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The TechBridge World Initiative: Broadening Perspectives in Computing Technology Education and Research

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ABSTRACT
The growing demand for technological innovation to empower developing communities and enable sustainable development requires new and creative educational initiatives. Thus, well designed higher educational initiatives geared towards appropriate technology for developing communities can have a significant global impact. This paper presents the challenges and benefits of a higher education initiative, TechBridgeWorld, at Carnegie Mellon University that focuses on innovating and implementing relevant technology for developing communities. The authors examine the potential intersections of computing technologies with education and sustainable development. Several programs launched through the TechBridgeWorld initiative are described, and results of a pilot study carried out in Ghana for one of the TechBridgeWorld programs, Project Kané, are presented. The paper concludes with an analysis of lessons learned by the authors through launching the TechBridgeWorld initiative, and other related experiences.

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Computing Technology, Education, Robotics, Sustainable Development

1. INTRODUCTION
The United Nations (UN) reports almost half of the world's population lives on less than $2 a day. Another billion people join them at the bottom of the economic pyramid forming a poverty base of 4 billion people; two thirds of the global population! But what exactly is poverty? TheWorld Bank's PovertyNet program [16] defines poverty as follows:

> Poverty is hunger. Poverty is lack of shelter. Poverty is being sick and not being able to see a doctor. Poverty is not having access to school and not knowing how to read. Poverty is not having a job, is fear for the future, living one day at a time. Poverty is losing a child to illness brought about by unclean water. Poverty is powerlessness, lack of representation and freedom.

Perhaps most importantly, "poverty is powerlessness, lack of representation and freedom." While solutions to poverty require food and other basic necessities in the short-term, a sustainable long-term solution to global poverty must involve empowerment of the poor to feed themselves and make their own livelihoods. Thus, sustainable development, that is, development that allows current generations to satisfy basic needs without depriving future generations of the same opportunities, is at the heart of the global agenda. In fact, eradication of extreme global poverty was the focus of the UN Millennium summit during which the world pledged to halve extreme poverty in the world by 2015 [13]. This is a goliath task that cannot be achieved by only a few.

In the more proactive, second paragraph of their definition of poverty, the World Bank's PovertyNet program [16] states:

> ... Poverty is a call to action - for the poor and the wealthy alike - a call to change the world so that many more may have enough to eat, adequate shelter, access to education and health, protection from violence, and a voice in what happens in their communities.

This statement rings true since poverty affects not only the poor, but everyone in numerous ways. Furthermore, eradicating poverty is not limited to providing food or water or any other single aspect, but instead, will require a multitude of both traditional and innovative efforts. Thus, eradication of poverty will require a concerted global effort; it cannot be accomplished by the actions of a few.

Traditionally, most people support and rely on charitable organizations to address poverty. However, it is increasingly evident that charity alone will not eradicate poverty; instead, a drastic change in how we view poverty and the poor is necessary. In the words of C. K. Prahalad [9], "If we stop thinking of the poor as victims or as a burden and start recognizing them as resilient and creative entrepreneurs and value-conscious consumers, a whole new world of opportunity will open up." A growing population of researchers, academicians, entrepreneurs, and multi-national corporations are recognizing the value, strength, and creativity of the population at the bottom of the economic pyramid and joining forces to battle global poverty in

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new and creative ways. Popular business models and products cannot be directly transferred to developing communities; instead appropriate business models and relevant products must be developed. The key to a sustainable program is empowerment of the people in the developing communities such that they are partners in the design and implementation of these programs. Thus, appropriately designed educational initiatives, in both developed and developing communities, must play a crucial role in this empowerment.

While most wonder how this topic concerns the field of computing technology, an increasing number of people are lobbying for innovative technology as a necessary tool for the empowerment of developing communities. In his flagship address at the Millennium Summit of September 2000, the UN Secretary General Kofi Annan made a declaration encompassing the whole scope of the UN's work and its future direction. This Millennium Declaration enunciates eight international development goals [13] which set the agenda for development-oriented Information and Communication Technology (ICT) initiatives conducted under UN auspices and led to the establishment of the UN ICT Task Force who reported, "the power of ICT can be harnessed to contribute substantially to realizing all of the goals in the Millennium Declaration either directly or indirectly." Moreover, one of the pioneers in Robotics and Artificial Intelligence (AI), Professor Raj Reddy, in his 1988 AAAI presidential address [11], urged AI and Robotics researchers to consider the challenges of the poor in technology research, and highlighted the necessity for innovative technology that will benefit the poor.

Inspired by the vision set forth by pioneers such as Professor Reddy and by the current demand for advanced technology relevant to developing communities, this paper focuses on the topic of computing technology for developing communities, and the role of higher education in this area of study. The presented case argues that innovating technology relevant to developing communities must not become the sole responsibility of developing communities but instead, is better achieved through partnership between developed and developing communities. The paper explores directions in which research and education in computing technology fields can benefit developing communities around the world, help achieve the Millennium Development Goals, and increase the diversity and creativity of the field through the process.

2. TECHBRIDGEWORLD

The TechBridgeWorld initiative [12], recently launched at Carnegie Mellon University, is creating research and educational opportunities in computing technology relevant to developing communities around the globe. The primary goal of this initiative is to increase the diversity and richness of computing technology through the enrollment of developing communities as consumers and producers of this technology. To this end, the TechBridgeWorld initiative creates two principal types of programs: on-campus opportunities to study topics relevant to the theme of technology for developing communities, and opportunities to engage in field studies and implementations of relevant technology in developing communities. All programs under this initiative are strongly linked to active partners in developing communities around the globe. Through these partnerships, bridges are formed between the Carnegie Mellon University community and partnering developing communities to exchange knowledge and creativity.

On-campus activities include new courses, seminars, and independent study opportunities at both the graduate and undergraduate levels. Some current academic activities are the "Technology for Developing Communities" (TFDC) graduate course, the "Technology Consulting in the Community" undergraduate course, the TechBridgeWorld seminar series, the Student Technology Exchange Program for undergraduate students, and the "V Unit" independent study option for graduate students. Fielded studies and implementations in developing communities require more careful planning, infrastructure, contacts, and planning timeframes and hence, have had a slower start. Nevertheless, the TechBridgeWorld initiative has successfully launched a few programs that provide opportunities for students and faculty to participate in field studies and implementations; namely, "Technology Consulting in the Global Community," some opportunities through the "V Unit," "Project Kané," and the "Health and Medicine E-Community" project. All of the TechBridgeWorld programs have been embraced with great enthusiasm by the Carnegie Mellon University community. Some of these programs and academic endeavors are described in further detail below.

2.1 Technology Consulting in the Community

Technology Consulting in the Community (TCinC) is a course aimed at juniors and seniors in computer science and information systems. Students learn consulting skills and develop them while working each week with a leader in a local community organization.

The course exposes students to the operations and programs of organizations at the forefront of domestic community development. Students work in all types of non-profit organizations serving health and human services, the arts, education, advocacy, as well as local governments and schools.

Student experience before taking this class tends to be with guerrilla service: showing up, volunteering for a few hours, and then running away. Most have not spent significant hours with a single community organization, and very few have been involved in its management and administration. In the class, each student works one-on-one with the leadership of an organization for 3 hours every week. They learn in depth how the organization serves its mission, and work to advance how the organization can sustain new uses of information technology.

This is not a conventional project course in which students focus on system development. Rather, the student's goal is to build the capacity of the organization to use technology in a way that is sustainable. This new capacity is typically more human than technical. The intellectual core of the course includes strategies and analytical tools to establish a professional partnership, broadly investigate an ill-defined set of problems in a complex organization, communicate technical ideas to a non-technical audience, distill and negotiate a scope-of-work, work with their partners to implement change in the organization, and document the outcomes.

The types of problems addressed have included managing client or donor information more efficiently, using computer-based videoconferencing to deliver remote services, providing home

access to course material for students and parents, improving communication with constituents, members, or among a board of directors, instituting a technology planning process, and many more. Since the spring of 1998, over 200 students have helped nearly 150 nonprofit organizations, local government agencies, and schools through this course.

2.2 Technology for Developing Communities

The Technology for Developing Communities (TFDC) course is a special topics course offered to all graduate students and advanced undergraduate students at Carnegie Mellon University.

The course investigates meaningful ways of utilizing advanced computing and related technology for development relevant to the world's poorer 4 billion people. The instructors consider technology to be an enabler of development, and encourage the students to study the intersection of technology, policy, and the business case with an emphasis on sustainable solutions. The precursor to this course was the ICT4B (Information Communication Technology for Four Billion) class taught in 2003 with collaboration from University of California in Berkeley, using real-time videoconference technology to create a virtual classroom across the two campuses. The course has since evolved to include a broader understanding of technology, and is now offered jointly through the School of Computer Science (robotics, software engineering, and computer science departments) and the H. John Heinz III School of Public Policy and Management at Carnegie Mellon University.

TFDC covers three broad areas relating to technology and development; the broad economic and social contexts of development, current applications of advanced technology for sustainable development, and current needs for advanced technology to promote sustainable development. The students engage in meaningful debates based on assigned readings of relevant topics, participate in the decision-making process for a fielded project, and complete independent projects. Independent projects vary depending on student interests and available data. Past projects cover a wide range of topics. Some examples are a study of the impact of technology on women in the sex trade in Russia, an investigation of the necessary infrastructure to "wire" Africa based on a study of available road maps, using smart meters to prevent electricity theft in India, examining the sustainability and impact of Intel Clubhouses, and examining the uses of advanced technology for medical diagnosis in Haiti's Albert Schweitzer Hospital. One of the students in this course designed a field study to investigate the appropriate use of an automated reading tutor to improve English literacy in Ghana. This field study was later implemented and has evolved into a new program, "Project Kané". Students in this class continue to be highly motivated and enthusiastic in their class participation and project implementation. Several past students have returned in later years to present class projects or other relevant topics. Class discussions are also enriched by the insights and experiences of the high percentage of students who have been Peace Corps volunteers in the past.

2.3 Technology Consulting in the Global Community

Technology Consulting in the Global Community (TCinGC) is a collaborative partnership between Carnegie Mellon students and faculty and governmental and non-governmental organizations throughout the world. A select group of Carnegie Mellon students travel abroad each summer to enhance their own technical, management, and communication skills while developing locally sustainable uses for information and communications technology.

The program was piloted in 2004, with 2 students consulting with the Ministries of Health and Education in the Cook Islands. In the summer of 2005, 11 students worked in various ministries and non-governmental organizations in the Federated States of Micronesia, Republic of Palau, the Cook Islands, and Sri Lanka. The activities they were involved with include defining an e-government strategy, creating public-health web sites and welfare-system databases, developing the skills of nascent support staff of World Health Organization-provided hospital computer labs, implementing a country-wide student information system, and integrating a Linux Terminal Server Project-based computer lab into a school system.

Before going abroad, students learn the program's capacity building consulting model and explore the cultural issues unique to where they are going. The assignment abroad is for 10 weeks, and they agree to provide remote support by email for another 2 months. As part of the consulting model, students produce a series of documents that articulate their thinking and facilitate communication with their clients and the faculty director.

TCinGC focuses on countries in which the application of information technology (IT) is in its early development stages and resources devoted to technology are scarce. Consequently, this opportunity forces students to carefully consider what non-obvious resources can be integrated into their solutions, how their solutions will integrate into and change the organizations that do not have a history of using IT, and how their solutions will be sustained once they are gone. Thus, students get to experience budgetary and organizational boundary conditions. Student participants in this program return enriched and excited about the possibilities technology has to offer to developing communities.

2.4 V Unit

The "V Unit" [15] provides graduate students with the opportunity to engage in independent studies that broaden their perspective of the impact of their research beyond the classroom and laboratory. In the V unit, where the "V" stands for "vision," the goal of the program is to help graduate students to learn how to formulate a vision for the greater impact of their research. Academic credit earned through the V unit can count towards the student's degree requirements. This opportunity was well received by the students and faculty, and has been adopted by several departments in the School of Computer Science (including the departments of computer science, robotics, language technologies, and human computer interaction), and the H. John Heinz III School of Public Policy and Management.

Students who sign up for a V Unit are required to submit a short proposal describing the proposed research, a schedule for the semester, a budget, any travel or accommodation requirements, at least one developing community partner, and a faculty advisor

with expertise on the research topic. The V Unit coordinators assist the students in preparing this proposal and approve the proposal prior to the start of the project. The student is required to meet with and update the V Unit coordinators once a month on project progress. Meetings between the student and faculty advisor occur as needed.

At the end of the semester all V Unit participants submit a technical report describing their research, and a written statement describing their personal experience in carrying out the project. All V Unit participants also give a public presentation of their work at the end of the semester. In general, V Unit proposals deal with topics related to the interaction of technology with development, society, or the environment. V Unit projects typically involve topics that popular funding sources do not fund.

Since its introduction to the Carnegie Mellon University community, the V Unit program has been quite popular, drawing in a variety of student proposals and faculty interest. Some examples of V Unit projects to date are designing a low-cost early warning system for detection of tsunamis in developing communities, statistical methods for evaluating soil properties for agriculture in the Tropics, designing an input device for semi-literate farmers in India to use computers, creating a grammar for Quechua -> Spanish translation for the indigenous people of Cusco, creating a medical translation to enable better doctor patient interaction for Chinese immigrants to the USA, investigating the impact of an automated English reading tutor in Ghana, and creating an e-community for information sharing on best practices in health and medicine in developing communities. Collections of V Unit reports will be compiled and published periodically.

2.5 Challenges

Establishing the TechBridgeWorld initiative posed several challenges which are discussed next. Obtaining necessary funding for educational initiatives relevant to developing communities can be challenging in the USA, especially if the developing community is not in the USA. The reasons for the challenge are often motivated by a lack of awareness relating to global benefits from such initiatives. Thus, enhancing this awareness is a critical need in developed communities. Along with this awareness, an important perspective to engender is that of recognizing value in developing communities. Emphasizing shared responsibilities, ownership, and benefits in global partnerships that address technology initiatives relevant to developing communities is therefore critical.

Another important perceptual challenge arises in effectively communicating the capabilities of technology and the positive and creative role technology can play in the development process. This challenge is twofold. First, progress in many developing communities is hampered by individuals in positions of influence who are reluctant to introduce new initiatives that may restructure the balance of power within the community. Any proposed interventions either need to be started at a sufficiently small level that they go undetected by such individuals until the project has grown strong roots, or must contain some component that makes the intervention attractive to such individuals. The second challenge arises from the difficult task of talking about technology to communities that have not been exposed to many forms of advanced technology. While this can be a challenge in the beginning stages of discussions with any developing community, it can also be a benefit since the meeting of different perspectives can often lead to creative and innovative solutions.

Beyond the perceptual challenges, many infrastructural challenges become manifest when establishing educational and research partnerships across cultural and national boundaries. Language barriers, cultural perspectives and clashes, insurance policies, health and dietary concerns, currency, environmental concerns, political corruption and instability, and safety concerns are some of the major challenges in this arena. However, many global partnerships currently succeed despite these challenges. Hence, appropriate partnerships to share relevant experiences, contacts, and infrastructure can mitigate many of these challenges.

A final challenge in establishing the TechBridgeWorld initiative arises in the attempt to build credibility within academia for the research challenges and educational value in creating technology relevant to developing communities. As with the birth of many new areas of research, much work was initially necessary to convince current researchers in computing technology that interesting research challenges abound in creating technology relevant to developing communities. However, with the success of several V Unit projects, the growing enthusiasm from students and faculty at Carnegie Mellon University, and the favorable reviews of relevant publications at technical conferences, this final challenge is quickly disappearing.

2.6 Benefits

Despite the many challenges in establishing the TechBridgeWorld initiative, the resulting and projected benefits continue to motivate the initiatives growth. One of the major benefits to be gained from initiatives such as TechBridgeWorld that explore technology applicable to developing communities is the empowerment of members of developing communities. This empowerment could be intellectual or related to skill-acquisition, but is often also economic as successful business models related to these technologies emerge. An additional benefit is the narrowing of the urban-rural divide which is significant, even within developing countries.

Along with the many benefits to developing communities, an important factor to consider is that the benefits are not limited to developing communities. Global partnerships between developing and developed communities to share information, knowledge, and expertise, and collaborate on technological innovations benefit all parties involved. The added perspective and creativity enabled through facing new challenges and benefiting from new cultural perspectives is a tremendous asset. In fact, a recent polling of CEOs of top engineering companies resulted in the joint consensus that international perspective and experience is in increasingly high demand for many employment opportunities in technical fields around the globe. Indeed, many technology-related multinational corporations such as Hewlett Packard, Microsoft, and Intel are investing in research initiatives to create technological innovations that can be marketed in developing communities.

In addition to the creative solutions generated from the interaction of diverse perspectives and skills, the field of computing technology is further benefited because of the new and interesting research challenges identified through such endeavors. A field of

research requires new and interesting research challenges if it is to thrive and grow. Recent numbers show declines in the number of students opting to study computer science and related areas of study at the undergraduate level. One hypothesis for this decline is a narrow perception of computer science and its applications among younger generations. Creative new endeavors that enable computer science students to apply their computing technology skills in new and creative ways, interact with communities across cultural and geographical boundaries, and gain new perspectives and cultural enrichment, may become one way in which computer science is redefined as an attractive option for future generations. While none of the programs under the TechBridgeWorld initiative expressly focus on diversity when recruiting participants, these programs have thus far attracted a diverse group of participants at all levels (students, faculty, staff, and partners). With enrollment of women participants at roughly fifty percent and a diversity of ethnic groups represented in the participant community, the TechBridgeWorld initiative program appears to be welcoming or interesting to many. Additional research is needed however to understand what factors attract women and other minority groups to this initiative, and whether initiatives such as TechBridgeWorld will eventually attract and sustain a more diverse population of computer scientists.

Along with presenting the challenges and benefits of establishing and growing the TechBridgeWorld initiative, this paper has thus far briefly described a variety of programs created through this initiative. While brief descriptions of a variety of programs provide the reader with an appreciation for the breadth of the initiative, more detailed information can provide the reader with useful information about implementing and fielding a project. Therefore, it is instructive to examine a TechBridgeWorld project in greater detail; the following section of this paper reports the founding and progress to date of "Project Kané."

3. PROJECT KANÉ

Project Kané, recently initiated under the TechBridgeWorld initiative, explores the role that technology can play in improving English literacy for children in Ghana, West Africa.

Implemented in collaboration with Associates for Change, Ghana, [1] Project Kané is motivated by the reality that, according to the United Nations, over 100 million children currently have no access to school, and numerous others who attend school fall short of the required level to be considered literate in today's complex world [14]. In Ghana specifically, a 2003 report submitted to USAID concluded that "There can be no question that the fundamental problem still facing the Ghanaian schools... remains basic literacy skills in English or Ghanaian languages" [3]. Several studies and programs, meeting with varying degrees of success, have been implemented to try and address this problem, but the issue of literacy is still one of the key development concerns in Ghana.

The problem of illiteracy has many facets and a diversity of approaches are applied to improving literacy among adults and children, in rural and urban areas. Project Kané investigates the effectiveness of an automated reading tutor in helping urban Ghanaian children learn to read in English. The investigation is based on the hypothesis that one contributing factor to the low reading proficiency of some children in Ghana may be the lack of opportunity to practice reading, particularly guided reading. Thus, with increased opportunities for guided reading practice, the child's proficiency in and motivation for reading can improve significantly.

Project Kané utilizes the LISTEN Reading Tutor [10], an automated reading tutor in development at Carnegie Mellon University since 1996, which displays stories on a screen and listens to children as they read aloud. By using speech recognition to analyze the child's reading, the tutor is able to give graphical and spoken feedback. This feedback is given when the reader makes mistakes, gets stuck, clicks for help, or is likely to encounter difficulty.

Several studies have shown the efficacy of the LISTEN reading tutor in helping children improve their English reading skills (e.g., [5], [6]). Of particular interest to us was a study in which the LISTEN reading tutor was successfully used by bilingual (Spanish and English) children in the Chicago area [8]. While previous studies were conducted with native English speakers, this study showed that the tutor could also be helpful to English language learners whose native language is not English. This observation was auspicious for the study in Ghana, where many children speak one or more native languages at home but attend school taught in English.

3.1 Description of the Study

Project Kané was designed based on three main considerations, namely (1) the technical goals of the study, (2) the social and cultural context of the study, and (3) the need for sustainability.

The technical goals of the study are to measure and compare the efficacy of two approaches to offering guided reading practice in English: (1) a technological approach using the LISTEN Reading Tutor and (2) a non-technological approach involving regular reading practice with an older, literate youth. Both these approaches were deemed feasible in the context of interest: an urban location in Ghana where computers are readily available (primarily in internet cafés) and where cultural norms dictate that youth are often given the responsibility of watching over younger siblings or relatives. The population of interest for the study is children from low-income backgrounds attending under-resourced public schools. This population is at risk of not learning how to read because reading is often not a part of family life (sometimes because parents are not themselves literate), and schools offer little opportunity for guided practice of reading.

Project Kané is structured in two phases: Phase I is a pilot study aimed at investigating the feasibility of the technology in the Ghanaian setting, identifying any factors that could affect the success or failure of the main study, and garnering interest and support for the project from relevant parties including teachers and parents. Phase II is aimed at quantitatively measuring the efficacy of the reading tutor compared to regular practice with an older youth, in helping children improve their reading.

Due to the amorphous nature of the questions that need to be answered during the pilot phase, the methodology employed in Phase I is informal and flexible, with a focus on observation and information-gathering, rather than the attainment of statistically relevant results. Phase II will employ a multi-treatment crossover experiment design in which each child, over a six-month period, participates in each of three "treatment" conditions: (1) the control condition with no special reading intervention, (2) guided

reading practice with the LISTEN reading tutor, and (3) guided reading practice with an older youth. The efficacy of each approach will be measured by administering tests between each treatment condition. For this purpose, two test instruments were selected from the repertoire of tests used by the LISTEN team in its research. These instruments – a fluency test [2] and a test of written spelling [4] – were selected because they measure skills important for reading and comprehension and they are relatively simple to administer.

Figure 1. Screen shots of the LISTEN Reading Tutor (user names have been changed to preserve anonymity)

Because the under-resourced schools of interest are unlikely to have computers, we had to come up with a sustainable model for regular use of the reading tutor. To this end, we decided to partner with an internet café near the school.

3.2 Preliminary Results

At the time of writing this paper, the pilot phase of the project has been completed. The goal of the pilot study was to answer the following questions:

1. Is the proposed methodology feasible? How easy is it to obtain parental consent for the study? How feasible is it to partner with a public school and an internet cafe?

2. How quickly do children of various ages with no prior computer experience learn how to operate the software?

3. How much instruction is needed to attain the above level of comfort with the software?

4. Is the voice recognition software able to perform acceptably with Ghanaian accents?

5. Are the students able to understand the "accent" of the narrators and the voice synthesis software?

6. Do children of various ages identify with the reading material available in the reading tutor and find it engaging?

7. What is the appropriate length of a usage session with the reading tutor for children of various ages?

8. Are the proposed test-instruments appropriate for the Ghanaian setting?

Figure 2. Children from Group 1 using the Reading Tutor

Figure 3. Children from Group 2 using the Reading Tutor

Two groups of children participated in the pilot phase. The first group comprised twelve children selected at random from grades two through four from the Abossey Okai Anglican 'A' Primary School, an under-resourced public school in Accra. These children used the Reading Tutor at CyberCity, a nearby internet café, for 20-30 minutes each day over a three week period. The second group of six children from a mixed middle and low-income neighborhood of Accra used the tutor in a home setting for 20-30 minutes for three days a week over the same three week period. Apart from one child in the first group who had played a computer game, none of the children participating in the study had ever used a computer, although they knew what a computer was. All the children speak a language other than English at home (see Figure 4).

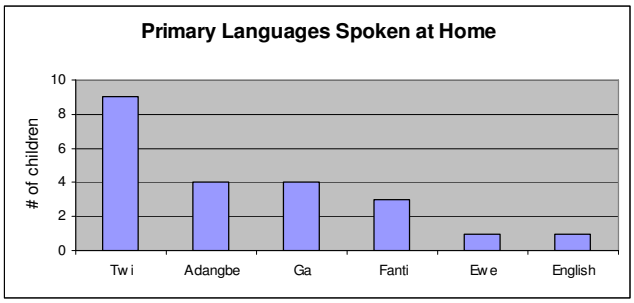


Figure 4. Languages spoken at home (note that a few children speak more than one language at home and sometimes a different language to each parent)

As was expected, the parents/guardians were enthusiastic about the study, and it was not difficult to obtain parental consent for participation. The headmistress and teachers of the Abossey Okai School were also enthusiastic about the project, as were the staff at CyberCity. This initial phase of the project proceeded unexpectedly quickly – we obtained agreement from the school, the internet cafe and the parents all within a three-day period. We picked the children up from school each day and bussed them to and from the internet cafe which was about 2 Km away.

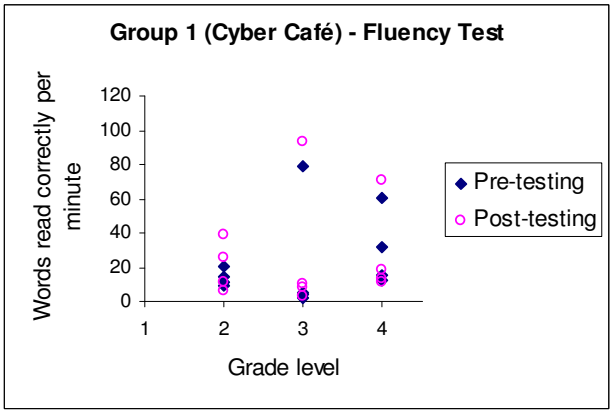
During the first session, pairs of children were given a brief 10-15 minute tutorial on the basics of using a computer. This involved pointing out the monitor, the keyboard, and the mouse, and then having each child practice pointing and clicking with the mouse and typing their name on the keyboard. This, combined with one or two reminders over the next couple of days, was all the instruction the children needed on how to use a computer.

The LISTEN Reading Tutor has two built-in tutorials aimed at teaching the children how to use the software. We found that these tutorials were not as effective with Ghanaian children as they were with American children. This appeared to be due to two reasons. First, the children were unfamiliar with some of the American terms used in the tutorials. As a former British colony, Ghana employs British, rather than American English. For example, the children were familiar with "surname" rather than "last name", and "class register" instead of "class roster". Secondly, many of the children seemed to have trouble understanding the American accent in which the tutorial was narrated. When the field researcher repeated the instructions from the tutorial in a Ghanaian accent, substituting some words with other words more familiar to the children, the children were able to understand. From this, we determined that before the second phase of the study, it will be necessary to re-narrate the introductory tutorials for a Ghanaian audience. Despite the initial challenge with the introductory tutorial, most of the children were able to operate the Reading Tutor software without help by their second or third session with the tutor.

We found that all the children enjoyed using the LISTEN Reading Tutor, and displayed a very high level of enthusiasm. The better readers could use the tutor for more than half an hour at a time and were often disappointed to have to stop when their time was up. The more challenged readers would tire after about twenty minutes, but would still look forward to their next turn.

The voice recognition software appeared to work adequately with the children's accents, and based on the graphical feedback given by the tutor, the children learnt quickly to recognize when the tutor did not "hear" them correctly and to repeat themselves when necessary.

Although we did not expect to observe noticeable gains in reading ability in the short three-week duration of the pilot study, we did conduct pre- and post-tests of the children using a fluency test [2] and a test of written spelling [4]. The purpose of this testing was to determine whether the chosen test instruments were suitable for a Ghanaian setting and also to get a sense of the current reading level of the children in the population of interest. The fluency test involves having the child read a passage aloud and counting the number of words read correctly in a minute. Ghanaian names were substituted for the American names in the passage, and the children did not appear uncomfortable with the test format. The test of written spelling involves having the child write down words dictated in order of difficulty. The children were familiar with this test format. There were, however, a couple of words (such as "tardy") which are not often used in Ghanaian English and as such, which the children were not familiar with. Figures 5 and 6 show the pre- and post-testing results. To put these results in context, some researchers have observed that comprehension improves with a reading speed of 60 or more words per minute [7]. The results confirm that many of the children we worked with are challenged readers. Although the results show very slight improvements between pre- and post-test scores, these improvements are not statistically significant.



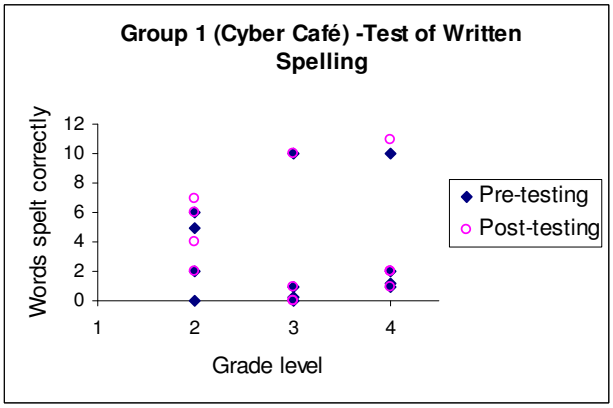


Figure 5. Pre- and post-test scores for group 1

The next phase of the study will shed light on whether either the technological or the non-technological approach to guided reading practice results in significant gains in reading ability, and which approach results in greater gains. As was its goal, the pilot study helped identify issues that must be dealt with during the second phase of the project. It also established strong local partnerships, which, as is discussed in the following section, we have found to be an important element of success in such projects. For these reasons, Project Kané promises to yield interesting results in its second phase.

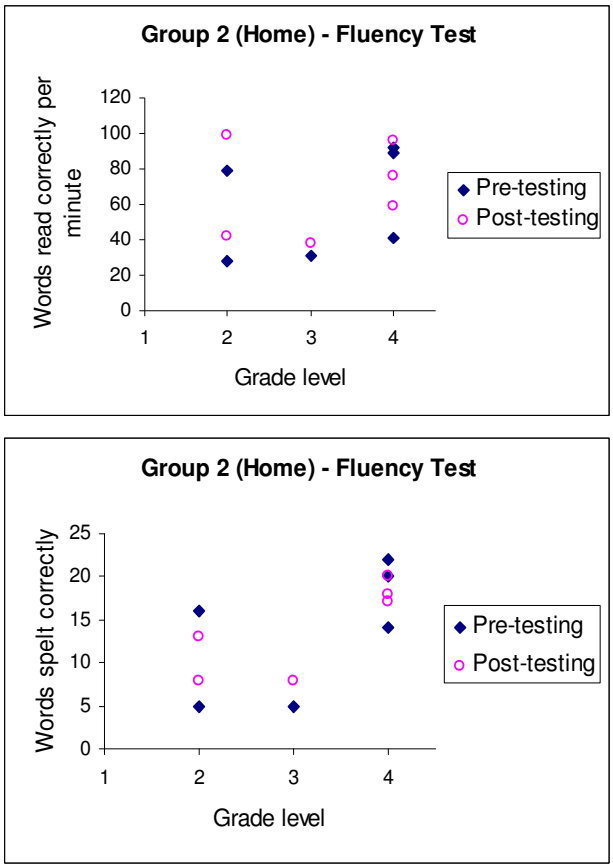


Figure 6. Pre- and post-test scores for group 2

4. LESSONS LEARNED

Designing higher educational initiatives to enable technological innovation for sustainable development is a new and largely uncharted region. Based on the programs described in this paper and the experiences of the authors, the following principles are identified as important elements of success:

4.1 Participatory research and design

People living in developing communities have a greater understanding of the needs of their communities. Participatory design couples these people with others who have the technical know-how to develop suitable technology. Such an approach results in a bottom-up solution that is often more sustainable than a top-down solution.

4.2 Empowerment, rather than aid

The key to sustainable development is empowerment of the members of the community to meet their own development needs. As such, knowledge transfer is often more important than technology transfer.

4.3 Shared, rather than individually owned resources

A significant challenge in developing communities is the high cost of technology. More research needs to be done in methods of reducing the cost and energy consumption of such technology. As long as costs remain high, an approach that has worked to address the affordability and profitability of technology is a shared access model, rather than individual ownership.

4.4 Local partnerships

This reiterates the point that was raised under participatory design, by emphasizing that people in or close to a developing community have a better understanding of its needs. However, in thinking about how to develop technology suitable to the needs of a developing community, the paradigm that technology must be in the hands of the individual members of the community should not be a limiting factor. Sometimes, a greater impact can be made by using technology to enhance the functioning of organizations that work with these communities.

4.5 Global partnerships

While local partnerships are required for local relevance, global partnerships are required for enhancing perspective and sharing resources. The importance of global partnerships is emphasized by its selection as the eighth Millennium Development Goal. Several models are currently being pursued for relevant global partnerships in technology-related higher education; there is still much to be learnt in this arena.

4.6 Sustainability

Initiatives enabling technological innovation and education for sustainable development are inherently interdisciplinary endeavors. Both the technical questions and the economic and social questions are equally challenging. Sustainability has many facets, including technical feasibility, economic feasibility, social and cultural relevance, and ownership. As more researchers, academicians and entrepreneurs enter this arena, many additional successful models will emerge.

4.7 Evaluation metrics

For purposes of funding and assessing academic merit, defining suitable evaluation metrics is crucial. This is not however a simple task. Many of these initiatives will not show measurable impact under conventional metrics for at least a decade. Hence, new metrics must be designed for evaluating shorter-term and longer-term impact. Funding agencies will also need to re-design short-term evaluation requirements for technology projects relevant to developing communities. A crucial metric for evaluating long-term impact will be the level of participation of developing communities in the innovation of technology.

5. CONLUSIONS

The growing demand for technological innovation to enable empowerment of developing communities requires new and creative educational initiatives. This paper describes some of the programs and presents some of the challenges and benefits in founding and growing the TechBridgeWorld initiative at Carnegie Mellon University. A detailed description of the pilot-phase evaluation of an automated reading tutor for improving English literacy in Ghana is also reported. The authors conclude by presenting a discussion of necessary elements for success when designing such initiatives.

The next few years will yield more detailed results from the described programs, and provide additional data for evaluating this initiative. We hope this paper encourages the implementation of many more educational initiatives that address the important topic of technology relevant to developing communities.

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