Wireless Technologies Bridging the Digital Divide in Education

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***Abstract*— The objective of this paper is to demonstrate how the latest wireless standards and technologies may overcome the digital divide in education in the developed and developing worlds.**

The concept of the digital divide is discussed in the traditional socio-economic sense and expanded in terms of the learner's location, age, culture and background. It is important that we understand the full extent and complexities of this division if we are to effectively bridge it. Why and how the digital divide may be bridged is examined. Apart from the inherent inequalities that need to be addressed from an ethical perspective, it is very much in the interests of governments and citizens globally that Information and Communications Technology (ICT) is made available to all as quickly and cost-effectively as possible.

New forms of wireless protocols are overcoming challenges of terrain, infrastructure and finance. It is proposed that, by leveraging open broadband wireless standards, like Wireless Fidelity (Wi-Fi*) and Worldwide Interoperability for Microwave Access (WiMAX*), and implementing Mobile Computing architecture, it is now possible to make dramatic strides in this direction. The paper continues with a general overview of these wireless standards and technologies followed by an in-depth look at Wi-Fi and WiMAX. The paper goes on to give examples of the Innovation Centre's involvement in delivering solutions and new usage models for eLearning that utilize the latest wireless standards and technologies. The challenges and successes of these projects are outlined and metrics are presented where available.

***Index Terms*— digital divide, wireless, WiMAX, Wi-Fi.**

I. The Digital Divide

The concept of a "Digital Divide" has been around almost as long as ICT has been publicly available. While traditionally it has come to mean a division in society, based on socio-economic factors, this does not "paint the entire picture". Location, age, culture and background also play a significant role in how likely users are to embrace ICT generally and eLearning in particular. There is also concern that some IT-savvy students are not being adequately catered for and a digital gap exists between schools and students. It is important that we understand and bridge the real digital divide going forward.

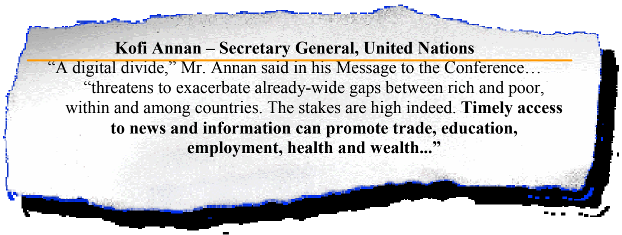

Figure 1. Mr. Kofi Annan on the Digital Divide ["The WiFi (Wireless Fidelity) Opportunity for Developing Nations", The Wireless Internet Institute, 2003]

At the beginning of 2005, approximately 700 million people worldwide had access to computing and the Internet. For those people, the effects of digital technology have been profound. However, most of the global population – approximately 6.5 billion people – do not, as yet, have access.

The developing world is particularly affected by the digital divide. For example, as of January 2005, India had 0.4% Internet and 0.2% broadband connection penetration [*"Broadband India: Recommendations on Accelerating Growth of Internet and Broadband Penetration"*, TRAI Report, 2005]. Obviously, this is extremely low and this country alone accounts for circa 17% of the total global population. However it is ahead on these statistics for Brazil, Russia and China which cumulatively account for a further 25% of the total global population [*"2004 World Population Data Sheet"*, Population Reference Bureau, 2005].

Often finances are a key issue in accessing ICT, and it is fair to say that the lower socio-economic groups within our communities and those in Less Economically Developed Countries (LEDCs) are often those suffering from ICT deficit.

While the digital divide is commonly classified as a social/political issue referring to the socio-economic gap between communities and countries, it should be remembered that this term also refers to gaps that exist between groups regarding their ability to use ICT effectively. The reasons for this "ability gap" include differing levels of literacy and technical skills, as well as the gap between those groups that have access to relevant, high quality digital content and those that do not.

Cultural issues also play a significant role. Usage models where it is assumed each learner has their own PC, PDA or other mobile device and require Euro/US-styled multimedia content may not be at all suited to the requirements of rural learners in LEDCs who may share

ICT equipment and will not identify with the design of the content.

The digital divide extends to sophisticated users who are not adequately catered to in the provision of digital content. This is especially relevant to students at all levels where schools and other educational institutions are not advancing quickly enough to provide content that is relevant to their audience. It is important that educators acknowledge this short-fall and work towards continually improving and enhancing the design and content of ICT components thus driving the "information-wealthy" to new heights.

Finally, social and legal constraints also contribute to this divide. This includes censorship and denial of access. There are a number of countries, including some very populous ones that attempt to strictly control access to the Internet and to Internet resources. The systems used to enforce such constraints, most notably proxy servers, inevitably affect the performance and currency of available data, and inevitably limit the breadth of available information, the range of resources accessed, and the number of people who have access to even that data which has not been proscribed.

II. Current Technical Limitations & Advancements

Practical limitations prevent cable and DSL technologies from reaching many potential broadband customers. Traditional DSL can only reach about three miles from the central office switch while many existing cable networks have not been equipped to provide a return channel. Converting these networks to support high-speed broadband would be expensive. The cost of deploying cable to new areas of low subscriber density would not, in many cases, be commercially feasible and in any case, would take years of disruptive infrastructure installation.

All of these factors are much more acute in developing countries where existing infrastructures are not as advanced and where enormous tracts of economically-deprived land are without infrastructure of any kind.

New forms of wireless protocols are overcoming challenges of terrain, infrastructure and finance. This is especially true in the developing world. By leveraging the Wi-Fi and WiMAX open broadband wireless standards and implementing Mobile Computing architectures, broadband can quickly and cost-effectively be deployed to areas not currently served. This can be done with little or no disruption to existing infrastructures.

III. Bridging The Divide

Wireless eLearning is being implemented throughout the developed and developing world. While much good work has been done, there is a sense that much remains to be achieved. While this may be disappointing, it may also be seen as an unprecedented opportunity. Due to technological advances, particularly in the areas of Wi-Fi, WiMAX, Mobile Computing and Voice over IP (VoIP), there are opportunities to reach audiences that heretofore were too remote or for other reasons beyond the digital divide. While technology is now allowing us to access this ever-increasing audience for eLearning, we must ensure that we can reach them in a truly holistic sense. This depends on us understanding the geographic, economic and cultural complexities of those we want to embrace.

> ***What was once a vast underserved population may be what management guru Dr. CK Prahlad has called "The single biggest market opportunity in the history of commerce."***

From the social, government and business perspectives, there are many advantages to facilitating those who before now - for whatever reason be it social or geographic - have not been part of the digital revolution. The citizens will benefit from being better informed and included in society thus creating better citizen satisfaction and a more educated populace. The benefits of a larger educated and well-informed workforce will have significant benefits for business and society in general. Bringing streamlined, efficient and effective applications to the technology-savvy user while demystifying technology services for the uninitiated will encourage a dramatic uptake in ICT. Availability of broadband services at affordable price levels will have significant impact on gross domestic product (GDP) and attract new investment, create jobs and a larger more qualified labour pool. In addition, greater availability will increase productivity through infrastructure creation and access to new and improved services.

The Business Case Value Drivers for bridging the digital divide include:

- Lifestyle improvement for citizens regardless of socio-economic status
- High availability of information for all users
- Access to educational resources for a vastly increased user base
- Unprecedented opportunity to exercise entrepreneurial skills regardless of user background

The key question is how the situation can be remedied and what actions will effectively create the digital opportunity? Research at Intel, indicates we are now at an inflection point. This is due to a number of factors:

- The cost of computing is steadily decreasing while growing capacity is being incorporated into a wide variety of form factors at price points within the range of users from a wide variety of socio-economic backgrounds.
- New forms of wireless protocols (Wi-Fi, WiMAX, etc) are overcoming challenges of terrain, infrastructure and finance. This is especially true in the developing world.
- The convergence of computing and communications means that this technology now has the opportunity to facilitate those who traditionally would have been outside its reach due to less developed environments and other demographic factors.

The time is right to focus more explicit and coordinated attention on the issue of Internet access and the attendant educational opportunities.

In parallel to the implementation of technology, digital content developers, designers, subject matter experts (SMEs) and providers need to be mindful of the various levels of ability and sophistication of their audience as well as cultural diversities. We must work to improve the knowledge of the "information-poor". When providing technologies that attend to the needs of those currently without ICT experience or ICT interest, we must understand that humans will only adopt something for one of two reasons: there is an absolute need for it or they have a personal interest in it. By nature, we don't like change especially if we feel it is being forced upon us. Cultural diversity must also be taken into account and the "norms" of developed countries must not be automatically assumed to be universal when designing for other cultures. Interestingly, we must also face challenges specific to the "information-wealthy" and continue to be innovative and creative to invent new exciting products to spur on the appeal of ICT in learning. Our approach to bridging the digital divide must be tactful and information rich.

IV. CANDIDATE WIRELESS TECHNOLOGIES

By leveraging open broadband wireless standards like Wi-Fi and WiMAX, implementing Mobile Computing (using the Occasionally Connected Computing model) and Intel® Centrino™ mobile technology enabled tools, it is now possible for governments and partners to make unprecedented strides towards narrowing the digital divide on a global scale.

Gartner* predicts that by the year 2008, there will be more than 167 thousand public WLAN hotspots around the globe and over 75 million users worldwide [*"Market Trends Worldwide, 2002-2008*", Gartner Inc., 2005]. WLAN will provide users with wireless high-speed access while it gives service providers great opportunities to stimulate growth in the wireless data market. Broad coverage and easy access will be critical factors for acceptance and growth of public WLANs and indeed wireless networks in general.

A. Technology Options

The diagram below shows the main network types and the technologies associated with each. Personal Area Networks (PAN), Local Area Networks (LAN), Metropolitan Area Networks (MAN) and Wide Area Networks (WAN) are mapped against ranges and throughputs.

We are especially interested in those technologies associated with the LAN, MAN and WAN network architectures and the proposed open broadband wireless standards are Wi-Fi and WiMAX.

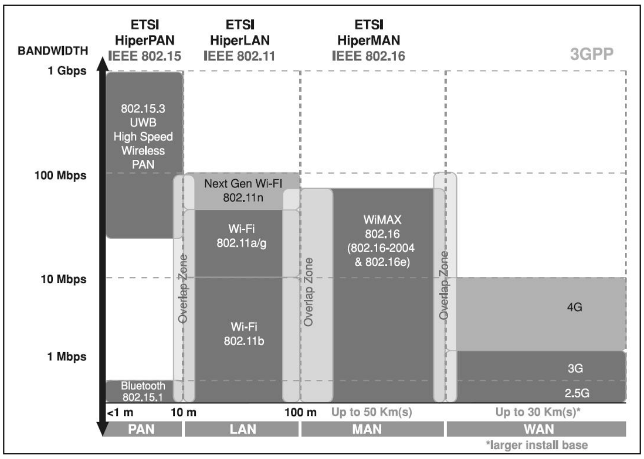

Figure 2. Wireless Technologies: Network Type, Range and Throughput

1) Wi-Fi

Wi-Fi is a high-speed data networking technology that provides an "over the air" interface between a wireless client and a base station or access point. It is being widely deployed in residential, enterprise and public areas worldwide and provides high-speed Internet access to users of mobile computers and PDAs (and cell phones in the near future) in myriad locations.

As a wireless data transmission over radio waves, it broadcasts across the 2.4 and 5GHz bandwidth spectra with speeds of up to 54 Mbps (theoretical) and is designed for coverage from 50 up to 125 meters.

Importantly, this technology forms the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard for wireless LANs. Work is ongoing in the certification of Wi-Fi equipment to existing standards while specification and ratification of new standards continues in line with technological advances. While progress is being made in this area there remain in existence many pre-standard Wi-Fi networks which, due to proprietary systems and lack of standardized methods of implementation and security, suffer from interoperability issues and connecting can be confusing for users. It should be noted that Intel's goal is to promote a common standards-based approach to address interoperability.

2) Wireless Mesh Network Solutions

Infrastructure mesh networks combine the characteristics of cellular networks with Wi-Fi technology. The result is a dense mesh architecture capable of cost-effectively and securely delivering broadband data to standard Wi-Fi clients over entire metro-areas. A standard does not currently exist for wireless mesh although work is currently underway towards incorporating a specification under the 802.11 set of standards. The majority of vendors for WLAN equipment have proprietary mesh implementations.

3) WiMAX

WiMAX is a rapidly maturing broadband delivery technology that provides a wireless backhaul alternative to cable, xDSL and Tx wired options. It is a non-Line-of-Sight (NLoS) point-to-multipoint technology that supports multiple licensed and unlicensed frequencies in the 2-6GHz range. With throughput of up to 75Mbps (theoretical) it has a range of up to 30 miles in ideal conditions although 4-6 miles typically would be the design radius. Robust bandwidth, guaranteed service levels, Quality of Service (QoS) support, built-in security and low cost make WiMAX an excellent choice for long distance backhaul applications such as linking Wi-Fi enabled mesh networks and hotpots to the Internet.

IEEE802.16-2004 is the current standard for WiMAX to provide a carrier-class fixed wireless solution. The IEEE802.16e amendment to the basic specification will enable a base station to support both fixed and mobile broadband wireless access. This aims to fill the gap between high data-rate WLANs and high mobility cellular WANs.

In 2005, Intel released its codenamed "Rosedale" WiMAX chip-set, the first of its kind. Currently, communication product manufacturers are incorporating this chipset into their WiMAX products.

4) Mobile Computing Architectures

Mobile Computing technology is designed to insulate users from network dependencies by making data and applications available when the user is offline. Upon re-connection to the network, information is automatically updated through a data synchronization process. This application architecture enables mobile users to work more productively and conveniently by:

- Adding online/offline functionality which allows users to work anywhere, any time, and to work without disruption, even when network connections are interrupted
- Providing intelligent roaming capabilities when moving from hotspot to hotspot which means users won't waste time reconnecting or lose critical data because of dropped connections
- Enabling the flexibility to access data and applications on various computing devices, whether they are laptops, desktops, handhelds or servers
- Tuning applications to conserve power and maximize performance extending battery life and delivering fast application execution

B. The Proposed Solution

By leveraging the Wi-Fi and WiMAX open broadband wireless standards and implementing Mobile Computing architectures, broadband can quickly and cost-effectively be deployed to areas not currently served. This can be done with little or no disruption to existing infrastructures.

Standards-compliant WLANs and proprietary Wi-Fi Mesh infrastructures are currently being proliferated widely throughout the world. As of 2006, standards-compliant WiMAX products are available to provide NLoS backhaul solutions for these local networks. WiMAX subscriber stations will also be available to provide access to customer premises such as schools and other educational institutions.

Next generation WiMAX and Wi-Fi enabled clients, due in 2007, will be able to directly access legacy proprietary Wi-Fi Mesh networks, newly deployed standards-compliant Wi-Fi Mesh networks and WiMAX networks.

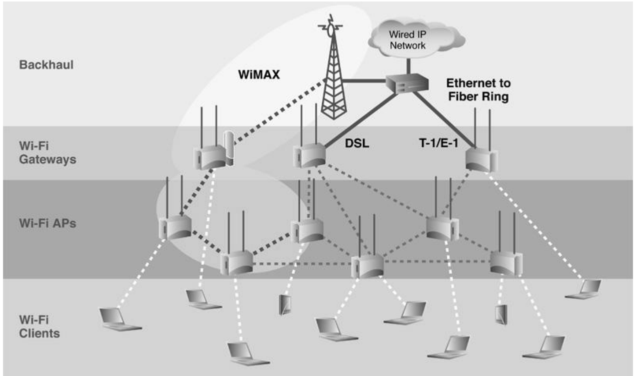

Figure 3. WiMAX and Wi-Fi Integration

This paper proposes that we capitalize on these emerging technologies and standards and work to promote and support their implementation. In doing this, we will surely be laying a solid foundation upon which the digital divide will be bridged.

V. ELEARNING INNOVATIONS AT INTEL

Intel® Innovation Centre has been involved in implementing wireless technologies in several eLearning projects both domestically and internationally. The following are examples at various stages of development.

A. Digital Community Initiative in the Developing World

The Innovation Centre is working with Intel India on presenting Government with a compelling case for the implementation of Digital Community initiative in Karnataka, India. Facilitation of education to students and adults, often in remote areas, features strongly in this proposal. The author visited Bangalore and, based on findings, created a blueprint on how this can be achieved. This was presented to the Government of Karnataka leading to the release of an Expression of Interest request by the Chief Minister. A Request for Proposals (RfP) document is to follow when interested parties will be invited to submit their proposals for "getting Bangalore onto the Digital Community continuum".

"Technology is already transforming lives in India, improving education and fuelling economic growth. We want to support the continuation of these trends," said Intel CEO Craig Barrett.

The Digital Community initiative addresses economic vitality, citizen satisfaction and bridging the digital divide. The pace of change is a critical challenge to governments managing communities, as citizens become more demanding and resources become scarcer. By adopting a wireless digital strategy, governments can meet this challenge. The Digital Community Continuum can be considered in four phases:

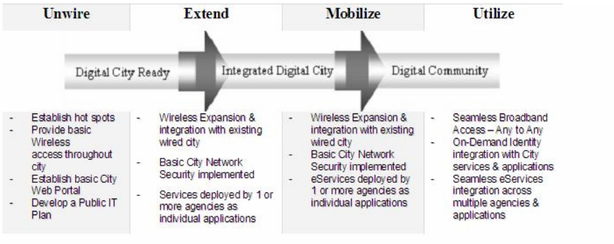

Figure 4. Digital Community Continuum

As technology opens doors to "connected" citizens, there is a very real danger than those without access to broadband technology are left behind, widening the digital divide. With this in mind, this initiative proposes a comprehensive strategy leading to a program that is cohesive, standards-based, scalable and future-proof with formal and on-going education as a key underlying objective.

B. Satellite Link for SchoolSat in Ireland

This European Space Agency (ESA*) funded pilot project was project managed by ATiT Ireland* with Intel® Innovation Centre and others providing the architecture and technical expertise. The objective of the project was to demonstrate the delivery of education-focused Internet services to schools via satellite technologies.

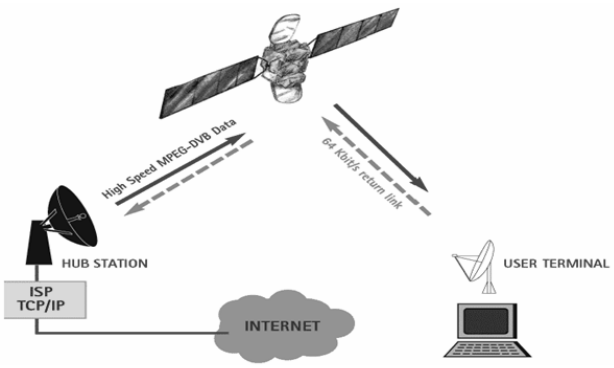

Figure 5. SchoolSat Technology Overview

The project involved nine post-primary schools in Ireland, in areas poorly served by broadband. The local authority (County Council) had difficulty in facilitating the Internet access requirements of the schools in this region and it was decided that a satellite service could play an important role in meeting these needs.

The satellite infrastructure was implemented and a multicasting service was provided whereby selected educational content from a number of leading sources, including the Innovation Centre's skoool™, was pushed to the schools on a weekly basis. This content was cached on a server at each school to be accessed locally by students and teachers enabling a rich media learning experience.

Using satellite technology to provide such a service offers advantages in that it can:

- Provide schools with fast access to the Internet
- Be installed in any school regardless of location
- Be installed relatively quickly; each school took, on average, half a day to install
- Provide a secure and managed network for schools
- Provide stakeholders with a system capable of pushing specific web-based content and digital resources to all schools instantly
- Be integrated with other existing and compatible services where such services exist

["SchoolSat: Final Report ", Reynolds S., 2004].

Much work was done in evaluating the success of this project at the participating schools and the following table is a summary of our findings:

Plans are currently underway on the implementation of multicast broadband over WiMAX technology as the next phase to this project. To this end, the Innovation Centre has completed a comprehensive research study on the technical and commercial feasibility of multicasting over WiMAX.

SchoolSat: Key Findings
Key Learnings
- All schools reported that they made valid educational uses of the Internet. - In some cases, the Internet formed a substantial part of teaching a particular subject. - Teachers' perceptions were that there was real learning benefit, the main one being increased student motivation. - In project work, teachers reported an increase in students taking responsibility for their own learning. - Teachers using on-line tests reported that these were particularly engaging with weaker students who were anxious to retake tests and increase their scores.
Key Barriers
- Teachers unsure how to use technology especially in a classroom context. - Difficulty in getting access to the computer room. - Worries about time used in working online and relevancy in examination terms.
Technology
- Satellite link provided 56Kbit/s performance for initial request, but high-speed subsequent performance. - Relatively fast installation; each school took, on average, half a day to install.

Figure 6. SchoolSat: Key Findings

C. skoool™ Learning Technology

Intel® Innovation Centre's skoool™ rich media learning service has helped transform the way 2nd level students learn and revise. Currently established in the UK, Ireland and Sweden, plans are at an advanced stage to deploy tailored offerings to developing countries in Africa and the Middle East. In addition, we are helping many Universities to unwire and have a significant programme

in Asia.
The skoool™ platform for education delivers:

- a state of the art dynamic database driven site running on high end Intel Architecture (IA) servers
- the Intel® eCDS peer-to-peer product for high media content delivery
- a flexible and efficient Content Management System
- a highly flexible information architecture
- tools for customer support, registration and community
- dynamic and flexible tracking and usage reporting
- and a well defined brand

The skoool™ platform is designed to deliver leading-edge e-learning to students anytime anywhere in low or high bandwidth environments.

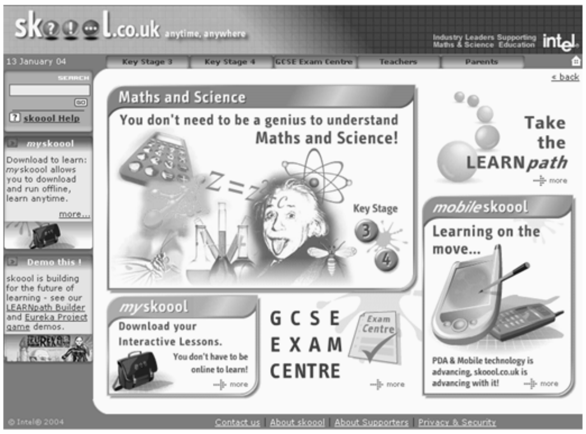

Figure 7. skoool™ Learning Technology

In addition to the established PC-based media-rich online and downloadable services available on the educational portal, work is ongoing in the implementation of online and downloadable learning material for PDA, mobile phone and smartphone.

The following table outlines our findings from these leading-edge service delivery pilots:

Mobile skoool™: Key Findings
Key Learnings
- Smartphone Learning Objects (LOs) have been successful at the proof-of-concept stage. - Short Message Service (SMS) facilities, e.g. study tips and competitions, have proved very successful with users. - Of all the SMS campaigns organised for participating users over the course of the school year, exam tips have been the most popular. - There is evidence to suggest that SMS / phone delivery type initiatives appeal to students that may be considered border-line performers.
Key Barriers
- There is not yet a critical mass of students with sophisticated handsets. - To date, the pricing of smartphones has largely been concentrated on the business community
skoool™ UK Statistics (2005)
- 67% of KS3 students reported that they had used the SMS service. - 38% of KS4 students had used the SMS service - 15% of KS4 students had used skoool™ content on PDA

Figure 8. Mobile skoool™: Key Findings

The proliferation of skoool™ technology is dependant on a solid infrastructure being in place.

In many cases, and especially in developing countries, there is a strong commercial and logical argument that this should be a wireless infrastructure. Some of the advantages of this approach include:

- High relative cost efficiencies for set-up and maintenance.
- Short installation period
- Non disruptive implementation
- Technology well suited to physical and environmental challenges.
- Standardized network equipment and strong product roadmap.

VI. CONCLUSION

Lack of access to ICT leads to a lack of education, wealth and income, in turn leading to lack of access to ICT infrastructure and services and so continues the digital divide. Several socio-economic groups, especially within the developed world, have benefited enormously from the innovative creations of the ICT industry, not least in the arenas of learning and collaboration. By sharing this experience and expanding the key uses of ICT in education to other groups within our own society and in the developing world we can kick-start the beginning of the end for the digital divide.

To date, communications equipment has been expensive and requires good infrastructure to be in place. Rural communities and developing countries often do not have either the necessary infrastructure or the available funding to put such infrastructure in place. With the advent of the new wireless technologies, there is an unprecedented opportunity to remedy this situation at a fraction of the cost, and in a fraction of the time, that would previously have been required.

We are progressing with our initiatives in wireless communications. Going forward we will be developing our existing projects and initiating new ones with specific emphasis on Wi-Fi, WiMAX, Mobile Software Initiative (MSI) and VoIP technologies. In parallel, we will continue to expand the skoool™ learning technology to other geographies worldwide with countries in Africa currently under consideration for deployments of tailored implementations.

Intel® Innovation Centre has a unique opportunity to work on both the educational side of eLearning and also the wireless technologies end. It is important that we use our experience and learnings from this to inform and promote the future of eLearning.

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Manuscript received 31 March 2006.