probably not possible in Swaziland.

3. Capacity Building, work load and Employment Status of teachers

In most of schools in the country, the teachers are overloaded and inadequately trained. A survey [13] done in 19 schools from the different regions indicated that 26% out of 123 Mathematics & Science teachers teach 3 subjects. This is relatively high according to international standards. The same report shows that44% out of 119 Mathematics & Science teachers strongly indicated the need for in-service training. The report also shows that 17% of the 18 ICT teachers from 15 high schools in the 4 regions are permanently employed, 16% are on contract employment while the other 67%are on temporary employment. Out of the 15 high schools in the survey, only 20% have two ICT teachers while 80% have only one ICT teacher [13].Currently, there is very few ICT teaching posts allocated by the Teaching Service Commission.

4. Internet usage

Providing all the students with Internet access is a very expensive proposition for most Government schools. This is more so in the case of rural centers and remote areas, where Internet connections are bound to be erratic, if available at all. A different challenge altogether when it comes to Internet usage is the effort involved in monitoring the students usage of the Internet to ensure that they do not visit educationally irrelevant and socially undesirable sites, thus detracting from the intended objective. The cost of Internet access via MTN or SPTC is still relatively high.

5. Language Barriers

English is the dominant language of the Internet. A big proportion of online content is in English. A large proportion of the educational software produced in the world market is also in English. For developing countries, such as Swaziland, where English language proficiency is not very high, especially outside urban areas, this represents a serious barrier.

6. Technical support

Whether provided by in-school staff or external service providers, or both, technical support specialists are essential to the continued viability of ICT use in a given school. General competencies that are required would be in the installation, operation, and maintenance of technical equipment (including software), network administration, and network security. Without on-site technical support, much time and money may be lost due to technical breakdowns [5]. Equipment failure is a large issue and most schools simply put unusable systems on the side and make requests for additional equipment. With heavy usage, constant power supply problems (interruptions and fluctuations) and environmental issues (most rooms are not air conditioned; for instance), the usage of a computer set diminishes. It is also essential to employ ICT technicians who are able to carry out repairs and maintenance.

7. Availability of locally developed content& Curriculum

Content development is a critical area that is too often overlooked [5]. There will be need for local development of appropriate ICT teaching and learning material for use in the schools. There is need to develop a common ICT curriculum that can be followed by the secondary schools.

8. **Inadequate policy and regulatory framework**

Notwithstanding the noteworthy efforts in establishing a NICI policy[12], its implementation plan[11], and the several sector specific policies such as the Ministry of Education ICT policy [10], most of these efforts are uncoordinated and the said document are still draft document yet to be adopted by the relevant stakeholders. The appropriate regulatory framework is also non-existence. Because of the inadequate policy and regulatory framework, the integration of ICT into the Swaziland secondary school system is currently uncoordinated and uncontrollable irrespective of the current initiatives.

Recommendations

Although ICTs do offer many beneficial opportunities for education, they are no substitute for formal schooling. The role of technology is to support school education and not replace it. Access to ICTs ensures enhancement of traditional or formal education systems, enabling them to adapt to the different learning and teaching needs of the societies. It is also important to note that the impact of ICTs in education depends to a large extent on the purpose for which ICTs are used for. There is need for the government of Swaziland to work on going beyond just appreciation of the value of ICTs. The country needs to go beyond policies that merely recognize the strategic role of ICTs for growth and development but to institutionalize concrete measures that support ICT initiatives. Available data shows that access to computers is improving with almost every secondary school in Swaziland guaranteed to have at least 20 computers by end of 2013, the cost of Internet connections is still relatively high and ISPs are still limited in the country [2]. These figures point to the need to frame appropriate policies, build adequate infrastructure, and set aside adequate funds in order to support the deployment of ICTs in furthering the education levels of the country.

It is important to keep in mind that ICTs in education may also have a disruptive effect, if the integration process is not properly managed or guided. ICTs are only a tool and their success in education will depend largely on policy level interventions that are directed towards how ICTs must be deployed in school education. No ICT potential is realized automatically. Placing computers and related equipment in every classroom and wiring every building for the internet will not solve yield results if there is no policy to guide the implementation and if constraints are not properly assessed and addressed. Also important to note is that Technology is only a tool: no technology can fix a bad educational philosophy or compensate for bad practice. Therefore, educational choices have to be made first in terms of objectives, methodologies, before decisions can be made about the appropriate ICT interventions [18].

The worst that could happen is for Swaziland as a nation to try and deal with these issues in isolation by reinventing the wheel and failing to learn from the experiences (and mistakes) of others. It is essential therefore for decision makers, planners, and practitioners to be well aware of the wealth of worldwide knowledge, research, experience and thinking. This awareness should not lead to transplantation of ideas and experiences but, rather, should enlighten, guide, and inspire locally conceived and implemented decisions and plans. Wadi D. Haddad (et al) notes that integrating technology into the educational process is not a simple, one - step activity. It is an intricate, multifaceted process that involves a series of deliberate decisions, plans and measures [18]. Strong, sustainable partnerships between the Government, private sector and civil society must be built to offset costs and mitigate the complexities of the integration of ICT in education systems. It is also important for the Ministry to note that introducing computers and connectivity into schools without sufficient curriculum support and curriculum related ICT- enhanced content is like building roads but without making cars available.

REFERENCES

[1] Blurton, C.“New Directions of ICT-Use in Education”, p. 20.
[2] Computer Education Trust, Interim Report, 2012
[3] Consortium for School Networking. “Taking TCO to the Classroom: A School Administrator’s Guide to Planning for the Total Cost of New Technology”; available from http://ctap.fcoe.k12.ca.us/ctap/dhs3.4/tco2class.pdf; Last accessed 3 June 2012
[4] Draft White Paper on e-Education, South Africa, 2004
[5] ICT in Education/Key Challenges in Integrating ICTs in Education, http://en.wikibooks.org/wiki/ICT_in_Education/Key_Challenges_in_Integrating_ICT in Education, Last accessed on 19 June 2012
[6] ICT-in-Education Toolkit for Decision Makers, Planners & Practitioners, Concept & Blue print http://www.ictinedtoolkit.org/usere/conceptblueprint.php, Last accessed on 19 June 2012
[7] Infodev, PriceWaterHouseCoopers: Essay II: ICT in School Education (Primary and Secondary), Information and Communication Technologies for India and South Asia, 2010, Accessed on 22 June 2012
[8] Kipsoi J. Emmy, Chang’ach John K., Sang Hellen C.: Challenges facing adoption of ICT in Educational Management in Schools in Kenya, Journal of Sociological Research, ISSN: 1948-5468, Vol.3, No.1, June 2012.
[9] Mfum-Mensah Obed, Computers in Ghanaian Secondary Schools, Where does equality come in? Current issues in Comparative Education, Teachers College, Columbia University, 17 December 2003.
[10] Ministry of Education and Training, Draft Policy for ICT in Education, July 2010
[11] National Information and Communication Infrastructure Policy: Implementation Plan 2012-2016, Kingdom of Swaziland, 2012
[12] National Information and Communication Infrastructure Policy, Kingdom of Swaziland, 2006
[13] Planning and Inspection Unit of Secondary Education, Ministry of Education and Training, Kingdom of Swaziland, in Collaboration with Japan International Cooperation agency (JICA) : Current Teaching Environment and Status of Teacher Education in the field of Mathematics/Science/ICT in Secondary Education, Interim Report, May 2012
[14] Researching Virtual Initiatives in Africa,
[15] htt://www.virtualcampuses.eu/index.php/Main_page, Last accessed 28 July 2012
[16] Shafika Isaacs, ICT in Education in Swaziland, Survey of ICT and Education in Africa: Swaziland Country Report, April 2007,
[17] www.infodev.org/en/Document.431.pdf, Last accessed on 23 July 2012
[18] UNDP Swaziland Country Report, 2010
[19] Victoria L. Tinio & Browne Stephen, ICT in Education, ICT for development, UNDP, Bureau for development Policy, 2002.
[20] Wadi D. Haddad, ICTs for Education: A Reference Handbook, Part1:Decision Makers Essentials, version 2.0. http://www.ictinedtoolkit.org/usere/pdfs/ICTs_for_Education_Essentials.pdf, Last accessed on 19 June 2012
[21] Wheeler S.: The Role of the Teacher in the Use of ICT Keynote speech delivered to the National Czech Teachers Conference University of West Bohemia, Czech Republic.

INTEGRATING TECHNOLOGY INTO THE TEACHING AND LEARNING OF MATHEMATICS

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Abstract

The Department of Mathematics at Jackson State University (JSU), Jackson, MS, a Historically Black College or University (HBCU) in an urban area, utilizes Mathematica, MATLAB, LaTex, and Tex to support instruction in several mathematics courses, including its calculus sequence. However, there are no professional development programs to train faculty how to implement these software packages. To address this professional development need at JSU and other HBCUs, a workshop has been designed to cultivate faculty technological, pedagogical, and content knowledge (TPACK). The JSU Annual Calculus Workshop, which will be held at JSU, is designed to develop faculty expertise in three areas: (1) using computer technology equipped for teaching, (2) learning and researching in the mathematical sciences, and (3) promoting the integration of technology into undergraduate mathematics research programs. The annual workshop will entail three daylong sessions, including a follow-up meeting that will provide intense training in the use of the aforementioned technologies. The participants in the Calculus Workshop will be 30 faculty members from mathematics departments at seven HBCUs. The Calculus Workshop aims to facilitate a community of learners in which the participants will contribute by presenting their best practices and detailing the impact of technology on their teaching, student learning, and undergraduate research experiences in the mathematical sciences. In order to ensure the effectiveness of the Calculus Workshop activities, evaluations will be used to systematically analyze the impact of the project on the TPACK of faculty participants. Later stages of the project will include assessments of student learning as a result of faculty participation in the workshop.

INTRODUCTION

The National Science Foundation (NSF) views innovations in technology as avenues for "developing sustainable approaches to the utilization of energy, water and natural resources" among a plethora of other necessary societal actions [1]. It, therefore, supports efforts that promote the integration of technology into research and education. These efforts are not only critical to the sustainability of the United States, but also, and possibly more so, to the growth of developing countries. The authors have designed a project that will ensure that professionals in the STEM fields are prepared to matriculate seamlessly into global arenas that utilize technology for the advancement of all countries. Particularly, post-secondary mathematics classrooms will be transformed through faculty development, technology-enhanced curriculum designs, and the advancement of undergraduate research endeavors.

Advances in technology have provided wonderful tools for teaching and learning. Increasingly, mathematics graduate programs, undergraduate research programs, and employers of mathematics graduates and interns expect students to be familiar with computer programming platforms such as Mathematica, MATLAB, Maple, and scientific word processing in LaTex or Tex. Particularly in mathematics, several tools have become accessible to instructors and students in the last several decades that are regularly used in mathematical research and in the application of mathematics to other fields. These software packages strengthen the ability of instructors to demonstrate the applications of mathematics and bring to life conceptual aspects of calculus, differential equations and many other advanced mathematics courses. These tools also increase the ability of students to learn and research individually outside of the classroom. With the plethora of technological tools readily available to instructors, it is pertinent that faculty are trained to capitalize on the benefits of their use. These benefits extend to classroom instruction, project assignments, homework tasks, and undergraduate research.

Although training is critical to faculty effectiveness in the use of technology, it is also important to construct ongoing support systems that will foster continued engagement with emerging technologies and instructional strategies. Findings from a study of a Geogebra professional development program indicate that access to software and resource materials are not sufficient for instructors to commit to implementation of technology in the classroom [2]. Access to a community of mathematics teachers who engage in curriculum improvement is an essential factor in their ability and willingness to adopt technology-enhanced instructional strategies.

The project described in this paper is a NSF-funded professional development program designed to increase the technological, pedagogical, and content knowledge (TPACK) of faculty at Historically Black Colleges and Universities (HBCUs). "TPACK emphasizes the connections among technologies, curriculum content, and specific pedagogical approaches, demonstrating how teachers' understandings of technology, pedagogy, and content can interact with one another to produce effective discipline-based teaching with educational technologies"[3]. The authors utilize a TPACK framework to carry out the workshop, housed at Jackson State University (JSU), and assess its effectiveness in training faculty to integrate technology into their undergraduate mathematics courses and research programs.

During the first year of the calculus workshop, the authors will design training to develop faculty skills in implementing Mathematica into calculus sequences, other upper level mathematics courses, and undergraduate research projects. Mathematica is a computational platform that not only allows users to expeditiously calculate mathematical values, but also provides graphics and animations that illustrate concepts that are otherwise difficult to visualize. The workshop will advance faculty knowledge of how to exploit the capabilities of Mathematica to provide simple and customized solutions to numerical and symbolic computation and presentation. Mathematica is the software of choice for the first year because it is currently being utilized at the initiating institution, JSU. In addition, many companies in the applied sciences that hire mathematics majors and employ mathematics majors as interns require skills in Mathematica. Upon successful completion of the first year, other software will be explored in the workshop to further enhance the use of technology in undergraduate mathematics programs. MATLAB, Maple, LaTex, and Tex, for example, are software packages that will likely be used as the focus of subsequent workshops.

The following activities will ensure that adequate preparation is provided and the participants experience an environment that will cultivate the desired community of faculty dedicated to student achievement.

1. Conduct a 3-day Calculus workshop to train participating HBCU faculty in teaching calculus with Mathematica;
2. Support faculty members as they incorporate the technology into both the teaching of calculus and selected upper division mathematics courses and mentorship of undergraduate students in research at their respective institutions;
3. Organize a mid-year workshop for participants to share insights of technology implementation, pitfalls common to novice users, and observed effects of student learning;
4. Advance the workshop to local, national, and international conferences on the use of technology in the teaching and learning of mathematics at post-secondary institutions; and
5. Cultivate an atmosphere of learning among participants to encourage continued engagement in technology-enhanced curriculum development.

Project Background

The workshop described here is centered on the notion that the careful implementation of technology in the classroom will further student understandings of mathematics at HBCUs. In the fall of 2001, the Department of Mathematics at JSU began the integration of Mathematica in the teaching and learning of the calculus sequence. Roosevelt Gentry, JSU professor, informally surveyed the departments of mathematics faculty at HBCUs in the state of Mississippi and found that almost all of those he surveyed were unfamiliar with Mathematica and were not even considering the infusion of technology into the teaching and learning of mathematics. Furthermore, the brief introductory workshops given by software companies that carried products, like Mathematica, were not sufficient in preparing faculty to teach because curriculum development was not addressed. As a result, Dr. Gentry began hosting what is now called the JSU Annual Calculus Workshop in 2003. It was a local workshop on teaching with technology offered to JSU faculty. With a small grant from the JSU Dean of the College of Science, Engineering and Technology the workshop was later expanded to include mathematics faculty from the other HBCUs in the state of Mississippi. Thus far, all five of the HBCUs in Mississippi (Alcorn State University, Jackson State University, Mississippi Valley State University, Rust College, and Tougaloo College), Alabama A. & M. University, and Southern University in New Orleans have had representatives from their mathematics departments participate in the JSU Annual Calculus Workshop. This effort has continued to generate interest and increasingly is becoming an intellectual gathering where participants exchange techniques and best practices of teaching and learning with technology. Some of the participating universities, namely Mississippi Valley State University, have incorporated the use of Mathematica in teaching calculus. However, technology is not widely used as a teaching and learning tool at the other participating institutions. Workshop evaluations revealed that the participants felt the length of the workshop had been too short to facilitate an adequate professional development experience. Participants also commented that they need the workshop to be a training ground where they can (a) receive hands-on experience using Mathematica (and other software), (b) develop technology-enhanced curriculum for undergraduate mathematics courses, and (c) learn to use Mathematica as a tool for enriching undergraduate research projects.

Project Design

Reflecting on the aforementioned concerns of the JSU Annual Calculus Workshop attendees about becoming skilled in incorporating technology into undergraduate mathematics programs, the authors decided to seek support from the NSF to build a community of faculty committed to improving undergraduate mathematics education at HBCUs. They proposed an expansion of the JSU Annual Calculus Workshop to include a three-day workshop, follow-up activities, expectations for faculty participation in undergraduate research, and ongoing support through an online forum. The new workshop was funded and designed to ensure that participating faculty will return to their institutions with knowledge they can incorporate into at least one of their courses and use to support the mentorship of students conducting research projects. Implementing these teaching and research strategies will require faculty to acquire new knowledge and skills to appropriately revise curriculum and teaching practices. As no formal trainings are currently available for faculty to attain these skills needed to effectively engage in technology-assisted instruction, the authors have redesigned the JSU Annual Calculus Workshop to address this void.

The JSU Annual Calculus Workshop will focus on developing faculty expertise in integrating Mathematica into classes and undergraduate research in the first year. In subsequent workshops, each participant will provide presentations on their best practices for technology-enhanced instruction. They will also share details of the impact of that instruction on their own teaching style, student learning, and student research projects in the mathematical sciences. Consequently, evaluations and assessments have been included to scientifically analyze the impact of the project on faculty participants. Later stage projects will determine the effectiveness of participation in the workshop on student learning in classes taught by these faculty members.

The main objective of the JSU Annual Calculus Workshop is to develop faculty expertise in the use of computer technology equipped for teaching, learning, and researching in the mathematical sciences. In order to achieve this goal the following specific objectives have been developed:

1. Encourage HBCU mathematics faculty to integrate technical computer software programs into classroom lectures, activities, and projects;
2. Enhance faculty understanding of the use of technology as a teaching, learning and research tool;
3. Develop faculty self-efficacy with the use of technology in the teaching and learning of mathematics in general, and calculus, in particular;
4. Train faculty in developing course curriculum and projects that incorporate technology;
5. Cultivate a community of faculty who are committed to enhancing calculus sequences and upper division mathematics courses through the integration of classroom technology.
6. Improve student understanding to increase the rate of successful completion of mathematics courses and ultimately improve the level of college retention at HBCUs.

Participant Recruitment

The recruitment of the first set of participants will begin in the Fall of 2012. The workshop is intended to attract at least 30 mathematics faculty members from HBCUs in and surrounding the state of Mississippi. The mathematics faculty members at these institutions are of diverse racial and professional backgrounds. The workshop will be advertised to other non-HBCU universities for a limited number of participants in the first year. In the second year, it will be opened to a wider set of participants to (a) disseminate the results of the findings from the first year experience and (b) attract new ideas and experiences in technology-assisted mathematics teaching and learning. Participants will be recruited via E-mail, the JSU website, and the websites of all targeted HBCUs. Previous participants will be a natural recruiting pool. E-Mails will be sent to all department chairs in the STEM areas in the surrounding states because many have mathematical methods, computational, or numerical analysis courses, so they can benefit from the workshop as well. One of the project investigators (PIs) will frequently visit the HBCUs in the state of Mississippi and hold recruiting meetings during these visits. The lead PI will also engage the two-year colleges to develop a seamless transfer process for students interested in the STEM fields. He will use this opportunity to set up recruiting meetings with mathematics and science faculty at the two-year colleges.

Project Activities

The outlined objectives will be attained through a multi-dimensional approach. In addition to participating in the workshop, participants will (a) develop a network of faculty supportive in each other's pursuits to enhance classroom instruction through technology, (b) attend and contribute to a follow-up workshop to share insights gained through implementation of Mathematica in the teaching and learning of mathematics at their respective institutions, and (c) collaborate to present their experiences to local and national audiences. The two-day workshop will be provided to both introduce faculty to the basic functions of Mathematica and expose them to specific examples and illustrations that can be immediately used in their classrooms. Each day will be broken into two 90-minute morning sessions and two 90-minute afternoon sessions. The first session will be devoted to a tour of Mathematica that demonstrates the fundamentals of its use. Subsequent sessions will be devoted to facilitating participant exploration of how to utilize Mathematica in the instruction of calculus topics ranging from differentiation to the Mean Value Theorem to triple integrals to conic sections. Participants will become well acquainted with the power of Mathematica and be given opportunities to extend their understanding of its educational use through interactions with colleagues from various institutions.

The academic collaboration formed in the workshop sessions will be critical in the development of a community that will support continued development of TPACK knowledge. The relationships formed at the two-day workshop will continue to flourish as the participants will be encouraged to share and respond to each other's questions and experiences throughout the academic year via email, periodic conference calls, and other online forums. These forums will further cultivate the interests that faculty have in the use of technology in mathematics classrooms and aid in troubleshooting as Mathematica is integrated into regular class sessions and undergraduate research experiences.

A one-day follow-up workshop will also ensure participants have an opportunity to communicate their struggles and success with Mathematica to the entire group. The mid-year workshop will also be arranged in the morning-afternoon session format. The morning session will focus on participant feedback on the progress they have made in integrating technology in the teaching and learning of mathematics at their institutions. Curriculum development for calculus and upper level mathematics courses will be discussed. In addition, participants will engage in dialogue to articulate strategies for securing funding to sustain technology-aided instruction at their respective schools. These discussions will also provide potential collaborators an opportunity to plan conference proposals and conceptualize manuscripts for submission to educational journals. One of the mid-year afternoon sessions will be reserved for evaluation and assessment. During that time the project evaluators will administer TPACK self-report surveys and conduct participant interviews to attain first-hand accounts of participant reactions to the workshop and its outcomes.

Project Evaluation

In order to effectively assess the impact of the project, a systematic evaluation of workshop activities will be conducted. The philosophy of the evaluation team is that an evaluation plan should be comprehensive, diagnostic, and prescriptive in nature and ultimately generate a wealth of information (based on both quantitative and qualitative data) regarding the workshop's effectiveness. The evaluation plan of the workshop allows for a formative on-going evaluation of project activities as well as long-term summary evaluation. It includes:

1. The systematic assessment and documentation of key aspects of workshop activities that are indicative of whether the project is functioning as intended;
2. A formative evaluation to identify problems and recommendations for workshop modifications will be conducted to improve the project and to further ensure that the project goals are met. More specifically, such an evaluation will aid in identifying what is working in the project, what does not appear to be effective and as a result of these assessments and evaluations, workshop changes can be proposed that aid in the realization of project objectives and goals; and
3. A summative evaluation to render a summary judgment on the critical aspects of the project's performance and determine if specific goals and objectives are met.

To ensure that the evaluation of the project is carried out in a systematic and objective manner a third party will serve as the external evaluator for the program under the direction of the PI and the Co-PIs of the project. The external evaluator has extensively researched teacher TPACK and the impact that faculty prior knowledge of technology has on the development of such knowledge. She will work with one of the Co-PIs to conduct annual evaluations and periodic assessments of the project using the TPACK model made prevalent by the work of Koehler and Mishra et. al. [4, 5].

Conclusion

Increasingly, undergraduate research programs and mathematics graduate programs expect students to be familiar with mathematics computer programming platforms and scientific word processing (such as MATLAB, Mathematica, Maple, LaTex or Tex). These expectations necessitate the integration of mathematical software into the undergraduate mathematics curriculum. Therefore, faculty training to ensure the appropriate implementation of technology in the classroom is critical in the preparation of students for advanced study in mathematics and other STEM fields. The calculus workshop described here is designed to provide this preparation to HBCU faculty members in six southern universities. The project also promotes a community of calculus instructors to offer continued support and assistance to its members as they navigate the process of developing instructional strategies that incorporate TPACK into the undergraduate mathematics curriculum.

The JSU Annual Calculus Workshop will combat isolated understandings of STEM content by integrating technologies and dynamic software to enhance student understanding. The value added by these technologies and software is that they minimize computational and visual limitations of manually solving mathematics problems. Thus, professional development in the use of Mathematica software will enable mathematics faculty to engage students in the classroom while revealing the theoretical aspects of mathematics and the power of its application to other STEM disciplines. The training that participants will receive in the JSU Annual Calculus Workshop will also extend to the enhancement of student capabilities to independently complete assignments, develop course projects, and engage in undergraduate research programs.

"The provision of educational resources including facilities, equipment, learning materials, and teachers is also fundamental to equity" [6]. Forgaz considers socio-economic status, urbanity, and wealth to be characteristics of an educational system that have a critical impact on access to technology in mathematics classrooms. The misfortune of many disadvantaged communities also consists of the prevalence of under-prepared and inexperienced teachers. The calculus workshop is designed to overcome these societal attributes of southern HBCUs through campus-wide provisions of necessary software and extensive faculty training. The Calculus Workshop outcomes include the development of manuals, teaching communities, and software training exercises that will be available for use by these communities, both nationally and internationally. Similar efforts can be modeled in developing countries to combat issues of equity that prevent students from reaching their full potential in mathematics and other STEM fields. In fact, international collaborative research efforts will be pursued to ensure that (a) the experiences and insights gained through participation are shared, (b) calculus workshop facilitators assist in the development of similar workshops abroad, and (c) international partners are included in the evaluation and improvement phases of the project.

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REFERENCES

[1] National Science Foundation (2011). *Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years* 2011-2016. Arlington, VA: National Science Foundation (NSF 11-047).

[2] Lavicza Z, Hohenwarter M, Jones K, Lu A, and Dawes M (2010). Establishing a professional development network around dynamic mathematics software in England. *International Journal for Technology in Mathematics Education*. **17** (4) 177-182.

[3] Harris J, Mishra P, Koehler M (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *International Society for Technology Education*. **41** (4) 393-416.

[4] Koehler M, Mishra P (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*. **32** (2) 131-152.

[5] Mishra P, Koehler M (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*. **108** (6) 1017-1054.

[6] Forgasz H, Vale C, and Ursini S (2010). Technological for mathematics education: Equity, Access, and Agent. In Hoyles C and Lagrange J (Eds.), *Mathematics Education and Technology-Rethinking the Terrain*, New York, Springer.

PROMOTING INTERNATIONAL VISIBILITY AND COLLABORATION OF WOMEN FACULTY FOR STEM-SBS STUDENT ADVANCEMENT

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Abstract

International visibility and collaboration of women faculty will do much for the advancement of education for students in Science, Technology, Engineering and Mathematics (STEM) disciplines. Securing this visibility and collaboration can be challenging. However in 2010, the National Science Foundation awarded Jackson State University in Jackson, Mississippi, a $3.5 million grant to fund a five-year program to transform the work climate for women faculty in the STEM and Social and Behavioral Sciences (SBS) disciplines. The program, called JSUAdvance, is aimed to advance careers of female tenured and tenure-track STEM and SBS faculty through mentoring, professional development and institutional change. Jackson State University is the first Historically Black College or University (HBCU) to receive a full award from the NSF's ADVANCE Institutional Transformation program. JSUAdvance launched several strategic initiatives to help women in advancing their academic careers and transforming the climates of the university to one more conducive for all. One component is the establishment of visibility opportunities specifically designed for JSU STEM-SBS women faculty to expand their horizons, and highlight their work and accomplishments locally, nationally, and abroad, as a core component of the program. This paper is about this component and concludes that Appropriate Technology can be the next step in furthering international peer mentoring relationships, benefitting faculty, students and communities more broadly.

INTRODUCTION

Jackson State University (JSU), a Historically Black College and University (HBCU) in Jackson, Mississippi, accepted the challenge to transform the overall work climate for women faculty in the Science, Technology, Engineering, and Mathematics (STEM) and the Social and Behavioral Science (SBS) disciplines. Although women have a definite presence on the campuses of HBCUs, women faculty with backgrounds in the STEM disciplines are disproportionately over-represented in lower faculty ranks and instructor positions, and are notably less visible in full professor and lower, middle, and upper administration levels. This has also been true at JSU.

However in 2010, the National Science Foundation awarded JSU, a $3.5 million grant to fund a five-year program to transform the work climate for women faculty in the STEM and SBS disciplines. The program, *JSUAdvance*, aims to advance careers of female tenured and tenure-track STEM and SBS faculty through mentoring, professional development and institutional change. JSU is the first HBCU to receive a full award from the NSF's ADVANCE Institutional Transformation program. *JSUAdvance* purposes to enhance the work climate for women faculty in STEM and SBS disciplines, inform academic communities about relevant gender issues at HBCUs, and benefit graduate and undergraduate students.

This project is already having a great impact on advancing women traditionally underrepresented and underserved in the STEM and SBS disciplines. *JSUAdvance* is obtaining a greater understanding of the issues that impact women and are promoting strategies that can be adopted by other HBCUs and Predominately White Institutions (PWIs), which seek the advancement of women of color. Results are being widely disseminated through traditional means and through visits to other HBCUs and PWIs. This ensures a broader adoption of positive practices for advancing women, in general, and women of color, in particular. The *JSUAdvance* Project is implemented through a 10-component program: 1) Summer Writing Retreat; 2) Visibility; 3) Mentoring; 4) Leadership; 5) Bias Prevention; 6) Policy; 7) Social Science; 8) Evaluation; 9) Dissemination; and 10) Management.

International collaboration is of increasing importance. "*Science and Engineering Indicators 2010* provides clear evidence that science and engineering research is becoming an increasingly international endeavor" [1]. Yet, participation by faculty from underrepresented groups is quite challenging [2]. Hence, the work of *JSUAdvance* through the Visibility Component is critical. This paper will discuss the international visibility programs of *JSUAdvance* to date, the results including the collaborations and the benefits to students, and the conclusions connected to Appropriate Technology.

I. The International Visibility Programs in 2011 and 2012—Travel and Collaboration

The Visibility Component of *JSUAdvance* is structured to advance the careers especially of senior STEM and SBS female faculty. This component seeks to advance female faculty by expanding their international horizons and to enhance the visibility of female faculty in broader communities by highlighting their work and accomplishments locally, nationally and abroad. More specifically, the expected outcomes include: a *JSUAdvance* Academic International Travel Group will be created to enhance the university's visibility abroad; the scholars in the *JSUAdvance* Academic International Travel Group will have multiple opportunities to present their scholarship, network, and explore potential collaborative partnerships abroad; and, individually and collectively the *JSUAdvance* Academic International Travel Group will explore their cultural, professional, and personal experiences abroad and how they can inform the development of future *JSUAdvance* academic international travel experiences, particularly for women. As is discussed below, in 2011 the *JSUAdvance* Academic International Travel Group traveled to and made academic presentations in India and in 2012 to South Africa.

A. *JSUAdvance* Academic International Travel Group - India 2011

The travel experience. The travel for 2011 was to Hyderabad, Chennai, Bangalore, and Delhi, India. The preparation for the group's travel was careful and extensive to better assure that the expected outcomes would be achieved. Specifically, selected faculty members were assisted as they obtained their necessary travel documentation. Arrangements with international partners for visit logistics were made. Pre-departure and cross-cultural orientation was held, to better enhance experiences abroad and to enhance the collaborative experiences with faculty abroad. The team also worked with each participant in deciding upon academic presentations to be made, based on each participant's expertise and the institutions to be visited. To better evaluate the travel experience both Pre-survey and Post-Survey instruments were developed and administered.

In all, four participants traveled together to India, all African American women. Two were from Computer Science, one Technology, and one from Biology. For some, this was their first travel abroad. In India, faculty made academic presentations on campuses, toured campuses and visited with institutional representatives. Participants reflected on what they were personally learning, through journaling and discussions with other participants. After the travel, participants completed a Post-Survey and participated in Post-Trip Briefings.

Discussion of Observations. A number of lessons were learned from the 2011 Visibility Component. These lessons were then implemented in 2012, with further adjustments planned for 2013. One lesson learned in 2011 was that to achieve the goals, it is better ideally to select teams of participants from similar disciplinary areas to form teams. A second lesson was the need to highlight both *JSUAdvance* group visibility and individual JSU faculty member visibility. In 2011 all participants presented to the same large group of academics at the host institution, with all JSU travel participants remaining together as a group the duration of the visit at the host institution. So in 2012, an adjustment was made to enhance collaborations and to highlight individual JSU faculty members. Thus, all JSU participants started the visit with a large group of persons from the host institution. Then, each JSU participant met with faculty members from the JSU participant's respective discipline for presentations and collaboration planning activities.

A third lesson learned was to engage faculty members from varying levels of international collaboration experience. Of the participants in 2011, only one had traveled to India before. However, for 2012, six participants traveled to South Africa, and four of the six had traveled to South Africa previously and had prior international collaborations. Fourthly, the 2011 trip presented the lesson that *JSUAdvance* should identify both potential collaborators and projects in advance, as part of the initial participant selection process. Prior to travel in 2012, participants had to sign a letter of commitment to identifying initiatives and partners from each institution visited and devising a plan for further exploration of the partnership. The plan for 2013 is to go further and facilitate an e-introduction of *JSUAdvance* participants to international institutional counterparts prior to travel. Collaborating opportunities then could be started prior, creating even more meaningful opportunities for face-to-face interactions on the visit.

B. *JSUAdvance* Academic International Travel Group – South Africa 2012

The travel experience. With the changes noted above, the application, selection and pre-briefing processes in 2012 were similar to 2011. For the Academic International Travel Group 2012, *JSUAdvance* partnered with the JSU Division of International Studies and organized a trip to South Africa. The cities visited were Cape Town, Durban and Zululand South Africa. Institutions visited included: University of Western Cape (Bellville, South Africa), Durban University of Technology (Durban, South Africa), University of Zululand (KwaDlangezwa, South Africa), and Kwa-Zulu Natal University (Durban, South Africa).

One goal in 2012 was to disseminate the application more to increase the number of applications received; the program received over twice as many applications. A number of applications were from women outside of the targeted disciplines, and the Team was able to obtain support from other Units within the University to expand the *JSUAdvance* Academic International Travel Group to a few individuals outside of the STEM and SBS disciplines. Six individuals traveled to South Africa, representing the disciplines of Psychology, Technology, Computer Science, Education, and Management. All participants were African American females.

Discussion of Observations. A number of lessons were learned from 2012 to be implemented in 2013. One lesson was the great value of a multidisciplinary focus. While there were twice as many applicants in 2012 as in 2011, many were individuals within separate disciplines not currently working on multidisciplinary projects. One concept which the team will explore in 2013 is the identification and development of a joint international collaboration whereby smaller projects from multiple disciplines can collaborate. Group travel still seems to be the most likely means of increasing the international visibility of women faculty at JSU. However, for future trips the travel may be as a group to organized international conferences with additional visits to related departments and institutions.

Another lesson related to the need to balance the travel team with individuals with ongoing, past or future international collaborations for peer mentoring. This balance affords the opportunity for community building and help to identify leaders and emerging leaders within the group who can facilitate the advancement of the larger group and university. On the 2012 trip, *JSUAdvance* obtained external support from the Office of Academic Affairs for a Professor and Department Chair from the Department of Higher Education who had visited South Africa on two prior occasions and is working on the submission of a proposal and a faculty member from the Department of Management and Marketing who serves as a member of the project team and Lead for the Mentoring Component who also had traveled to South Africa before presenting a joint presentation between Mahatma Gandhi College (MGC) in Guntur, India and JSU. The presentation was to internationalize the curriculum at JSU and MGC to assist MGC in the development of an executive MBA program and to assist women in India in the development of micro enterprises. UNCF and USAID sponsored the Conference in South Africa. A third member of the Team had traveled to South Africa twice, one time to present at the global HIV aids conference and the second project was a community health project related to HIV aids where she spent time in residence at University of Zululand. This mixture of individuals familiar with the institutions visited in South Africa was valuable. The fourth member of the team with international experience was the liaison, who knew and had worked with many of the individuals from the International Studies Divisions, which the travel team was hosted by.

The team also learned the great benefit of having an accompanying travel liaison. During 2012, *JSUAdvance* secured funding external to the project to support the liaison, who is the JSU Associate Dean for the Division of International Studies. This allowed not only someone dedicated to facilitating the institutional meetings among faculty and administrators from multiple disciplines and the intra-country travel within South Africa, but her participation provided a University point person to facilitate the collaborations resulting from this visit and the collaborations that are already in place between the various sets of institutions. This will facilitate institutionalization of activities beyond the life of the *JSUAdvance* grant.

As to the lesson about timing, while early in the summer session is the best timing for individuals from JSU, i.e., the academic year has ended and the summer session has not yet started; this time period has not been the ideal time for visits to institutions in India and South Africa. While both sets of institutions accommodated the group and there were a number of faculty available to interact with, it was their exam and grading periods. Extended visits to allow for visiting lectures must definitely be scheduled outside of the international institution's testing or break periods.

A further lesson was learned about the need for a formal workshop on establishing sustainable international collaborations. During both 2011 and 2012, there were pre-trip briefings held. A focus in 2011 was on what to expect from a cultural perspective. For 2012 an overview was provided, as well as literature was given to each participant to review. While clear expected outcomes were established and travel protocol discussed, a more formal approach on how to establish sustainable international collaborations should be developed for 2013, and include: formal communication, establishing contact, pre-assessment for establishing partnerships, the give and take of partnerships, and levels of professional engagement from concept papers to obtaining funding for research from both U.S. and International funding agencies.

One concept, which emerged out of the discussions at Durban University of Technology (DUT), was the need for International Peer Mentors. DUT, similar to JSU, is a comprehensive, urban institution. DUT's goals are to emerge from a Technology school to one that offers both technical and traditional degrees. They are seeking to expand their offerings of Master's and PhD degrees. There is a great need and demand for their faculty to focus on their research productivity much of which supports the community, the country, and potentially the world. JSU has similarly increased its focus on research. An area of discussion for 2013 is to identify appropriate peer mentoring relationships through the development of joint research collaboration plans to be signed off by the respective deans of both institutions.

Another concept, which emerged out of the discussions, is a need and opportunity for International Leadership Development, in areas such as Higher Education Administration and STEM Education. In discussions between the University of KwaZulu Natal and the *JSUAdvance* delegation, there was identification of the need of a joint program in this area. An area to be explored during 2013 is the integration of bias awareness in JSU's Higher Education PhD program as well as that of our international partner. A second area of international education leadership is to look at jointly serving underserved Engineering communities though enhancement in math and computational thinking skills. An additional lesson is the need for submission of a formal trip report from everyone participating from JSU. In order to ensure, that individuals follow-up on their identified partnerships, a formal report template was developed for 2012, consisting of an area for describing the nature of the group and individual discussions, five ideas for potential partnership, and periodic deliverables and sessions.

C. Initial Assessment

The 2011 participants all completed the International Visibility Pre-Survey. Their ranks ranged from assistant professor to full professor with one person not identifying her rank. Only half of the participants were tenured. The number of years worked at JSU ranged from 1 to 15, and half of them indicated they were approaching a promotion review. The range of prior exposure among the participants was varied. All participants had experience presenting research on a national scale. And, some had experience presenting research on an international scale.

Interestingly, prior to their travel to India, half of the participants did not plan to contribute to international research or travel abroad to disseminate their research. Those who had no international experience gave reasons including: never been invited, insufficient funds for travel, little access to informal networks for opportunities, no knowledge about research opportunities abroad and did not understand the steps involved. While all of the participants currently have publications, half of the participants were not working on international publications. Only half had a desire for international visibility opportunities prior to travel to India. The majority felt they could be a valuable part of international collaborations with scholars in India, while only half were reportedly knowledgeable about STEM and SBS research conducted abroad. Only half knew of benefits related to participating in international dialogue prior to traveling to India.

The post-survey results suggest the travel was highly successful for each participant. Having traveled to India, all participants indicated they would travel abroad again for academic purposes. Reasons given included: a belief that exploring international collaborations for academic purposes shows the importance of STEM; the academic travel provided a great opportunity for networking with colleagues in India with similar interests; and, the travel facilitated the opportunity for the establishment of an international community of researchers. Following the trip to India, all participants reported a growth in confidence in their abilities to: understand the steps for participating in international forums, present to an international audience, and work on new publications including international publications.

Post travel, all participants reported a subsequent strong desire for more international visibility and plans to continue communications with scholars in India.

One benefit of the travel is to afford the JSU female faculty an opportunity to engage with women from other countries. Only one participant thought that women in India have very different experiences than women at JSU when it comes to STEM-SBS academic careers. The travel enabled the majority of the participants to be able to identify women in STEM-SBS disciplines who are considered leaders. They all agreed it enhanced JSU's international visibility.

When asked about personal and professional gains, participants mentioned knowledge gained in relations to cultural differences and the opportunities for collaborations. One of their biggest obstacles included overcoming anxiety of traveling to some areas abroad. When asked how will travel to India help shape their academic career, it was stated by at least one participant that contacts will lead to collaborations, grants and publications which will help towards promotions and success in the field. The trip was regarded as successfully completed. For example, as a result of the trip, a relationship was established with the U.S. Embassy in India, and one junior faculty member reports the completion of a related international journal article. Initial findings based upon assessment of the surveys from the South Africa travel group suggest similar themes and benefits.

II. Potential Benefits and Advancement for STEM Students

The international visibility of female faculty at JSU through *JSUAdvance* will bring many benefits to both graduate and undergraduate students, female and male student. Although a formal mechanism to measure this impact has not yet been constructed, anecdotal evidence suggests the great benefits to the students.

First, an increase in the number of female students in STEM-SBS will benefit the university and the larger society. Women bring additional perspectives to the disciplines which matter in addressing national and international issues. The visible model of collaboration could do much to attract more female students to the discipline, which will enhance learning for all students. "[R]esearch shows that females tend to prefer active and collaborative learning environments in which new material is contextualized into real-world situations" [3].Thus modeling these environments may stimulate interest in students and potential students in the field. Furthermore, some researchers note that women may be more attracted to work that "make[s] a difference in the world" [4]. As discussed above, a number of the potential collaborations relate to work that could improve conditions for women in the USA and abroad.

Also, universities can improve the climate for all faculty, and the recruitment of female faculty, by modeling the "integration of female faculty" into the department, discipline and university [5]. For reasons not completely understood, women may be left out of opportunities to travel and collaborate abroad in male dominated disciplines. Therefore, travel groups, as those spearheaded by *JSUAdvance,* provide essential opportunities for women to advance.

Conclusion

This paper directly relates to the Conference Theme, "Appropriate Technology for the 21st Century: Linking Education, Research and Practice to Inform Policy." Women are not generally a part of collaborative, international research efforts in STEM disciplines.

Women and men students, potential students in STEM-SBS, and faculty and administrators need to see women visibly engaged [6] at advanced levels in the discipline and the university. Moreover, since the number of women in each STEM department of an institution may be few, if any, women may lack the community of scholars with which to engage. This paper reports on the *JSUAdvance* International Group Travel Initiative which encourages multi-disciplinary and multi-institutional collaboration for female STEM faculty. This gives them a community of scholars with which to collaborate and also gives them a community without borders.

"Appropriate Technology for the 21st Century" can facilitate this community without borders. Technology has an important role in sustaining this community without borders for female STEM faculty. The collaborations and partnerships created pursuant to this international travel can be sustained through the use of technology for ongoing communication and discussion.

In addition, the future technologically driven peer-mentoring partnerships can extend throughout institutions benefiting all faculty, not just females in STEM. Even though there is a need for formal faculty mentoring programs, currently institutional policies do not reach beyond, and some instances within, their institutional borders to develop these programs. The travel groups discussed in this paper, therefore, can provide a framework for international peer teaching and mentoring. With the addition of Appropriate Technology, financial hindrances to such mentoring can be diminished.

While there are international collaborations with similar initiatives in some HBCUs, such as the outstanding efforts at Howard University, the project reported on in this paper focuses specifically on the inclusion of women in STEM and on the use of group international travel.

In conclusion, the Visibility component of *JSUAdvance*, not only benefits the careers of the female faculty travel participants and those they collaborate with, but also advances and enhances the entire university climate and culture, the discipline, and our globalized society, both within the USA and abroad, as a whole.

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REFERENCES

[1] Globalization of Science and Engineering Research: A Companion to Science and Engineering Indicators 2010. *National Science Board, National Science Foundation.*

[2] Hogan, A. Zippel, K, Frehill, L & Kramer, L (Oct. 2010). Executive Summary. *Report of the International Workshop on International Research Collaboration.*

[3] Knight, DB, Mappen, EF & Knight, SL (Winter 2011). A Review of the Literature on Increasing the Representation of Women Undergraduates in STEM Disciplines through Civic Engagement Pedagogies. *Science Education and Civic Engagement*. **3**, 1, 44, 36-47.

[4] Book, RG (2011). Women Recruitment/Retention in STEM Fields. *Proceedings of the 2011 Midwest Section Conference of the American Society for Engineering Education.* 1-4.

[5] Why So Few? Women in Science, Technology, Engineering, and Mathematics, Executive Summary and Recommendations (2010). *American Association of University Women: Breaking Through the Barriers.* 1-12.

[6] Milgram, D (Nov. 2011). How to Recruit Women and Girls to the Science, Technology, Engineering, and Math (STEM) Classroom. *Technology and Engineering Teacher.* 4-11.

KNOWLEDGE AND TECHNOLOGY TRANSFER THROUGH OPEN AND DISTANCE LEARNING MODE

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Abstract

The just ended cholera and today's typhoid epidemic have been a public holocaust in Zimbabwe. Whilst these life claiming ailments are real, most people with disabilities in Zimbabwe have been observed to face social and technical barriers from accessing safe water and sanitation. The exclusion of a significant number of people in accessing safe water and sanitation impedes achievement of MDG goals on health for all and weakens the overall development potential of a country. In today's world, nations are devising sustainable and holistic approaches to water and sanitation management. Negative attitudes, lack of knowledge on inclusive water and sanitation infrastructure designs has a direct impact on people with disabilities' access to water and sanitation services. Institutions can utilize Open and Distance Learning mode to reach the unreached. Inclusive technological developments, modifications and transfers can be done through an augmentative approach among universities. Universities can be more relevant to society if they develop a common vision of finding solutions to the communities they serve. This includes lobbying for inclusive sanitation policies and informing policy through research, workshops, awareness campaigns and conferences.

INTRODUCTION

People with disabilities have been observed to be marginalized by traditional facilities that are used to access safe water and appropriate sanitation in Zimbabwe. This is despite the fact that some 10% of persons in the country, including one in six poor people, can be considered to have impairment [2]. The purpose of this paper is to explore the role of Open and Distance Learning (ODL) mode in reaching out to the unreached on issues of appropriate water and sanitation. It shows how ODL mode can be utilized by Zimbabwe and other developing countries to improve delivery of safe water and appropriate sanitation services to people with disabilities. More so, the Endeavour is to show how technology transfers activities can be made through ODL facility to benefit all. Consequences of poor sanitation and neglect will be highlighted in the first part of the paper. The experiences of Zimbabwe in supporting people with disabilities to have access to water and sanitation are set out and solutions to overcome the barriers are put forward. Viable recommendations on appropriate ways to take into account the disability dimension in development interventions will be made. This will be with particular reference to contributions that can be made by ODL universities to fight cholera and typhoid in Zimbabwe.

Background

Zimbabwe has battled to contain a cholera and typhoid outbreak since 2010 to date. Despite efforts to arrest the bacterial infections, outbreaks still continue in towns and major cities of the country [8; 9]. The Ministry of Health and Child Welfare has been up in arms with the ailment which has claimed lives across the country to no avail. Outbreaks of typhoid and cholera have become a major constraint to development. United Nations report asserts that 2.6 billion people- 40 percent of the world's population have no access to toilets and sanitation [3]. About two million people die every year due to diarrheal diseases; most of them are children less than 5 years of age. People with disabilities are worse off in terms of accessing appropriate sanitation facilities in Zimbabwe. We have noted that a number of issues are contributory to this gap in access to sanitation facilities for people with disabilities. These include lack of education or little education among most persons with disabilities as well as lack of knowledge and negative attitude among able bodied persons. More so, inappropriate sanitation infrastructure in Zimbabwe have been observed to be a result of poverty, negative attitude towards persons with disabilities as well as lack of knowledge by policy makers, misappropriation of allocated funds and mere negligence. From a focus group discussion made with members of the National Council of Disabled People of Zimbabwe (NCDPZ), gaps noted included the following:

- Most toilets are designed without persons with disabilities in mind thus difficult to access.
- Home sinks and water tapes are too high for persons in wheelchairs.
- Boreholes are in accessible for hemiplegic and paraplegic individuals.
- Most persons with disabilities in Zimbabwe are poor thus cannot afford renovations of home sanitation infrastructures.

What the above concerns suggest is the need for adequate investments in the improvement of living environments of all people. Improvements in infrastructure have a key role in the achievement of the Millennium Development Goal number 6 [7] in Zimbabwe which appear to be still lagging. The country has however made some progress on trying to protect people from typhoid and cholera though the struggle to meet numerical targets to access safe water seem almost insurmountable. While awareness campaigns are being done by the Ministry of Health, we have noted that only a few persons especially those in urban setup and those who have access to technologies such as televisions, radios have access to information. The challenge is on what can be done to meet the sanitation target by 2015 in Zimbabwe as well as other African countries with similar sanitation problems. Continuous outbreaks of cholera and typhoid in most developing countries are a cause for concern. What is worrisome is the silence that has prevailed among universities in Zimbabwe and yet lives of students and potential students of the very universities are being affected by the diseases. Universities play a very important role in solving world's problems by ensuring a sustainable tomorrow. The responsibility to address global and national issues ideally involves everyone who in some way is impacted regardless of who created the problem.

Universities and Social Responsibility

Organizations are usually responsible for the severe environmental degradation we experience [1]. The argument may be due to the fact that, more universities are setting their quality benchmarks on the number of publications, number of postgraduate students, etcetera without sufficient focus on the applicability of the produced researches and of whether or not it will be of any help to the bottom billion. The question of what motivates universities to commit to their social responsibilities however exists. In most developing countries including Zimbabwe for instance, there seem to be no specific law that obliges universities to consider social responsibilities as part of their role. The activities in question is thus more voluntarily-based and still unexplored. We believe that universities are social constructions, influenced by decisions of individuals who work there thus university management should be in a position to make decisions based on incorporating the principles and practices of accountability, transparency, ethical behavior, and respect for customer satisfaction, especially on issues of sustainable development. Community involvement and development either by individual lecturers or through university partnership are both integral parts of broader sustainable development. Thus the relevance and quality of universities can be measured by their involvement in the promotion of sustainable development.

The challenge of cholera and typhoid outbreaks in Zimbabwe demands the involvement of all universities in promoting good hygiene practices and in the development of appropriate technologies that accommodate both able bodied and persons with disabilities. Public and private universities have mushroomed in Zimbabwe since independence at an average of two universities in each province of Zimbabwe and so has Open and Distance Learning (ODL) mode of university education delivery. Zimbabwe Open University (ZOU) is an example of institutions that bases on ODL mode. The latter ODL state university has a regional office in all the ten province of the Zimbabwe. Of interest to note is that conventional universities are also moving away from the mode of delivering education in a four walled building to reaching out to the people in the form of block release programmes, Virtual Open and Distance Learning (VODL). This is to say, conventional universities are developing parallel modes of teaching and learning too. Such universities in Zimbabwe can make use of ODL mode of delivery to make meaningful contributions in combating water and sanitation challenges we are facing as a nation.

ODL mode of delivery in Zimbabwe has attracted most adults and those whose needs for formal education were thwarted in the past by limited places in the conventional set up. Through ODL mode, people can get formal learning in the comfort of their work places, homes and they can learn whilst earning. The world has become a global village where technology such as ICT is playing a pivotal role in promoting education and other developmental projects of organizations and countries. As such, ODL institutions in Zimbabwe are utilizing such technologies, for instance, computers and cell phones to transfer knowledge to the door steps of most people. Universities in Zimbabwe in collaboration with the Ministry of Health can utilize the ODL channels of communication to disseminate information on sanitation to those who are geographically spaced. Specialists in Disability studies and Special Needs can initiate Braille for people with blindness on good hygiene awareness pamphlets as well as the need for sign language. ODL mode in Zimbabwe seem to be the cheapest and effective way to reach out to people whose economic and social environments handicap them from accessing information on sustainable development.

People with Disabilities and Sanitation

People with disabilities in Zimbabwe experience discrimination practices in social, education and employment sectors. This causes the majority of them to be poor. According to the World Bank in [5] the proportion of people with disabilities is 20% among the poor. In post-conflict countries the overall figure also exceeds 20%. This means that people with physical disabilities which are a result of conflicts are significant. Once teachers, we noted that even in regular schools, children with disabilities are underserved to have access to water and appropriate toilets. Zimbabwe is signatory to the Salamanca Declaration [10] on inclusive education. While this move is positive we have observed that children using wheelchairs in Zimbabwean primary schools find toilet access problematic. Door locks both at home and schools are too high to reach and limited space inside the latrine restricts movement. Taps are often too high, making hand washing and self cleaning problematic. More so, most public schools do not have assistant persons to assist children with disabilities to toilets and to fetch water. Thus where the source is not close by, users find it difficult to carry water to the latrine for washing. Pupils who crawl due to severe physical disabilities find the school toilet floors too dirty, especially as they often crawl with bare hands. Given the right infrastructure people with disabilities can be as functional as anyone else. Unfortunately, this is most often not the case in Zimbabwe because the accessibility of infrastructure is inadequate. Disabled people have no access to infrastructure services as they are often poorer, have no education, no job, live in poor housing conditions and they are at much higher risk to malnourishment, pollution, accidents, infectious diseases etc [4]All these conditions lower their functioning capacity. Our experience is that, most persons with disabilities in Zimbabwe come from poor families who can only afford to enroll them to the cheapest schools with poor and inadequate facilities.

World Health Organization (WHO) and UNICEF made significant contributions in the construction of boreholes in schools and communities when cholera first broke out in Zimbabwe in 2010. The mechanisms of the boreholes are made in the advantage of able bodied persons; those in the wheelchair and visual impairment are left out. Interviews and focus groups held with people with disabilities zeroed on the fact that, sanitation technology in Zimbabwe is not relevant to their livelihood. Toilets, tapes and boreholes for example were argued to be insensitive to their conditions. While these practices may be attached to myth and stigma, the major problem that Zimbabwe faces seem to be misinformation on issues of disabilities and lack of expertise in the development of appropriate technologies that are inclusive. The project baseline surveys of any community need to include the sanitation needs of person with disabilities, for instance pit latrines with wide doors to accommodate those on wheelchairs sound stimulus to indicate toilet hole, accessible boreholes etcetera. We believe sanitation challenges we are facing as a country or continent can be ameliorated by providing specific opportunities for people with disabilities to participate in project planning and design.

Universities and Appropriate Technologies for Sanitation

Water and sanitation projects in Zimbabwe and most African countries tend to rely on the same worn out approach and this includes, depending on heavily subsidized government or donor-sponsored latrine and borehole constructions. Solutions to typhoid outbreaks in Zimbabwe can be achieved if universities involve students in the development of appropriate technologies. Lecturers can carry out survey researches to find out what people are willing to use and maintain, and on which sanitation technologies are locally appropriate. Universities in Zimbabwe should desist from ‘brown paper lecturers’ to full time participation on issues of water and sanitation. These universities can utilize ODL component that they have adopted to reach out and tape indigenous knowledge among diverse communities so that they develop sanitary facilities that are locally made for cost effective and inclusive purposes. By making use of ODL students who live are scattered in all geographical areas of Zimbabwe. In such, universities can initiate technological development required by particular communities in which those ODL students reside. The point is, as knowledge centers, universities need to instill and demonstrate to their students and graduands the importance of inter-sectoral collaboration in meeting challenges we face as nations thus a spirit of active participation in community development has to be instilled in them.

We have noted that most ODL students hold key posts in their organization or are very influential in their communities they live. As such ODL institutions hold an upper hand in initiating collaborative approaches to community development. Collaboration is needed between technical agencies or companies and disability organizations, to provide expertise to the other sectors. This can be achieved through empowerment trainings, exchange visits and practical collaborations. Persons with disabilities need information and knowledge about possible solutions to make facilities more accessible, so that they can participate more actively in sanitation issues. They also need information about the benefits brought by maximum participation on basic health and hygiene promotion as well as technological innovations. Thus apart from teaching, universities should get into the communities and participate in combating cholera and typhoid in Zimbabwe. This can be done in vast ways which include tailor making their curriculum in relevant faculties so that they develop students who are initiative, technologically oriented and able to solve community problems. For instance BUSE has developed disaster management programmes. In such programmes, disability component can be factored in to become more inclusive for people with disabilities. In Zimbabwe, most foreign donors have been reluctant to allocate additional funds for financing disability related components in infrastructure projects and other sustainable development projects. Universities can donate knowledge to communities by embarking on a consultative process. But as long as people with disabilities are left out in information dissemination on good sanitation habits, the outbreaks will continue. Improved accessibility of environments, products and services from the disability perspective improves the quality of the environment and services for all people.

Education and training opportunities provided through ODL mode are one of the few educational areas in which persons with disabilities in the developing world can be well represented. ODL helps to overcome some of the challenges that persons with disabilities especially those in wheelchairs, face when the only other opportunities for education and empowerment courses are provided through conventional means. Ndiwalana [6] argues that the design of a distance learning curriculum needs to be sensitive and relevant to cross-national cultural experiences. The needs, the experiences and the context of the people the curriculum is intended to serve must be taken into account. Thus the mass education enhanced by ODL institutions seems to be crucial to the development of accessible water and sanitation facilities in Zimbabwe.

The development of appropriate and accessible facilities needs to be based on a clearer understanding of what problems people with disabilities face and what already works for them. ODL technical specialists need to research and find out what is appropriate for persons with disabilities, for instance those with low limbs. One of the focus group participants with low limp, for example, suggested development of wheelchair with an inbuilt pedestal pan. This according to him was likely to reduce unhealthy and unhygienic practices some people with disabilities end up engaging in as a result of problems in accessing toilets and water facilities. Research based on an informed point of view is likely to enable expertise and graduands in engineering departments to have an inclusive outlook in their development of home and public infrastructure. The solutions identified may inform policy and can then be incorporated into standard designs. As such, the active involvement in communities by universities in development of appropriate facilities is likely to give communities concerned a sense of ownership of developed sanitation projects.

Changing Primary Demand for Sanitation

Households at all levels need to prioritize construction of toilets with appropriate access facilities and water access to persons with disabilities. Awareness campaigns on the importance of inclusive sanitation facilities are vital. Thus where sanitation coverage is low and latrine technologies unfamiliar, primary demand for inclusive sanitation must be created through community awareness campaigns. Appropriate knowledge and awareness may enable households to re-allocate their expenditures to include such new product category in their budgets, for example, modified household toilet seats. One of the interviewee pointed out that members of family can not involve themselves in costly innovations to satisfy only one member of family with disabilities. The bread winner with disability pointed out that, while he does want to renovate his house to suit his acquired physical disability, he doesn’t have the financial resources. This scenario requires a greater upfront investment in marketing and promotion and the marketing department in ODL faculty can be more effective to convince individuals to try developed trial sanitation infrastructures. Technological innovations spread slowly at first, because few consumers know about or understand them, but demand picks up as increasing numbers of consumers become familiar with the product. Thus universities can utilize their outreach departments to campaign on good and inclusive practices of sanitation as well as educating consumers about the new products that the universities and partner companies would have developed. Product showrooms, tours of the homes of adopters, mobile promotions of latrine products, are all ways of providing opportunities to learn more about benefits of improved sanitation and technology to make this possible.

More so, to address particular obstacles faced by sub-groups, such as females with disabilities, targeted promotional events, such as showroom days, and well designed literature can be organized to target them. This means that appropriate technologies can be developed on a consultative basis. Providing simple-to-understand information, access to knowledgeable people, and financing opportunities available in one convenient location as well as a type of toilet can go a long way in enabling communities to develop a behavior change in their approach to sanitation issues. ODL institutions such as ZOU can develop its regional centers into Information Centers on sanitation facility options and these may help consumers evaluate options, and make decisions much more quickly.

A Collaborative Approach to Sanitation Challenges

Universities in Zimbabwe need a common cause where National University of Science and Technology, for example, develops a trial product for sanitation and Zimbabwe Open University builds the distribution channel of the developed facility, through its students who are in all communities of the country. Such should target policy makers, local council, persons with disabilities and the general community. A ‘university sanitation day’ can be agreed upon and set aside, where good hygiene practices can be demonstrated to society and trial sanitation facilities appropriate to all can be advertised. In such personal benefits of sanitation through exposure to sanitation products and adopters, ideally in a home setting is enhanced among persons as they learn about available technologies, how they work, and what they cost as well as collecting advice and opinions from trusted sources. Our observation are that, communities in Zimbabwe trust and respect university lecturers, thus taking advantage of this positive attitude may see universities making a vast contribution to the defeat of menacing diseases in Zimbabwe. ODL policies and strategies need to be reviewed to see how disability and vulnerability can be included in issues of water and sanitation at national, provincial and community level. ODL can enhance this by empowering its students to lobby for sanitation policy and strategy reviews. This can be done in consultation with representatives of the disadvantaged groups so that inclusivity is taken note of in policy formulation. Awareness-raising is needed to draw attention to the issue among various community levels and to improve their understanding of the benefits and cost-effectiveness of accessible/inclusive design. Among the disability sector, community service by lecturers can stimulate demand, and promote understanding of the benefits of safe water and sanitation. Existing information about good hygiene practice in Zimbabwe needs to be documented and made easily available to people with sensory impairments too. This can be done through existing ODL communication modes and networks. Universities can inform policy by practically reaching out to unreached in the form of research, knowledge transfer and development of trial appropriate sanitation technology that are inclusive. With such, cholera and typhoid challenges may be ameliorated in Zimbabwe and elsewhere.

Conclusion

Universities can play an important role in the sustainable developments of any country. Through the use of ODL facilities, universities in Zimbabwe can combat outbreaks of cholera and typhoid by lobbying for inclusive policies and developing appropriate sanitation facilities for all.

REFERENCES

[1]Alshuwaikhat HM, Abu-Bakr, I (2008). An Integrated Approach to Environmental Management Practices. J. Cleaner Prod., 16; 1777-85.

[2]Chimedza, R., & Peters, S. (1999). Disabled people's quest for social justice in Zimbabwe. In F. Armstrong, & L. Barton (Eds.), Disability, human rights and education (pp. 7-23). Buckingham, UK: Open University Press.

[3]Gazi, M, A. (2009). *Role of Education in National Development.* http://bdeduarticle.com/education-policy

[4]Jones, H. and Reed, B. (2005). *Water and Sanitation for Disabled People and Vulnerable Groups: Designing Services to Improve Accessibility.* Leicestershire: WEDC

[5]Mpofu, E. (2004). *Learning through inclusive education: Practices with students with disabilities in sub-Saharan Africa.* In C. de la Rey, L. Schwartz, & N. Duncan (Eds.), Psychology: An introduction (pp. 361-371). Cape Town, South Africa: Oxford University Press.

[6]Ndiwalana, A. 2011. Uganda Case Study. *Transformation-Ready: The strategic Application of information and communication technologies in Africa.* Final Education Sector Study, Annex 8. ICT Development Associates Ltd. http://etransformafrica.org/sites/default/files/eTA%20-%20Education%20

[7]UNDP (2007). Human development to eradicate poverty. New York: UNDP.

[8]Zimbabwe. *The Herald*, 13 July 29, 2012

[9]Zimbabwe. *The Herald*, 26 July, 201216

[10] Zimbabwe.Presidential Commission on Education (1999). *Nziramasanga Commission* Report. Harare. Government Printers.

A NOVEL WAY TO INTRODUCE UNDERGRADUATE ENGINEERING STUDENTS TO RESEARCH AS A MENTORING RESOURCE AND ENHANCING THEIR EMPLOYABILITY SKILLS

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Abstract
There is abundant information about how universities can improve the employability of their students especially through seminars and career fairs. However, there is not much discussed about undergraduate research. American engineering universities concentrate on design principles and ability to use mathematics and science in solving problems. It is well known that the following attributes are very important to engineering employers: practical application and understanding of theory to solve real world problems, innovation and creativity, ability to perform in teams, technical breath, ability to communicate (and some business skills). Research skills are important for technology and effective in participating in the global community, for developing appropriate infrastructures, and to promote sustainable development initiatives. The Department of Electrical and Computer Engineering undergraduate curriculum has design components that involve minimal research. Our approach is to introduce research to future graduate students in the engineering profession. A student with research experience is highly desirable in industry as well as in graduate studies. The faculty selects students based on their academic capabilities and interest in graduate studies to do research. The department is a member of the Engineering Research Center group based in Renssellaer Polytechnic Institute in Troy, New York. We present the smart lighting communication system and other as students' case studies. Light emitting diodes (LEDs) are increasingly replacing fluorescent and incandescent lamps (electrically inefficient devices) as ordinary light sources. They are more efficient than fluorescent and incandescent lamps. LEDs operate at low dc voltages and take less current (about 20 volts dc and 1.5 Amps) as compared with conventional light sources that operate at 110 volts, 60 hertz ac, and around one amp or more.

1. INTRODUCTION

The continuous improvement or advanced standards of the citizens of any nation depends on continuous research. For many decades the US has continued to enjoy the global leadership role in developing and implementing cutting edge research [1] in universities and other agencies. However, there are few underrepresented minority groups of researchers. The contribution of a diverse population of scientists and engineers is necessary to meet the world's competitive environment in technology and research for development. Presently, very low percentage of under-represented groups participate in research. According to the US census bureau underrepresented groups will make about 48% of the workforce by the year 2050 as opposed to 26% in 1995. There is always a need for more science, technology, engineering and technology (STEM) workforce. At the moment STEM labor force is mostly white. However, there is a talented underrepresented group that needs to be tapped and trained for research and improved technology. The main funding sources for research include the National Science Foundation and other federal government agencies such as Department of Defense.

This paper discusses how undergraduate students are introduced to how do research in an innovative way under the guidance of the engineering faculty especially during the summer months of May through August. They learn about the overall impact of research to society, significance and research methods. They are introduced to mathematical formulations, algorithms, simulation, the level of details needed for the research, clarity, and hands on approach. They are introduced to such diverse areas in research including communications (proposal writing, report writing, oral presentations) teamwork and interpretation of data. They also learn about the specific aims of a research topic and the significance of the research approach. Students with experience in research will generally increase their employability chances,

2. The Importance of Undergraduate Research Engineers

The engineering and science communities in the US are trying several methods of introducing undergraduate students to cutting edge research and also to motivate them become future researchers and educators. [2]. Howard University is one of the Historically Black Colleges and Universities (HBCUS) that offer advanced degrees including doctoral in electrical and computer engineering. Howard has a leadership role in the US and to the global community. There are several advanced research centers on campus including an energy based and materials science and nanotechnology research centers with concentrations of research presently in electric power smart grid. These research centers generally train graduate students (master and doctoral students) how to perform research, a requirement for graduate thesis, and the mission of Howard University includes research and teaching contribution to the global community. Even though, the Department recruits graduate students every year, the intake is not enough to fill graduate studies positions. Our aim is to introduce undergraduate students to research techniques and also to motivate them to pursue graduate studies up to the doctoral levels as well as improving their employability skills. We recruit a handful of the top students for summer research under the leadership of the faculty and work alongside with graduate students. They go through lectures, seminars, research methodologies, communications and technical writing and how to write technical papers for scientific journal. The department has introduced a required special research experience course in the curriculum in addition to existing capstone design courses.

Ability for undergraduate engineering students to perform research will also improve their employability skills in industry. According to [6] the chances of employability of a graduate student include communication skills, ability to function in an interdisciplinary team, integrity, and intellectual ability. The graduates must be able to apply theory to real world problems posed by industry customers. They must have understanding of theory, be creative and innovative. They must have ability to perform experiment and interpret data according to Accreditation Board for Engineering and Technology (ABET) program outcome assessment of courses requirements. They must possess life-long learning including technical breath. Business skills will be helpful. Our students are required to take a course in economics. It is important that our trained engineering graduates with research skills will be competitive and meet industry and academia research needs. Besides, design requirements in our curriculum, we introduce research in the curriculum. And of course, a researcher must have computational and experimental skills for verification of theory and hardware as well as communication skills to interpret results to the industry customers. Some of the research centers in the school of engineering also run summer outreach programs. The participants consist of selected undergraduate, graduate and high school students. The Department of Electrical and Computer Engineering at Howard University is a member of Engineering Research Center group headquartered at the Rensselaer Polytechnic Institute, Troy, New

York. We form part of the Smart Lighting Research Group. A research in smart Light Emitting Diodes (LEDs) is presented as a case study of research done by selected undergraduate trainee students at Howard University last summer.

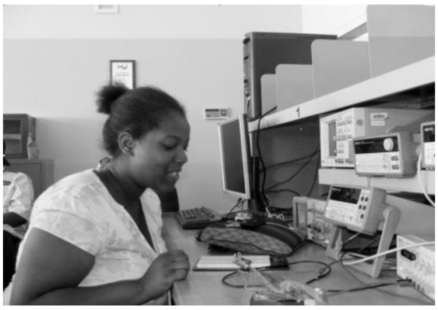
3. The Mobile Studio and Research Other Tools

In addition to several existing research tools the mobile studio has recently been introduced in the department to aid in undergraduate research. It serves as a hardware research for experimental verification of theories developed as well as in can be used for simulation of theories developed. The mobile studio is a portable lab that can be adapted to suit several hands on experience in several scientific and engineering disciplines. Our department has introduced the mobile studio approach that requires hands on and lectures simultaneously. The mobile studio is portable lab. The studio eliminates the need for several bulky classical lab equipment required for research. The studio consists of: (a) a Tablet-PC (lap top) with special software that mimics instrumentation and other features. (b) input/output I/O board that consists of dc power supplies, function generator and it can be used for analog or digital experiments. (c) A bread board that contains the hardware set up for the hands on approach. It is connected to the I/O board that is connected to the Tablet PC via a USB cable. Additionally, traditional labs are equipped with bulky work benches and large expensive instruments and other equipment (such as large function generators, oscilloscopes and power supplies) sources that consume a lot of electric energy for operation at this time of the world's crisis and dwindling energy sources. Due to limitation of space and bulky equipment, students work areas are limited and thus they forced to work in overcrowded groups. It contributes to a few students in a group who can actually participate in performing hands on the tasks required for the lab under investigation. The rest only act as recorders. They hardly participate or contribute to the success of the lab.

The circuit under test is on a bread board and it is connected to I/O board. This unit (tablet PC, I/O board, bread board system) forms the mobile studio. Simply, the unit is known as the mobile studio. It occupies rather a small portable space (much less than a cubic foot). The cost is rather low, less than $1000 per station. Thus a mobile studio is made available to each student in a course as well as one for the instructor. The mobile studio provides the functionality of a regular lab in a portable package. The instructor, as well as students, work in synchronism to provide lecture and hands on at the same time. Data collection at the PC is a synch. The PC acts as instrumentation (ammeter, voltmeter, oscilloscope with basic two-channels) as well as the control panel for the labs. The studio cost less and takes less power and space. Thus it is suitable for appropriate technology institutions on limited budget.

a. The Mobile Studio Concept

The mobile studio research and teaching concept that is normal a practice of other departments (such as architecture, arts) has been adopted by engineering departments due to advances in technology and miniaturization. It consists of Tablet-PC that acts as instrumentation and input/output I/O board that serves as computer interface via USB cable. Thus the usual old fashioned laboratory setup that includes separate oscilloscope, multi-meter, power supply, function generator and others (digital equipment) has been replaced with the 'portable' mobile studio setup that consists of a breadboard, Tablet PC (personal computer) and I/O Board that is a small hardware portable platform. The package shown in figure 1 allows individual participation since it occupies a small space and it is less expensive compared with bulky lab expensive lab equipment.



Old Fashion Traditional Lab Concept-Bulky Presentation

Compact Mobile Studio- Smart Lighting Presentation

Figure. 1 also shows the I/O board instrumentation panel displayed on the tablet PC screen. The I/O board emulates a function generator, oscilloscope, voltmeter, Spectrum analyzer, ±4 V DC power supply and is capable of digital operations. Thus the board output dc power supply lies within the range of -4V to +4V, hands on experiments.

The mobile studio concept originates from Rensselaer Polytechnic Institute, RPI, Troy, New York, the originator of the mobile studio concept. Thus due to flexibility of the mobile studio, the approach was extend to electronics courses at the junior level. Now, in addition to above course, the studio is being used in digital, circuits, and electronics courses, as well as in senior capstone design projects. It has also be introduce in freshman introduction to electrical and computer engineering courses, and high school outreach programs.

The students obtain experience in experimentation; measurements also obtain direct plots instead of using paper and pencil for plot later when the experiment is completed. Instant plots allow for instant correction just in case of a wrong data set. Their mobile studio work coupled on the spot with comments from the instructor. It enhances the individual's understanding of the subject both theory and practice (through experimentation). The Mobile studio in several fields such as civil and mechanical engineering use transducers to convert other signals to electrical signals to enable the studio to interpret results.

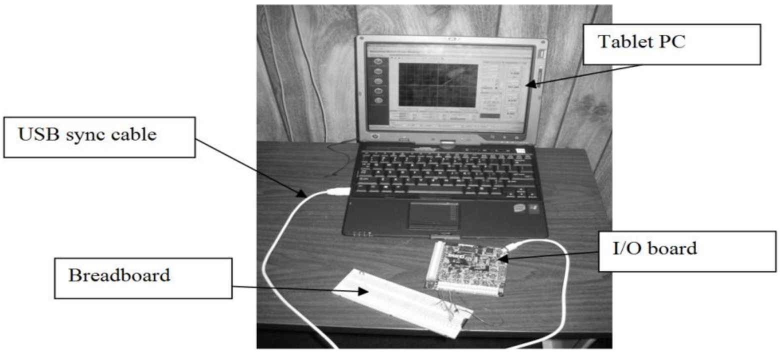


Figure 1: Mobile Studio Station

4. Sample: Case Studies

We present here some undergraduate research experience of undergraduate students and outreach program.

a. Active Filters

i. Summary

This hands on experiment serves explores research active filters by concentrating on second order active filters with specifications such as cut-off frequencies, (bandwidths), gain, and quality factor.. These are frequency selective circuits that can be modified for several different applications. Three circuits, band pass, all pass, and low pass filters, are designed using the Tow-Thomas Bi-quad filter design. The circuits are tested on PSPICE and the low pass filter is experimentally tested using the mobile studio. The results show the expected frequency responses.

ii. Objectives

In this research experiment we will study three active selective frequency circuits: Band Pass (BP), b. All Pass (AP), c. Low Pass (LP). We obtain the frequency response of the filters and compare to the design specifications.

iii. Introduction

Filters are frequency selective circuits that are used for many electronics applications, including instrumentation and communications. They may be classified as passive (no require external power), or active ones that do require power. Passive filters use resistors, inductors, or capacitors to operate, while active filters may use transistors, op-amps, and passive elements. The advantage of using active filters lies in the fact that their gain can be varied to a value greater than unity. A second order filter has the general transfer function of the form:

$$T(s) = \frac{a_2 s^2 + a_1 s + a_0}{s^2 + \left(\frac{\omega_0}{Q}\right) s + \omega_0^2}$$

Where Q is the quality factor and ω_0 is the pole frequency. The zeros of the transfer function determine the type of filter.

iv. Problem Statement

The purpose hand on lab is to explore research into different types of active filters using the Tow-Thomas Biquad Filter realization and the corresponding table of design data. Figure 1 shows the circuit to be used for each application.

v. Theory/Calculations

The component values to be used for each frequency response realization will be calculated using the Design Data table provided. We show the low pass design results.

Low Pass Filter

$Q = 10,\ \omega_0 = 10^4\ rad/s,\ \ C = 1\mu F,\ r = 20\ k\Omega,\ R = \frac{1}{\omega_0 C} = \frac{1}{(10^4)(1\ \mu F)} = 100\ \Omega$

$C_1 = 0,\ R_1 = R_3 = \infty,\ R_2 = \frac{R}{gain} = \frac{100\ \Omega}{1} = 100\ \Omega,\ QR = (10)(100\ \Omega) = 1\ k\Omega$

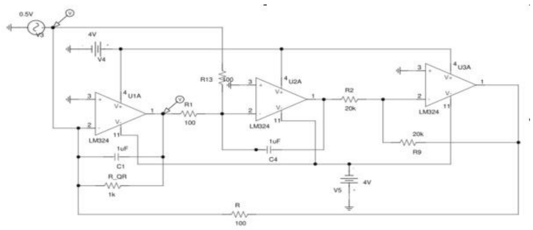


Figure 2. Left: Low Pass Filter Circuit Design (Using Tow-Thomas bi-quad Filter Design)

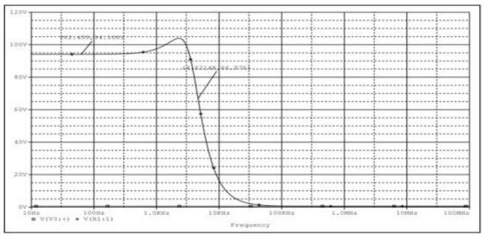


Figure 3. Right- Frequency response from simulation

vi. Simulation

Each filter circuit from Figure 1 was set up in PSPICE in order to obtain the frequency response. An input voltage of 1 V was set and an AC sweep was run from 10 Hz to 100 MHz (100 kHz for band pass). Figures 2, 3 display the results.

vii. Experiment (Mobile Studio)

The following list of equipment was used in this experiment: Resistors: 100, 1k, 20k Ω, Capacitor: 1 μF, Operational Amplifier IC (LM324).

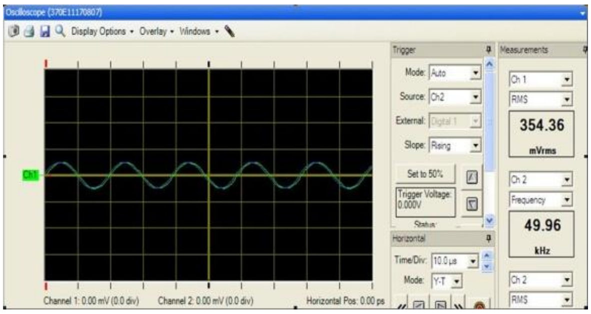


Figure 4. Voltage Waveforms at f = 50 kHz

For actual experimental results, the low pass filter design yielded results. The circuit in Figure 1 is set up. The input V_i is set to 1 V pk-pk and the frequency of the signal is increased from 10 Hz to obtain the frequency response. Figure 4 displays the voltage readings at certain input signal frequencies. From the Mobile Studio frequency response, 3dB frequency is about 2 kHz.

viii. Conclusion

This lab serves to show the use of a single Tow-Thomas filter configuration to obtain different selective circuits. PSPICE and experimental are identical results.

b. The Outreach Summer Program

The program emphasizes electrical and computer engineering and it is designed to provide an exciting, hands-on, research-centered introduction to engineering design using smart lighting (for communications) research projects using the mobile studio. Howard University is committed to providing an education environment that is accessible to all students. **Sample Project:** Optical emitter-Receiver Project; each team writes a report and makes oral presentation (before invited guests-especially parents).

c. Case Study: Light Emitting Diodes

Students' summer research also includes smart lighting research where they investigate several possibilities of using ligh emitting diodes for other applications besides lighting such as data communications. LEDs also take less power and operate at low dc voltages, more efficient than fluorescent and incandescent lamps with 120 volts, 60 Hz supplies. The students recent work involve characterization such as acoustic signatures and thermal expansion (variation temperature) at the pn junctions variation due to high frequency rectangular pulses using MOSFETs as switches in driving the LEDs to provide high illumination levels. They study the effect of rise and fall times o the pulses on the LEDs.

5. Workshop

The department has also presented mobile studio workshop at the Fourth International Conference on Appropriate technology (4ICAT) organized by Howard University at the University of Ghana, Accra-Legon, Ghana, November, 2010. The purpose was to introduce the studio as a teaching as well as a research tool for students, faculty and industry. Figures 5 and 6 below show attendees and instructors from Howard and RPI.


Figure 5. Attendees at Mobile Studio Workshop


Figure 6. Instructors

6. Conclusion

Our aim is to introduce undergraduate students to research in the curriculum in the academic years as well during summer as research trainees. The students are motivated to work under the supervision of the faculty and being able to brainstorm with graduate students. We are very positive this research approach will attract these young minds to pursue graduate studies and make a contribution to engineering research and cutting edge technology and education profession. The experience will also improve their employability skills. The introduction of the mobile studio as a teaching or research tools has helped reducing bulky lab equipment. Thus students can take home the studio to continue with their ongoing work. It has also increased the awareness of engineering and research in high school students who participate in the department's summer outreach program. The studio is a good inexpensive portable lab for appropriate technology.

Acknowledgements

We thank students and staff for their contributions in introducing research in the undergraduate curriculum. We also like to thank the Smart Lighting research group of Rensselaer Polytechnic Institute (RPI) for their support of the research.

REFERENCES

[1]Gary S. May, Daryl E. Chubin, 'A Retrospective on Undergraduate Engineering Success for Underrepresented Minority Students', Journal of Engineering Education, Vol. 92, and No.1 January 2003, pp. 27-39.

[2]Nayaranan Komerath, Marilyn Smith, 'Research Seminars as a Resource in Mentoring Undergraduates', Innovations, INEER, 2011, pp. 183-193.

[3]Peter Bofah, Mohamed Chouikha, '*The Versatile Mobile Studio'*, Proceedings International Conf. on Engineering Education Belfast, UK, August 21-26, 2011.

[4]Margaret Morgan, Pearse O'Gorman, 'Enhancing Employability Skills of Undergraduate Engineering Students' Innovations, INEER, 2011, pp. 239-246.

[5]Elizabeth Stephan, David Bowman, et al, 'Thinking Like an Engineer', An Active Learning Approach', Pearson, 2011

[6]Don L. Millard, *"Expanding the benefits of Mobile Studio Classroom", <u>http://mobile</u>* studio.rpi.edu/Project.aspx, 2007.

[7]George C. Beakley, et. al., "Engineering, an Introduction to a Creative Profession", 5th. Ed, NY, MacMillan Publishing Co., 1986.

[8]S. Joust and D. Dibasic, "Experiencing Learning Environments: Do they prepare Our Students to be Self-Directed?" Journal of Engineering Education, July 2006.

[9]Adel S. Sedra & Kenneth C. Smith, "Microelectronics Circuits", Holt, Rinehart and Winston, Saunders College Publication, Sixth Edition, 2010

[10]Peter Bofah, Mohamed Chouikha, *'Integrating Lectures and Labs Using the Mobile Studio",* International Conference on Engineering Education, Proceedings, Gliwice, Poland, Jul 18-22, 2010.

[11]Peter Bofah, Mohamed Chouikha*, "Innovation in Engineering Education: The Mobile Studio",* 4th. International Conference on Engineering Education, Proceedings, Accra, Ghana, November 2010.

BIOMIMICRY IN CIVIL ENGINEERING EDUCATION

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Key words: Biomimicry, Civil engineering education, Materials research, Capstone course

Abstract:
Integrating an appreciation for life sciences into civil engineering education can lead to solutions for the built-environment which have a natural elegance, are eco-efficient in performance, cost effective, have a low-carbon footprint, and are harmonious with the environment. Biomimicry (learning from nature's solutions) opens a limitless resource for materials research and design innovation throughout the civil engineer's career. Biomimicry can easily be introduced into the framework of existing civil engineering curriculums. A case study is presented where this has been accomplished through the capstone course in civil engineering. Relying on their formative theoretical knowledge, students are taught to dig into nature's abundant toolbox of solutions to make appropriate adaptations to real-world infrastructure challenges. A cradle to cradle approach to engineering design is cultivated. The paper notes that during the last century, civil engineering research has not been as robust and transformative as other science and engineering fields. A review of historical developments in materials manufacturing is made along with conjecture as to why the material choices for civil engineering works remain changeless; this, in spite of widespread global environmental demand for smaller carbon footprints.

INTRODUCTION

The last hundred years has witnessed remarkable, unpredictable, and rapid advances in technology on an unprecedented scale. Revelations in mathematics, physics, chemistry, biology, and information management have all given birth to engineering innovations which have transformed our communities in radical ways. The field of civil engineering, as a subset of that transformation, has helped facilitate this technological revolution, but only in a utilitarian way.

Civil works include roads, rails, tunnels, and bridges which connect people to people and people to resources, such as factories, power plants, hospitals, skyscrapers, entertainment complexes, airports, places of worship, and places of higher education. These structures define the infrastructure of our world and proudly mark human progress.

Although civil works are often the recognized monuments of the human landscape, the materials of this infrastructure remained relatively the same during the century. Concrete, stone, steel, masonry, and lumber have been the dominant construction materials for hundreds of years. These materials have guided the physical form of our infrastructure to the present day. Civil engineering innovation has been stagnant in other areas as well. The technology of on-demand potable water has seen only minor improvements during this period. Innovation in solid waste and waste water management seem largely focused on reforming past practices which were economically practical but environmentally irresponsible. Compared to the dramatic advances in other science and engineering disciplines, innovation in civil engineering appears both slow and minimal.

This paper suggests that guiding civil engineering students to look to the bio world can lead to solutions which accelerate the pace of innovation of our built environment while being eco-efficient, sustainable, and even beautiful.

In an MIT laboratory, Dr. Daniela Nocera and his team have created what they call an 'artificial leaf'. The leaf is a practical, working mechanic made up of nickel and cobalt. Like a leaf, the synthetic silicon device separates the hydrogen and oxygen by using solar energy. A single leaf placed in a gallon of water could potentially generate electricity enough to light a house. [1]

The idea of applying biomimicry to structural engineering also offers great potential. "Forms in nature are derived from the forces by which they are or have been subjected. In contrast, the built environment tends towards pre-determined forms such as flat planes, which due to their inefficiencies are compensated through mass or the addition of supporting members. In this regard, architect Antoni Gaudi was well before his time. Gaudi looked to nature as his mentor, and his building forms, like nature were derived from the forces acting upon them. Through the intelligent use of form, Gaudi provided resistance to the acting forces, subjecting his materials to high levels of force within their capabilities achieving great structural efficiency."[2] These are just two of many advancements possible when biomimicry is applied to a problem.

Introducing Students to Biomimicry

Biomimicry was introduced to the capstone Senior Design course for civil engineering during the 2011-2012 academic year at Howard University, Washington, DC. USA. The course offered a unique opportunity to introduce students to the bio world. The course is a two semester, required course in the undergraduate civil engineering curriculum. It is governed, in principle, by the broad guidelines of the Accreditation Board of Engineering and Technology (ABET). Students must draw upon their formative engineering coursework to define and solve a real world design challenge. Often, more than their previous coursework is needed. What they don't know, they must self-learn. Teams are organized and presented an open-ended problem. Working together, an orderly, systematic approach is developed to achieve the desired outcomes. Industry collaboration is sought as part of the learning process.

The technical understanding required to apply biomimicry to the built environment is, at best, in its infancy with this student population. The biological sciences are not part of the civil engineering curriculum. Biology and chemistry also have their own esoteric vocabulary. These sciences must be introduced from a fresh perspective; less for memorization of terminology and processes, more for an appreciation of their intrinsic simplicity and complexity, from the atomic level to the system level.

Two books on biomimicry were required reading before a project was introduced. The books were: "Biomimicry: Innovation Inspired by Nature", Janine Benyus and "Cradle to Cradle, Remaking the Way We Make Things", McDonough and Braungart. Tests were given to ensure that the books were read and the student could articulate the content matter verbally before the class. Cradle-to-cradle design intentionally seeks the multiple reuse of created products rather than a permanent return to the waste pile.

A second skill set required is an observant eye. Awareness develops appreciation and appreciation encourages observation; expanding the ability to see a natural solution to a human problem.

Senior Design I (2011): Failed Septic Systems on Kent Island, MD.

The project selected for the 2011 academic semester was in response to a local news article on the dilemma facing residents of Kent Island, Maryland. The island is located in the

Chesapeake Bay, approximately four miles from Annapolis, MD and consists of 31.6 square miles. It has a high water table and is not served by a public water treatment facility. Residents have septic systems on their lots. On the southern end of the island, many of these systems fail during heavy rainfall. The septic systems remove bacteria but not the nitrogen or phosphorus. The pollutants flow into the bay waters creating a dead zone of algae around the island's southern end. "Four out of five homes here are pumping water-fouling nitrogen into the bay every time they flush, Queen Anne's County health officials estimate. Some even leak raw sewage into their yards or drainage ditches during wet weather."[3] The state prohibits future development on the island yet allows existing residents to continue using their failed systems. This presents a dilemma. The cost of a public waste water treatment system is high. Residents don't want to pay for it nor do they want more development. The class began to seek an improved means to treat household waste on a residential site while satisfying the state guidelines for acceptable discharge into Chesapeake Bay waters using biomimicry. Such a solution would, presumably, stop existing pollution while allowing more development at low infrastructure investment.

Team Objectives and Criteria:

The table above presents a summary of the project criteria presented to the students. The class was organized into three teams: Pre-treatment System, Treatment System, and Discharge System. Each team defined their design criteria for inflow and outflows, including intra-team standards where outflow criteria of one team was dictated by the inflow requirements of the team ahead of it.

Design Process:

I. The first phase included: research into state mandated criteria for effluent discharge to the Chesapeake Bay, review of existing septic system design and construction standards for the state of Maryland, and review of other regulations and policy documents affecting wastewater treatment, research into the typical character of household wastewater for a single family home.

II. A field visit was made to the site and site data collected, including topography, subsurface geology and soil properties, hydrologic factors, drainage character, lot data. Where information was not easily accessible, assumptions were made regarding the probable existing conditions.

PROJECT CRITERIA

Treatment is to be performed only within the boundaries of the lot. Use the following lot addresses: 123 Long Point Road, Stevensville, MD. The lot was selected after a map study of properties which best fit the typical condition of the problem.

Solutions must be replicable to other residential lots on Kent Island.

Solutions must be readily adaptable to existing homes on Kent Island.

All existing conditions and final designs must be reliably quantifiable and based on the real conditions of the project site.

Apply cradle to cradle design principles for zero-impact on the bay ecology.

Consider and validate the ruminant digestive system of a cow as an appropriate model for the new system.

III. Understanding the site conditions at Kent Island was a key challenge. Another was to comprehend the bio-chemical processes of a cow's digestive system. This was relatively foreign material to the students and required self-learning.
IV. Collaborations between interdependent teams was essential for a cohesive solution. To that end, at least one student from each team was asked to work with two teams.
V. Teams were required to keep records of meetings, attendance, decisions, process documents, and to record the individual contributions to the end process. A project management web portal was established for collaboration, file sharing, and document archiving.
VI. The final work product was a conceptual solution which satisfied all criteria. The system was graphically documented and components identified. A rationale and technical justification for each component relative to the criteria was prepared. A final report and presentation was made before interested faculty and students.

The scope of this course did not allow for detailed testing to validate the concept. Neither did it include detailed design of any component parts. The general objectives of integrating theory with practice were achieved. A biomimicry approach further enhanced the process and yielded creative results.

The Ruminant Digestive System as a Model:

Why the ruminant digestive system? Ruminants are hoofed mammals that have a unique digestive system that allows them to better use energy from fibrous plant material than other herbivores. The stomach of ruminants has four compartments: the rumen, reticulum, omasum and abomasum. The esophagus functions bidirectionally in ruminants, allowing them to regurgitate their cud for further chewing, if necessary. It was noted that the cow's digestive system efficiently processes foodstuffs such that the waste product is free of nitrogen. Nitrogen and phosphorous removal from septic tanks was a critical discharge criteria. Unlike monogastrics such as swine and poultry, ruminants have a digestive system designed to ferment feedstuffs and provide precursors for energy for the animal to use. [4] Mimicking how this system behaved could be a pathway to a solution.

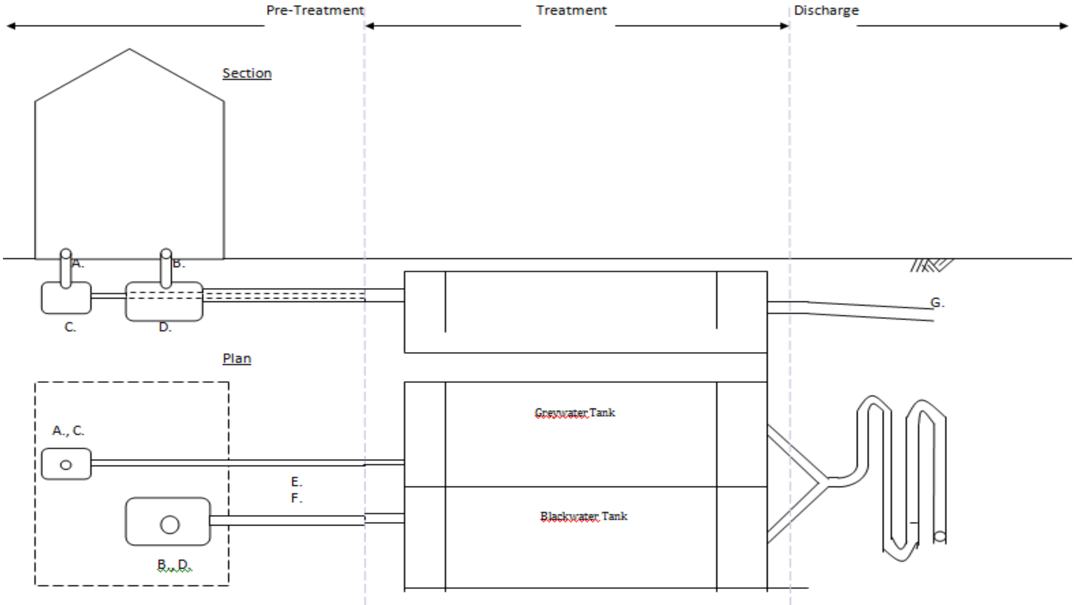
Distinction was made between the inputs to the cow's vegetative digestion to the normal household waste. Applicability was narrow and a more rigorous evaluation was warranted. As an exercise into biomimicry with undergraduate students, the desired learning outcomes were achieved. Future classes may continue to explore and refine their work.

Final Design Concept:

The following were features of the final design concept:

1. Install a grease separator prior to inflow to the tank.
2. Impose a limitation on waste inputs to toilets, bathroom sinks, and garbage disposals.
3. Reconcile vertical placement of the treatment tank with winter frost depths and maximum high water table.
4. Install a two chamber tank; one for grey water and the other for black water with separate piping systems. The septic tank was correlated with the rumen and abomasum where the wastewater is allowed to ferment. Special enzymes from the stomach walls was an unresolved design feature.
5. The discharge from the tank was modeled after the intestines. Flexible pipes with a folding pattern allowed additional distance and time to continue the breakdown of waste and achieve additional filtration. Perforations in the pipe for leaching to the soil were placed at the end of the discharge system. The soil was considered a final part of the treatment system.

6. Opportunity to take out nitrogen and phosphorous was explored through plantings within the discharge fields. Hardy (low-maintenance) plants were sought with root systems that would not pose a threat to the pipe discharge. If vegetation could absorb these elements before their outfall to the bay, the algae problem would be eliminated.



Reference: A. 2in pipe from gray water sinks w/ and w/o garbage disposal. B. 4in pipe from dark water toilets. C. Gray water oil separation batch. D. Dark Water oil separation batch. E. 2in pipe from oil separation batch to treatment tank. F. 4in pipe from oil separation batch to treatment tank. G. 4" pipes polymerized vinyl chloride

Civil Engineering Materials Research and Biomimicry

The question of why innovation stagnates in civil engineering is appropriate to ask. A look at the construction marketplace and the economic/political forces which are involved may shed a little light. It is within the construction industry that civil engineering work is manifest. The construction industry is also a leading economic indicator in financial circles. This, because of the high volume of construction materials required and size of workforce employed on a given project. Civil engineering education is largely focused on supplying the technical and managerial staff to grow and sustain this industry. The industry's growth objectives, therefore, have a strong influence, both on what is taught and what research priorities are funded. The pursuit of alternative research and education pathways which do not serve the interests of the construction industry easily become underfunded, devalued, or frustrated.

For example, the sub-discipline of structural engineering is strongly connected to the concrete and steel industry. Mastery of concrete and steel design principles are core academic courses which lead to stable employment opportunities. Research grants are prominently sponsored by the same industries. Relative to steel and concrete materials research, are there similar research grants available for alternative construction materials? The answer is very little within the United States. Outside of the United States, a few organizations such as IC-NOCMAT (International Committee on Non-Conventional Materials and Technologies, 1984) and ABMTENC (Brazilian Association of Materials and Non-Conventional Technologies, 1996) have organized conferences and collaborated to promote the development and dissemination of knowledge on non-conventional construction materials. These materials are non-polluting, consume little energy in their production and utilization, are low-cost, and are environmentally sustainable. Furthermore, they seek to tap natural resources available locally to break dependence on expensive materials such as steel.

Significant innovation in materials research has taken place in aerospace engineering, computer engineering, and the defense industry. Technical advancements were often top-secret and would sit for decades before they were available for commercial applications. Materials research in civil engineering, with the exception of asphalt paving, remained focused on the steel and concrete industry.

The industrial era was sparked, in part, by the introduction of the Bessemer process for steel production in 1858. With this process Andrew Carnegie gave birth to giant, Carnegie Steel and helped transform the United States into a global economic power. Carnegie's contribution was one of scale and vertical integration rather than technological significance. Carnegie's methods of mass producing steel at low cost and high efficiency created a competitive advantage during an era of almost no government control. Using the demand for track steel by the transcontinental railroad, he leveraged his resources to control the entire manufacturing chain of steel, from raw material to finished product. Breaking away from the steel industry's historic dominance on research priorities remains a daunting challenge.

In recent decades, the high carbon footprint of steel and concrete has been called into question by the sustainable engineering movement. China, for instance, is now the world's number one producer of steel. In a 2010 assessment of their industry, it was noted that "The lax environmental standards and regulations for the steelmaking sector also need to be further strengthened and highly polluting and energy-guzzling small steel enterprises should be shut down. The rapid expansion of high energy-consuming steel production is unaffordable, both economically and environmentally, in the long run."[5]

The steel industry justifies itself in the material's ability to be recycled multiple times in a "self-sustaining loop".[6] The environmental impact of steel is, however, linked to its enormous energy cost. The manufacture of cement, a key component of concrete, emits significant quantities of CO2, NOX, SO2, particulates and dioxins into the atmosphere. Quarrying activities associated with the cement industry also impacts land use and biodiversity [7]. A number of universities have expanded their post-graduate engineering education to introduce students to the fabrication, computer simulation, and experimental testing of alternative materials. Traditional structural materials are contrasted with fiber reinforced concrete materials, fiber-reinforced polymeric materials, and bio-based composites.

Biomimicry offers an almost unlimited universe in the search for alternative construction materials. Consider, for example, a spider's silk. "Somehow the spider had learned to manufacture a composite [two types of material in one], three hundred eighty million years before we decided composites would be all the rage! ... Compared ounce to ounce with steel, dragline silk is five times stronger, and compared to Kevlar (found in bulletproof vests), it's much tougher - able to absorb five times the impact force without breaking. Besides being very strong and very tough, it also manages to be highly elastic, a hat trick that is rare in any one material." [8] In contrast to steel which requires about 440 kWh per metric ton to run an electric arc furnace with temperatures of up to 1800 degrees Celsius, the spider's work is done at normal temperatures using simple chemical products and has no carbon footprint. We have much to learn from the spider.

Biomimicry applied will also reflect in the structural form of our built environment. Instead of linear, box-like, and repetitive forms, nature is quite the opposite. The double curvature of the orchid's petals, the cellular structure of bamboo plants, and the criss-cross outer shell of the palm tree are all beautiful yet perfectly efficient in structural form. If architects like Gaudi and Gehry can imitate nature's form, should not also the civil engineer?

Conclusion

Innovation, creating new ways of doing old things, can be an elusive goal if proper incentives and educational awareness is lacking. Within the traditional undergraduate curriculum of civil engineering, little is likely to change over the short term in the pedagogy and accreditation criteria. The Senior Design capstone course presented a unique opportunity to plant seeds for innovative and sustainable design in these imminent engineering graduates. However, a serious integration of biomimicry into civil engineering must take place in the realms of post-baccalaureate education for research to become vibrant. The constraints of funding and industry support are obstacles.

The class was considered a breeding ground for more dynamic and robust change in the profession as the student moved on into higher academia, professional engineering, or other aspects of the engineering and construction industry. To the extent that those seeds of cradle to cradle thinking have been planted, they are more likely to take root and bear fruit through the diverse career paths of the students. Opening their eyes to nature's perfection as a potential answer to any problem in the built environment can only lead to innovation; an innovation, which expresses true sustainability in the human and environmental sense.

REFERENCES

[1] Shetty, Anuradha "Artificial Leaf to Generate Energy Naturally", *Science and Technology*, 29 March 2011,

[2] O'Meara, Joshua, "Biomimicry of Orchids: Lessons in Structural Form for the Built Environment, 2010.

[3] "Septic Pollution Woes Divide Kent Island", *Baltimore Sun*, Sept. 25, 2011

[4] "Understanding the Ruminant Animal Digestive System" Mississippi State University Extension Service, Publication P2503

[5]"China's Steel Industry: An Update", EAI Background Brief No. 501, YU Hong & YANG Mu, Jan. 14, 2010

[6] Tata Steel Construction, 2012, http://www.tatasteelconstruction.com/en/sustainability/carbon_and_steel/

[7] Ian Marlowe and David Mansfield with contributions from Neil Hurford, Alistair Bird, and Sue Wood, "Toward a Sustainable Cement Industry", Substudy 10: Environment, Health & Safety Performance Improvement, December 2002

[8] Benyus, Janine. "Biomimicry - Innovation Inspired by Nature", *Harper Perennial*; p 132, 1997

INDIGENOUS KNOWLEDGE SYSTEMS – A POTENTIALLY DEEP APPROPRIATE TECHNOLOGY RESOURCE

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Abstract

Indigenous knowledge systems (IKS) comprise knowledge systems that have developed within various societies' independent of, and prior to, the advent of the modern scientific knowledge system. IKS from various cultures evolved into broad and comprehensive knowledge systems, such as those from ancient India, China and Africa, that addressed societal and traditional knowledge issues in various fields important to human survival and the quality of life, including agriculture, health and water, amongst others. In this paper, the IKS of India and China, with particular focus on agriculture and health, are examined for methodologies and received understanding, within the context of identifying and evaluating appropriate technologies for development. Although much work on the cataloguing and documenting the IKS has been completed in these two countries, there is a paucity of attention that has been paid to the scientific rationale and technological content and methodologies of these indigenous knowledge systems. In our work, we examine more closely the scientific and engineering rationale of selected indigenous technologies for agriculture and health that demonstrate a holistic approach to development and their societies. The evaluation reveals that many technologies classified as "appropriate" for developing communities to address basic needs of water, sanitation and agriculture have their roots in indigenous knowledge systems that have survived in some form, albeit at a much diminished level. We demonstrate that these studies potentially provide valuable resources for appropriate technology development. The extensive history of IKS and practices in India and China provide a rich resource and a history of engagement, success and failure that could beneficially inform communities in their search for improved quality of life. The paper concludes with a preliminary evaluation of certain African knowledge systems in agriculture, water and health, and suggests an approach to conservation of these IKS to better inform development for social justice, especially on the African continent.

INTRODUCTION

Indigenous Knowledge Systems

Indigenous knowledge (IK) and indigenous knowledge systems (IKS) refer to knowledge and knowledge systems that are unique to given culture(s) or society [1]. IK and IKS are seen as separate and different from the "international knowledge system" which includes knowledge generated by universities, research institutions and private firms. International knowledge is knowledge created from modern scientific systems research and development which are all part of the global scientific and technological enterprise of human civilization. This knowledge is acquired through formal education and "book learning" and enhanced by advanced study, internships, training and mentoring that essentially ensure that the extant avenues and processes for scientific knowledge creation, affirmation and dissemination are maintained and continued.

Indigenous knowledge is also recognized as reservoirs of knowledge pertaining to specific geo-cultural contexts. The breadth of indigenous knowledge and what populations given systems encompass can span the scale from small indigenous communities to national systems such as *Ayurveda* [2] and *Unani* [3] and some IKS have extended beyond their local origins to gain worldwide acceptance, such as acupuncture, all in the area of indigenous medical knowledge systems. At the basic level, IKS are the basis for local-level decision making and include information, knowledge, practices and rituals pertaining to agriculture, health care, food preparation, education and natural-resource management within indigenous communities and cultures.

However, IK and IKS are hard to define and categorize because they are politically "loaded" terms. Defining what and who is "indigenous" can be a delicate exercise in minimizing the diversity of people that would be offended or antagonized by either being referred to as indigenous or not being included in the indigenous category or grouping. Questions raised in the context of claims to indigenousness can include whether somebody was a prior occupant of the land or what length of time a community and its forebears occupied particular regions. As the mix of peoples of different backgrounds and ethnicities becomes greater, the situation becomes more complex and the discourse has to dissect whether only communities that are native, aboriginal or tribal should be included or focused on. Characterizing and defining what IKS encompasses, various appellations for this broad well of knowledge have been recognized, proposed and articulated [4]. These include indigenous technical knowledge (ITK), ethnoecology, local knowledge, folk knowledge, traditional knowledge, traditional environmental (or ecological) knowledge (TEK) as well as people's science.

Given the diversity of definitions for IKS, there is, nevertheless, a commonly accepted understanding and appreciation of IKS that is based on a shared understanding as well as an epistemic community focused on the same semantic space around the theme of traditional knowledge in various contexts. It is easier to articulate characteristics of IK and IKS and in so doing attempt to operationally define IKS in context. First and foremost, IKS are always local – based and rooted to a particular place and set of experiences, and generated by people living in those places. IK is often transmitted orally, or through imitation and demonstration. IK result from practical engagement in everyday life, and it is constantly reinforced by trial and error. Most importantly, IK is empirical knowledge based on practice and results that are beneficial to the community. More importantly, IKS do not often have substantial grounding in explicit theoretical knowledge.

Furthermore, IK is characterized by repetition, aiding in retention and reinforcement of ideas. IK also tends to be constantly changing, being produced and reproduced, discovered as well as lost, as a culture or community prevails and flourishes. IK is *not* static, unlike pre-conceived notions formal academia tends to hold over IKS. IKS also tends to be focused on the broader public community and hence IK is shared to a much greater degree than other forms of knowledge, especially global science with its current focus on intellectual property – hence the coinage of the term `people's science'. Given that IKS are deeply rooted in local culture, tradition and ritual, IK distribution tends to be socially segmented and clustered, usually asymmetrically within a population. The clustering and segmentation may be age based, gender based or even based in a particular segment of the community that is engaged in that particular effort and activity.

The preservation and survival of IKS is usually through the memories of "special" individuals – specialists and acknowledged IK knowledge bearers of a given community through experience, ritual or political authority. IK does not exist in any one place or individual - it is mostly devolved in the practices and interactions of people in a community. The organization of IKS is essentially functional. Most importantly, IK is situated within broader cultural traditions – hence one cannot easily separate technical from non-technical, or rational from non-rational knowledge and practices [5].

The use of IKS in local level decision making is exemplified in the *panchayathi raj* system of India [6] which is characterized by the grass root unit of local self government based with authority in the village council. Panchayati Raj is identified as institutional expression of democratic decentralization in India. Decentralization of power to the panchayats is seen as a means of empowering people and involving them in decision making processes. The council's in the Panchayath Raj include elders and locally elected representatives who would be familiar with IKS, especially in connection with land use, agricultural practices and developments to improve local quality of life.

In summary, indigenous knowledge systems are local and community based, providing the socio-cultural information necessary for community survival and flourishing within the community's local environmental, geographical and cultural context. IKS facilitates communication and decision-making within a community. Most importantly, IKS is dynamic, continually influenced by internal creativity within a community, and experimentation by the community in response to their environmental, social, and public health and safety stressors. IKS are also informed through contact with the external, broader world which provide additional information and inputs into existing processes and practices within a community and allow for growth and development of IKS.

There is a critical and important linkage between IKS and capacity building for development. IKS address critical quality-of-life and standard-of-living issues. The predominant domains of IK and IKS are focused on "appropriate technologies", the critical vision of which is empowerment of people to take control of their human, natural and technological resources, aimed at efficient utilization to improve the quality of their lives. Boon and Henz [7] have catalogued indigenous knowledge that have relevance for sustainable development in Africa showing, for instance, that modern intellectual property laws do not adequately protect indigenous knowledge and innovation of traditional healers and medical practices in Africa [8,9].

Appropriate Technology

The widespread use of the term "appropriate technologies" requires a discussion and articulation of what exactly it means for a technology to be deemed "appropriate". Indeed, appropriate technology (AT) has always been difficult to define. AT's development and implementation have been a source of debate for some time [10]. Nevertheless, over the course of the decades of discourse and discussion about AT and what exactly it constitutes, there has developed some general received knowledge about AT, including that it should only require small amounts of capital, emphasize the use of local materials, be relatively labor intensive and be small scale and affordable. A major tenet of the philosophy of AT grounds it within specific and individual communities – thus AT must be comprehensible, controllable and maintainable without the otherwise high levels of education or training that might be required for the maintenance and operation of more capital intensive and complicated and imported technologies.

Further, true adherence to the ethic of AT requires that local communities must be included at all stages, from technology conceptualization and innovation to development to implementation. Any technology that claims the mantle of "appropriate" should also be adaptable and flexible, while eliminating – or at least minimizing - adverse environmental impacts [11]. An earlier paper [12] provided a broad over view of appropriate technologies available for water collection, treatment and storage in the context of land reform and a more recent version updated appropriate water technologies in the context of public health.

Indigenous Knowledge Systems and Appropriate Technology

IK and IKS provide communities with ***local*** knowledge, experience and expertise – the received wisdom and "common sense" – as they pertain to community survival and flourishing in the local environmental and resource context. IKS focus on appropriate technologies that need to be developed and implemented to enable communities to respond positively to their environmental and resource challenges, and to develop and promote processes and practices that ensure sustainable survival. IKS are based in the diverse and widespread human creativity in thinking about communities' environment and about addressing human and social needs. Creativity and innovation was rooted in the capacity of human intelligence to rationally solve problems at the local level with local ingenuity. This diverse human creativity [13] was hindered and dominated by the juggernaut of large-capital funded science and technology development that focused not on meeting human needs but instead on producing a product that would maximize profit. The modern scientific knowledge system, tied closely to large capital and the colonization easily displaced IKS across the globe as rapid industrialization in the West required more and more resources and raw materials. There was usually no directive on assessment or evaluation of the actual impact of large-capital socio-technological interventions on addressing unmet social needs.

Basic community needs including appropriate shelter, clothing, water, food, energy, healthcare, education and information and communication technologies form the complex of modern civilization's necessities that must be sourced and provided for any community to survive, prevail, flourish and endure. Appropriate technologies have been, and will continue to be developed by communities to address these needs. The measure of the technology's appropriateness is tied to how well and how sustainably that particular technological intervention and practice is implemented to address the targeted community need.

It is useful to examine a range of appropriate technologies that address these fundamental needs and investigate how these can be incorporated into technologies that the community is interested in and committed to engaging with to promote principles and practices that enhance sustainability for local communities.

There are plentiful examples of appropriate technologies that exist and are being utilized and applied that stem from indigenous knowledge. An excellent example is the application of the neem tree in various aspects of rural life, ranging from health to agriculture [14]. Another example is the use of turmeric in its numerous applications from health to animal husbandry [15]. These examples of IK have larger connections and have been observed in multiple communities and regions, and can also be seen as more local in level. On a more expansive social scale, the belief in and use of alternative medical systems provides pertinent examples, including ***Ayurveda, Accupuncture, and Unani*** [16]**.**

The ancient knowledge system of *vrikshaturveda*, which advocates agriculture with only natural inputs, frowns on the use of pesticides and inorganic fertilizers which have numerous adverse consequences [17]. Instead, in *vrikshaturveda*, agricultural inputs are created by manipulating traditional agricultural products and outputs. Thus a plant foliar spray as well as an insecticide and pesticide is produced from a concoction consisting of cows urine and dung mixed with yogurt, milk and *ghee* (clarified butter). IKS does not only apply to health and agriculture. It is also pertinent to the management of resources within communities. Thus, the water harvesting systems that have been developed recently have their origins in age-old and well established practices for the collection and storage of water, as demonstrated by the various water harvesting and storage systems of southern India, including the *Ery* (tank) systems of Tamil Nadu, the *Kere* systems in Karnataka, and the *Cheruva* system of tanks in Andhra Pradesh [18].

Turmeric provides an excellent example of an indigenous knowledge/practice being undergirded and supported with scientific and clinical investigations that seek to understand the efficacy of turmeric use in traditional medicine with the aim of understanding mechanisms and efficacy of indigenous knowledge/technology practices. Turmeric has widespread uses in both Ayurvedic and Chinese medicine as an anti-inflammatory, to treat digestive and liver problems, skin diseases, and wounds. Some of this efficacy is a result of the powerful antioxidant properties of curcumin, the main component of turmeric, which has also demonstrated ability to lower enzyme levels in blood to reduce inflammation and platelet clumping to form blood clots. The vast trove of indigenous knowledge about turmeric and its used in indigenous medical practice have lead to investigation of the use of turmeric for the treatment of a number of medical conditions including indigestion/dyspepsia, ulcerative colitis, stomach ulcers and osteoarthritis pain. Turmeric has also been suggested as a preventative for atherosclerosis, an anti-cancer agent, and as an anti-viral and antibacterial agent [19]. The vast amount of research on turmeric is provoking new interest in this spice's medicinal properties and re-energizing appropriate and local medical technologies to address health issues of relevance.

Traditional Chinese Medicine (TCM) is an example of an IKS that has been preserved and sustained over the past several thousand years [20]. Nevertheless, TCM as an IKS can be productively analyzed and there is an urgent need to develop an understanding of TCM as they are widely practiced but insufficiently understood from a modern biomedical context [21]. Given the pervasiveness of TCM in China and its wide use within communities, it is a rich resource that can be exploited to develop and further public health. Governmental support and endorsement of acupuncture as an effective medical practice has been amply forthcoming from the Chinese government, and that support has been extended in other countries where the scientific and medical rationale behind acupuncture effectiveness has now been widely accepted as an acceptable component of effective treatment strategies to address diseased states as well as chronic conditions including obesity, addiction and pain [21].

African indigenous knowledge systems (AIKS) have emerged into the academic mainstream over the past decade and begun to occupy a justifiably more prominent place in development discourse on the continent [22]. AIKS have been deemed worthy of investigation and study for their potential to contribute to education for all (EFA) in Zambia. For instance, Benda [23] has argued formal schooling education, in its current form may not be the right vehicle to deliver EFA goals. Proposed hybridization of alternative forms of knowledge with formal schooling could address challenges identified; curriculum and pedagogy reforms can enhance achievement of EFA goals, although hybridizing AIKS with formal schooling will only become significant if an economic value is added to the AIKS, such as practical skills embedded in AIKS to foster career building, entrepreneurship and apprenticeship.

As Mbeoji [7] demonstrated, intellectual property law development needs to recognize and address IKS and take into account the contribution of AIKS and other IKS to modern scientific research and the "intellectual property" that ensues from the technology development that is either a straight copy of extant indigenous knowledge or that relies heavily on the information and knowledge content of AIKS and IKS. For example, the traditional knowledge or medical use of plants (TKMP) is a very large component of AIKS as well as IKS from China (acupuncture), India (ayurveda, unani) and other countries, cultures and indigenous peoples the world over. To protect AIKS and IKS from intellectual property theft, it is necessary to grant legal effect to the existing indigenous protocols for the protection of the knowledge possessed by innovative native healers. It is insufficient to simply tinker with the dominant regimes of intellectual property which perpetuates the colonial mind-set that indigenous peoples did not have autochthonous and effective legal regimes for the propagation, transfer, sharing, and alienation of knowledge. It is not too late in the day to accord native healers the legal cover for autochthonous and familiar protocols by which they have protected, transmitted, and improved upon their knowledge for thousands of years [7].

Gopalakrishnan [24] examined the significance of India's ancient knowledge systems in contemporary life, drawing on India's rich tradition of intellectual inquiry, and a textual heritage that goes back to several hundreds of years. In an attempt to probe how India's knowledge systems may become the foundation for future research, and she shows that there is solid government support for this through the National Mission for Manuscripts, India from 2003 to 2008. The paper also probes issues relating to the access, documentation of manuscripts and how sharing and dissemination of information can be facilitated through the appropriate use of the digital technology [25].

IKS systems have a holistic approach that is very different from the compartmentalization models with the separate "silo mentality" and "breaking things down" approach of the modern scientific and technological knowledge systems. Indigenous knowledge systems offer a rich source of local know-how and built capacity that can provide the information and knowledge capability to address community resource and survival issues in various contexts. This is especially so within the context of a developing country economy that has not sought expertise from indigenous talent.

As Goonatilake [13] has so clearly documented in his comprehensive work on "third world" science, creative and sophisticated solutions were implemented using indigenous know-how and technology for various problems, ranging from agriculture to health and from energy to the environment. In order to preserve these IKS and enable them to have meaning, impact and sustainability for developing communities, knowledge management (KM) programs at the national level need to be established that can serve numerous functions. These KM programs can first provide an IKS resource development function by providing a clearing house where IK on agriculture, natural resources management, food systems, traditional medicine and health systems, and arts and crafts can be collected, compiled, documented and disseminated in focused and pertinent ways to assist communities in need.
Nations should endeavor to develop institutes, departments, and programs that are enabled and empowered to conduct inter-disciplinary research on indigenous knowledge systems, specifically focused on those knowledge systems which would have the most meaning and impact within national, local and community contexts. Indigenous communities should be included in the education and research efforts from the very beginning in these IKS preservation, research and development activities. Interdisciplinary research and partnerships must also engender efforts, perhaps in synergy with state-sponsored programs or multi-lateral agency funded programs, to transfer indigenous knowledge systems to communities that need them; these should be seen as the initial steps in a committed long term effort to promote the sharing and exchange of such knowledge within countries and the broader global community. Academic efforts must link education, research and practice by facilitating outreach and collaboration between researchers and practitioners of indigenous knowledge systems, and in the process work to establish district, regional and community level indigenous knowledge centers wherever underserved communities exist across the globe. These community based centers would work to popularize and spread the use of indigenous knowledge through print and electronic publications and workshops and community demonstrations. These efforts should be paralleled at national and international levels through seminars, workshops, and conferences. As these efforts are initiated and developed, IKS can become integrated into national development knowledge resources and eventually IK may become the reflexive resource that communities first seek out for a tool chest for problem solving.

Conclusion

In conclusion, it is clear that "western" scientific knowledge and technology development and implementation has been receiving increasing criticism for the inability of the socio-technological system developed to address basic needs such as water, sanitation and energy broadly and equitably across the globe. A specific case in point would be the Bakolori Dam in Nigeria [26], which sought to "develop" the Sokoko State in northwest Nigeria with this large scale intervention in 1978, but the impact 35 years later has not been promising. So while large infrastructure development projects are clearly needed and have a place, indigenous knowledge, local technology and experience must be given an opportunity to address issues at appropriate scales. At the same time, it is also clear that indigenous knowledge systems are often over-optimistically presented as completely independently viable alternatives to conventional capital intensive, multilateral agency prescribed infrastructural development. Following Balasubramaniam [25], IKS are neither simple nor primitive and can be sophisticated and appropriate for the context.

Given the global water and sanitation situation and the miserable state of community development and poverty eradication, there is a clear need for fresh approaches. This might include a more effective and creative interaction and interchange between indigenous knowledge systems and modern international scientific knowledge systems. We must critically examine, assess and evaluate the strengths and weaknesses of both scientific and indigenous knowledge systems, focusing on a comprehensive documentation and assessment of indigenous knowledge-based technologies that have the potential for significant impact in development. This comprehensive documentation effort would have an underlying theme of technologies that are appropriate and relevant to the local community. It thus behooves researchers engaged in study of appropriate technology to look for guidance and ideas from indigenous knowledge systems. A substantive and critical component of appropriate technology and socially relevant computing should be to make sure that mainstream scientists and people with local knowledge work together to improve agricultural and natural resource management systems and sustainability.

The incorporation of IKS into the database of resources relevant to the initiation and implementation of appropriate technologies for sustainable development should be a critical focus of government knowledge creation and management efforts. Engagement in this process of documentation, evaluation, assessment and adaptation of IK and IKS into nationwide and community efforts would be a natural outgrowth of governmental emphasis on sustainability and community uplift while contributing substantially to capacity building in the country.

REFERENCES

[1]Ellen, R and H. Harris, 1996. "Concepts of indigenous environmental knowledge in scientific and development studies literature: A critical assessment," East-West Environmental Linkages Network Workshop 3, Canterbury 8-10 May 1996.

[2]http://en.wikipedia.org/wiki/Ayurveda - Ayurveda (Sanskrit: आयुर्वेद; *Āyurveda*, "the complete knowledge for long life") or ayurvedic medicine is a system of traditional medicine native to India and a form of alternative medicine. Accessed Sep 21, 2011.

[3] http://en.wikipedia.org/wiki/Unani - Unani-tibb or Unani Medicine also spelled Yunani Medicine (/juːˈnɑːni/; *Yūnānī* in Arabic, Hindi-Urdu and Persian) means "Greek Medicine", and is a form of traditional medicine widely practiced in South Asia. Accessed Sep 21, 2011.

[4]Warren, D. M. 1991."The Role of Indigenous Knowledge in Facilitating the Agricultural Extension Process". Paper presented at International Workshop on Agricultural Knowledge Systems and the Role of Extension. Bad Boll, Germany, May 21-24, 1991.

[5] Flavier, J.M. et al. (1995)""The regional program for the promotion of indigenous knowledge in Asia", pp. 479-487 in Warren, D.M., L.J. Slikkerveer and D. Brokensha (eds) *The cultural dimension of development: Indigenous knowledge systems*. London: Intermediate Technology Publications.
[6] Mahesh, A. 2011, Panchayathi Raj System: A Historical Persepective" at http://shodhganga.inflibnet.ac.in/bitstream/10603/2392/11/11_chapter%203.pdf; Accessed 10/9/2012.
[7] EK Boon and L Hens, (Eds)(2007) Indigenous Knowledge Systems and Sustainable Development: Relevance for Africa; Kamla-Raj Enterprises.
[8]Mgbeoji, I, (2007)"African Indigenous Knowledge Systems and Patents: Is the Patent System Relevant to the Native Healers of Southern Nigeria?," *Tribes and Tribals, Special Volume No. 1: 77-92* in EK Boon and L. Hens (eds); Kamla-Raj Enterprises.
[9] DeWalt, B.R. 1994."Using Indigenous Knowledge to Improve Agriculture and Natural Resource Management", Human Organization, 53 (2) 123 – 131.
[10]Rybcynzski, W, *Paper Heroes; Appropriate Technology: panacea or Pipedream,* Penguin, USA (1991).
[11]Darrow and Saxenian, *Appropriate Technology Sourcebook*, Volunteers in Asia, Stanford, CA (1986).
[12]Tharakan, J., "Appropriate Technology and Water Availability and Use: Impact on and Implications for Land Reform," *Proc.1st Intl. Conf. Appropriate Technology, July 2004*, pp. 97 – 104, National University of Science and Technology Press, Bulawayo, Zimbabwe (2004).
[13]Goonatilake, S, 1984. *Aborted Discovery – Science and Creativity in the Third World,* Zed Press, London.
[14] National Research Council, 1992. "Neem: a tree for solving global problems" Washington, DC, National Academy Press. 141.
[15] http://www.turmerichealthbenefits.net/ Accessed Sep27, 2011.
[16] Center for Indigenous Knowledge Systems, http://www.cfiks.org/; Accessed Sep 23, 2011.
[17] Natarajan, K., 2003. *Panchagavya – A Manual*, Other India Press, Goa, India.
[18] Mukundan, T.M., 2005. The Ery Systems of South India – Traditional Water Harvesting, Akash Ganga Trust, Chennai, India.
[19]Aggarwal BB, Sundaram C, Malani N, Ichikawa H. 2007. Curcumin: the Indian solid gold. *Adv Exp Med Biol.*;595:1-75.
[20] Hartzell, M, 2005. Making sense of indigenous knowledge systems: the case of traditional Chinese medicine, Southern African Linguistics and Applied Language Studie, 23(2): 155–175.
[21] Hsu, DT, 1996. Acupuncture – A Review, Regional Anesthesia, 21(4):361-370.
[22] *African Journal of Indigenous Knowledge Systems*,2002, Volume 1, Issue 1.
[23] Banda, D. 2008. *Education For All (Efa) And The 'African Indigenous Knowledge Systems (Aiks)': The Case Of The Chewa People Of Zambia*, PhD Dissertation, University of Nottingham, UK.
[24]Gopalakrishnan, S.2009., Manuscripts and Indian Knowledge Systems: The Past Contextualising the Future, 3rd Int'l UNUESCO Conference.
[25] Balasubramanian, A.V., 1987. "Is Indigenous Technology Simple?" *Patriotic and People Oriented Science and Technology* Bulletin, Serial No. 11, pp. 45 – 57.
[26] The Bakori Dam Project, http://en.wikipedia.org/wiki/Bakolori_Dam, Accessed, 10/9/2012.