

Promoting Human Capital Development through ICT Creativity and Innovation

RN BEYERS

Thesis submitted for the degree Doctor of Philosophy in Learning and Teaching at the
Potchefstroom campus of the North-West University

Promoter: Prof. Dr A. Seugnet Blignaut

Co-promoter: Prof. Dr Marlien Herselman

August 2010

Dedication

I dedicate this thesis to my wife Brenda and our children Lisa, Kevin and Andrea for their love and support throughout the many years that this project has taken to realise as a life-time ambition.

Acknowledgements

I would like to acknowledge a number of people and organisations who have made this thesis possible:

- Prof. Seugnet Blignaut, for her continued support and encouragement in assisting me with my educational career in this thesis. She served as an inspiration to see it through to the end and persuaded me—together with Prof. Marlien Herselman—to believe in myself
- To the staff and pupils of St Alban's College, who afforded me many opportunities, including the chance to do outreach work. Special mention must be made of the three headmasters under whom I served: Mr Ronnie Todd, Mr Grant Nupen and Mr Tom Hamilton
- Mrs Merryl Ford and the staff of the Meraka Institute, who afforded me the opportunity to step out of the classroom and to develop the "Young Engineers and Scientists of Africa" initiative
- Dr Neville Comins, who acted as my mentor for many years. He was able to stimulate new ideas and hidden energies within me which ultimately changed my academic life
- To the Ulwazi Committee, consisting of Mr Richard Gerber (Department of Communications), Mr Ronnie Seeber (Former Motorola), Johann Strauss (SMART Interactive Whiteboards), Mr Leslie Hlangani (Gatang Comprehensive School) and Steven Tayfield (Former Sangari) for their continued support
- To the staff of the Advanced Manufacturing Technology Strategies involved in the Fab-Lab project—under the guidance of Dr Greg Mitchell—for the wonderful opportunity of exposing learners to such a stimulating environment
- The National Research Foundation and the North-West University for the bursaries received
- Magdel Kamffer for her administrative support.

I wish to thank everyone who has contributed to the development of my academic career: both locally and internationally.

Opsomming

Die Bevordering van Menskapitaalontwikkeling deur middel van IKT Kreatiwiteit en Innovasie

Suid-Afrika ondervind 'n groeiende aanvraag na meer geskoolde werkers, veral in skaars vaardighede soos wetenskap, ingenieurswese en tegnologie. Die bestaande onderwysstelsel slaag nie daarin om in hierdie behoefte te voorsien nie. Leerders word ontoereikend voorberei vir die uitdagings gebied deur 'n nuwe en snel ontwikkelende samelewing; die ou samelewing bestaan in praktyk nie meer nie. Hierdie tesis beskryf 'n nasionale ontwikkelingsstelsel van tegnologie-innovasie wat jong leerders kan begelei tot geskoolde werkers as 'n langtermynbelegging vir toekomstige kundigheid met betrekking tot wetenskap, ingenieurswese en tegnologie. Om hierdie uitdaging aan te spreek wys hierdie tesis op die behoefte aan digitale insluiting, integrasie van gemeenskappe, die dinamiese werking van Inligting-kommunikasietegnologie (IKT) in klaskamers, die verkenning van geleenthede vir die uitbreiding van snelprototipering in skole, asook die bevordering van digitale geletterdheid in die algemeen. Hierdie lys is nie omvattend nie, maar in hierdie studie bied die navorser voorbeelde van elkeen van bogenoemde ontwikkelings aan in die vorm van vyf joernaalartikels.

Die ondersoek het plaasgevind in die Tshwane-area en het manlike en vroulike leerders in laer- en hoërskole ingesluit. Die keuse van navorsingdeelnemers was afkomstige uit beide goeie en benadeelde gemeenskappe en leerkragte was verantwoordelik vir die keuse van respondente aan die studie. 'n Metodologie van ontwerpnavorsing (design research) is tydens hierdie studie gevolg. Die grootste gedeelte van die navorsing het in 2001 begin en die hoofstudie is voltooi van 2007-2010. Die klem in die studie was hoofsaaklik op kwalitatiewe navorsingmetodologie, terwyl in 'n beperkte mate ook van kwantitatiewe navorsingmetodologie gebruik gemaak is.

Die bevindings van hierdie navorsing beklemtoon dat dit noodsaaklik is om die omvang van die ondersoek uit te brei en die gekonseptualiseerde intervensies uit te bou. Hierdie pedagogiese skuif beweeg weg van blote inligtingsoordrag na 'n kreatiewe, innoverende en stimulerende omgewing. IKT skep geleenthede vir gemoniteerde betrokkenheid van leerders by wetenskap, ingenieurswese en tegnologie. Die studie bied 'n oplossing om die digitale kloof te oorbrug deur die kreatiewe gebruik van interaktiewe virtuele klaskamers wat leerders in naburige en afgeleë plattelandse klaskamers digitaal insluit. Die navorsingsbevindings dui aan dat verskille tussen leerders van bevoorregte gemeenskappe en voorheen benadeelde gemeenskappe onbeduidend is wanneer hulle deur IKT bemagtig word.

Die strategiese belangrikheid van IKTs, kreatiwiteit, en innovasie is sleutelkomponente van 'n strategie vir die ontwikkeling van Menskapitaal, veral noudat daar 'n toenemende behoefte aan skaars vaardighede in sleutelareas is. Na-matrikulasie intervensies bied slegs korttermynoplossings wat op die lang duur nie haalbaar is nie. Hierdie tesis doen 'n beroep op die vestiging van 'n ontwikkelingspylyn vir wetenskap, ingenieurswese en tegnologie reeds vanaf grondvlak om sodoende 'n basis te verseker vir 'n nasionale stelsel van innovasie as 'n langtermyn- en volhoubare belegging in die toekoms.

Sleutelwoorde

- Menskapitaalontwikkeling
- Netgenerasie
- Kreatiwiteit
- Innovasie
- Konstruktivisme
- Digitale insluiting
- 21ste eeuse vaardighede
- Talentidentifisering

Abstract

There is a growing call for more skilled workers—especially in the scarce skills of science, engineering and technology (SET). The current educational system is failing to address these issues, learners are being ill-prepared to cope with the demands of a society that has moved on; and learners are being prepared for a society that no longer exists in practice. In order to address this problem, this thesis calls for a greater emphasis on issues of digital inclusion, integration of whole communities, understanding of the dynamics of integrating ICTs into the classroom, exploring opportunities for the expansion of rapid-prototyping at school level and the promotion of digital literacy. Though this is not a definitive list, the researcher has developed working solutions to each of these issues, as presented in five journal articles.

Investigations were conducted in the Tshwane area with male and female learners in both primary and secondary schools. The selection of the learners from both advantaged and disadvantaged institutions was left to the teachers. Design research was the main methodology adopted for this research. The investigations started in 2001 and the bulk of the work was concluded between 2007-2010. Greater emphasis is placed on a qualitative approach with limited quantitative analysis.

The findings of this research indicate the need to extend the scope of the investigation and to massify the different interventions. The pedagogical shift has been away from information transfer, towards using information communication technologies to promote creativity and innovation in a stimulating constructivist environment. This has led to an opportunity to track learner involvement in SET events over their school careers and to identify talented individuals. In addition, the findings indicate that there is little difference between learners from advantaged and disadvantaged communities. Added to this is the development of a solution to address the digital divide through the creation of virtual interactive classrooms which can digitally include learners from geographically separated classrooms in remote communities.

The strategic importance of ICTs, creativity and innovation are key components of a Human Capital Development strategy, especially at a time when there is a growing shortage of scarce skills in key areas. Post Grade 12 interventions are short term solutions that are not sustainable. This thesis calls for the establishment of a SET pipeline from grassroots level, in order to grow the feeder stock for a national system of innovation as a long-term investment in the future.

Key Terms

- Human Capital Development
- Net Generation
- Creativity
- Innovation
- Constructivism
- Digital Inclusion
- 21st Century Skills
- Identification of talent

Solemn Declaration of Authorship



NORTH WEST UNIVERSITY
YUNIBESITH YA BORONGE-BOPIRIBA
MOORWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Academic Administration SOLEMN DECLARATION

Solemn declaration by student

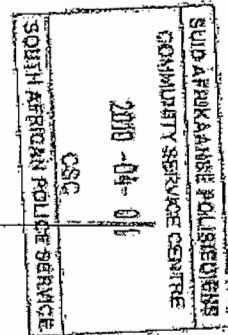
I, Mr. R.N. Beyate declare herewith that the mini-dissertation/dissertation/thesis entitled, Promoting Human Capital Development through ICT Creativity and Innovation which I herewith submit to the North-West University as completion/partial completion of the requirements set for the PhD degree, is my own work, has been text edited, and has not already been submitted to any other university.

I understand and accept that the copies that are submitted for examination are the property of the University.

Signature of student [Signature] University number 21986444

Signed at Potchefstroom this 01 day of April 2010

Declared before me on this 1st day of April 2010
Commissioner of Oaths: [Signature]
SKC

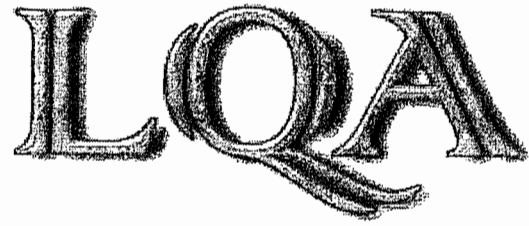


Declaration by supervisor/proptor

The undersigned declares:

- 1.1 that the student attended an approved module of study for the relevant qualification and that the work for the course has been completed or that work approved by the Senate has been done;
- 1.2 the student is hereby granted permission to submit his/her mini-dissertation/dissertation or thesis;
- 1.3 that registration/change of the title has been approved;
- 1.4 that the appointment/change of examiners has been finalised and
- 1.5 that all the procedures have been followed according to the Manual for post graduate studies.

Signature of Supervisor: [Signature] Date: 1/4/2010



Language Quality Assurance Practitioners

Mrs KA Goldstone

Dr PJS Goldstone

14 Erasmus Drive

Summerstrand

Port Elizabeth

6001

South Africa

Tel/ Fax: +27 41 583 2882

Cell: +27 73 006 6559

Email: kate@pemail.co.za

pat@pemail.co.za

30 March 2010

TO WHOM IT MAY CONCERN

We hereby certify that we have language edited the thesis prepared by Mr R N Beyers entitled PROMOTING HUMAN CAPITAL DEVELOPMENT THROUGH ICT CREATIVITY AND INNOVATION and that we are satisfied that, provided the changes we have made are effected to the text, the language is of an acceptable standard, fit for publication.

A handwritten signature in black ink that reads 'KA Goldstone' in a cursive, flowing script.

Kate Goldstone

BA (Rhodes)

SATI No: 1000168

UPE Language Practitioner (1975-2004)

NMMU Language Practitioner (2005)

A handwritten signature in black ink that reads 'PJS Goldstone' in a cursive, flowing script.

Patrick Goldstone

BSc (Stell)

DEd (UPE)

Ethical Clearance



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
INSTITUTIONAL OFFICE

Private Bag X1290, Potchefstroom
South Africa 2520

Tel: +27 18 299-4900
Fax: +27 18 299-4910
Web: <http://www.nwu.ac.za>

Tel: 018-2994852
Institutional Research Ethics Secretariate

2010-04-08

Dear Sir/Madam

RESEARCH ETHICS APPLICATION NWU-00007-10-S2

Promoting Human Capital Development through ICT Creativity and Innovation
Project leader: Prof S Blignaut
Student working on project: R Beyers

We hereby acknowledge that above application is approved by the NWU Research Ethics Committee.
A formal approval certificate will follow shortly. Please contact me with any queries.

A handwritten signature in black ink, appearing to read 'H. Halgryn', written over a horizontal line.

Yours sincerely

HM Halgryn

Institutional Research Ethics Secretariate

Contents

Dedication	i
Acknowledgements.....	i
Opsomming	ii
Abstract	iv
Key Terms	v
Solemn Declaration of Authorship.....	vi
Certificate of Proofreading and Editing.....	vii
Ethical Clearance	viii
List of Figures.....	xii
List of Tables	xiii

TOWARDS ESTABLISHING A PIPELINE FOR SCIENCE, ENGINEERING AND TECHNOLOGY

1. Problem and Motivation for Research	1
2. Review of Relevant Literature	2
2.1. Creativity and Innovation.....	5
2.2. The Net Generation	7
2.3. The Digital Divide.....	10
2.4. Social Inclusion.....	11
2.5. Constructivism	12
2.6. 21st Century Skills	14
2.7. National System of Innovation.....	16
2.8. Human Capital Development	20
3. Research Aim, Objectives and the Purpose of this Study.....	20
3.1. Main Research Question.....	22
3.2. Sub-questions	22
4. Research Design and Methodology	22
4.1. Design Research	23
4.2. Population and Sample.....	24
4.3. Data Collection.....	25
4.4. Data Analysis.....	26
4.5. Paradigms.....	26
5. Ethical Aspects	27
6. Presentation of this Research	28
6.1. Preliminary Structure of Articles	29

Article 1

THE ULWAZI CONCEPT–VIRTUAL INTERACTIVE AND COLLABORATIVE CLASSROOMS OF THE FUTURE

Abstract	33
Introduction.....	33
The Problem Identified.....	34
The Birth of the Ulwazi Concept.....	35
Some Outcomes of the Pilot Project	38
Transformational Outcomes.....	38
Recommendations.....	40
Conclusions	44
References	44

Article 2

A FIVE DIMENSIONAL MODEL FOR EDUCATING THE NET GENERATION

Abstract	46
Introduction	46
Learning Theories.....	48
A Proposed Conceptual Model	48

The First Dimension – X Axis (Survival Strategies).....	49
The Second Dimension – Y Axis (Knowledge and Comprehension)	50
The Third Dimension – Z Axis (Spatial Orientation)	50
The Fourth Dimension – Time	51
The Fifth Dimension – Global vision	52
Implications for Teacher Training.....	52
Implications for Schools	53
Implications for Learners	54
Conclusions.....	54
References	54

Article 3

EXTENDING THE EDUCATION AND SOCIAL BENEFITS THROUGH 'HUB SCHOOLS'

Abstract.....	56
Introduction.....	56
Building Blocks of the Hub School Concept.....	60
Principles of the Hub School Concept.....	68
Educational Benefits of a Hub School.....	70
Conclusions	73
References	74

Article 4

NURTURING CREATIVITY AND INNOVATION THROUGH FABKIDS—A CASE STUDY

Abstract.....	76
Introduction.....	76
Science, Engineering, Technology and Outcomes Based Education.....	78
Theoretical Perspectives	79
Group Demographics.....	80
Summary of the activities for the day.....	80
Summary of the findings	81
Conclusions and Recommendations.....	82
References	84

Article 5

THE BROADER ISSUES OF INTRODUCING A DIGITAL KIDS PROGRAMME

Key Words.....	85
Introduction.....	86
Concept Analysis.....	87
Action Research	87
Digital Literacy	88
The Technological Ladder vs. the Digital divide.....	89
A National System of Innovation (NSI).....	90
The Digital Kids Programme	91
Pilot Project Feedback.....	92
Additional research opportunities.....	94
Conclusions.....	95
Glossary of Terms	96
References	98

SYNOPSIS, REFLECTION AND CONTRIBUTION

1. Introduction.....	102
2. Synopsis of the Findings	104
3. Addressing the Main Research Question	105
3.1. Possible Implications for the Deployment of Hub Schools.....	105

3.1.1.	Opportunities for Further Research Based on the Hub School Concept.....	106
3.2.	Development of a New Educational Model of an ICT Learning Environment.....	107
3.2.1.	Opportunities for Further Research Based on the Five-Dimensional Model of Education.....	108
3.3.	Utilizing Broadband Technologies to Digitally Include Learners in Remote Locations	108
3.3.1.	Additional Research Questions Emerging from the Ulwazi Concept.....	112
3.4.	A Rapid-prototyping Environment to Stimulate Creativity and Innovation	113
3.4.1.	Opportunities for Further Research Based on the FabKids Concept.....	115
3.5.	Digital Literacy Taught as Part of Technology Clubs at Schools.....	115
3.5.1.	Opportunities for Further Research Based on the Digital Kids Concept	117
3.6.	Addressing the Main Research Question	117
3.6.1.	Opportunities for Further Research	121
4.	Limitations of the Study.....	122
5.	Recommendations	123
6.	Contribution of the Study.....	124
BIBLIOGRAPHY		127

List of Figures

Figure 1: The Knowledge Funnel.....	17
Figure 2: Four paradigms for the analysis of social theory	27
Figure 3: Five-Dimensional Model of Education	107
Figure 4: A Graphic representation of the meta-analysis of Key Concepts used in the Articles.....	119
Figure 5: A graphic representation of how the main arguments from the different article are interrelated	121
Figure 6: The education system, society and the curriculum.....	124

Article 1

Figure 1: A Schematic Representation of the Ulwazi Network Diagram	36
Figure 2: Ulwazi Phase 2 – Tshwane Smart Learning Network – Concept Diagram	42

Article 2

Figure 1: The education system, society and the curriculum.....	47
Figure 2: Five Dimensional Model of Education.....	49
Figure 3: Moving from a teacher-centered to a learner-centered approach	53

Article 3

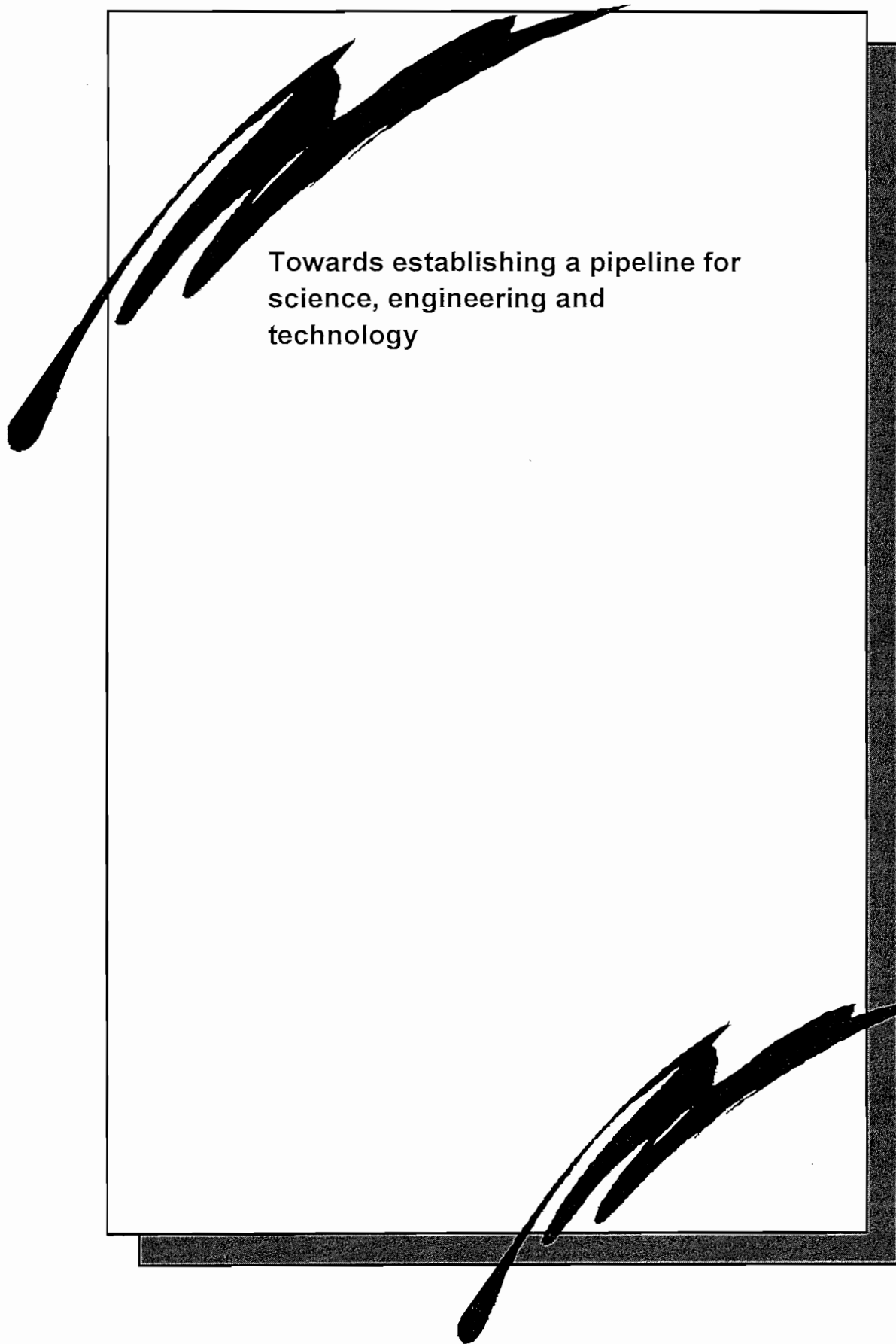
Figure1: A Schematic Representation of the Concept of a Technological Ladder.....	59
Figure 2: A Photograph of a 3-Terminal System.....	61
Figure 3: A schematic Diagram of the First Mile First Inch Concept.....	62
Figure 4: A Photograph of the installation of A Cantenna as part of a Mesh Network	63
Figure 5: A schematic representation of the Original Ulwazi Network.....	65
Figure 6: A schematic representation of various YESA interventions highlighting the focus areas across the different grades	67
Figure 7: A Schematic representation of the Hub School Concept using Mesh technologies to the remote schools and distributing further to the local communities	68
Figure 8: A schematic representation of the interrelationship of education, health and social benefits within a connected Hub School community.....	70

Article 4

Fig. 1 Two students and a teacher observing the laser cutter in action	81
Fig. 2 Shows team members assembling the final product including the electronic compo- nents.....	81

Article 5

Figure 1: The YESA Skills Grid	87
Figure 2: A Schematic Representation of the Concept of a Technological Ladder.....	90
Figure 3: Representing the annotation of the Electrolysis of Copper II Chloride.....	92
Figure 4: Represents a select number of graphics in the animation series.....	92



Towards establishing a pipeline for
science, engineering and
technology

TOWARDS ESTABLISHING A PIPELINE FOR SCIENCE, ENGINEERING AND TECHNOLOGY

1. Problem and Motivation for Research

This investigation is based on the researcher's own experiences over two decades of interacting with a wide range of learners. The introduction of modern technologies provided a stimulating digital curriculum interface to interact with individuals on their own terms. The researcher discovered differences amongst the learners through many of these interactions.

These interactions range from the simple introduction of animation in science lessons to stimulating multidimensional competitions involving the application of a range of skills, solving the challenges of a transport divide for outreach projects, as well as the initiation of a high level of a national project to address skills development among the youth in South Africa. Experience from the involvement in international projects has provided a key input in the formulation of many of the ideas—including the recognition of two strategic projects at an international level.

The researcher aims to highlight the importance of understanding not only hardware and software issues, but more importantly the human elements, or *warmware* (Beyers, 1999) of introducing technologies into the classroom, which in many respects, are potentially the most difficult. Learners today, whether they are from successful private schools or deep rural previously disadvantaged schools, have a great deal in common. Talent in the latter schools is generally not identified because of a lack of criteria to do so, as well as teachers being inadequately prepared to stimulate these learners effectively.

The recent introduction of an Outcomes Based Education (OBE) approach in South Africa was designed to transform the country's needs, as far as genuine skills development is concerned. However, the system is producing few learners with suitable competencies in Mathematics, Science and Technology. Modern Information Communication Technologies (ICTs) have the potential to share top teachers through virtual interactive classrooms to support learners in more rural underserved areas to address real educational needs (Miller, 2000).

The researcher's experience has led directly to the founding of a programme to develop youth in Africa, especially in the areas of Science, Technology, Engineering, Mathematics and Innovation (STEMI). The approach that was adopted was not purely academic, but

rather focused on providing opportunities to promote creativity and innovation, as well as entrepreneurial opportunities through stimulating hands-on experiences. In many respects these interventions start where such programmes as computer literacy stop, focusing more on a constructivist approach to empower learners, rather than simply to teach or train them.

There is an opportunity for human capital development to begin from grass-roots level through the introduction of a range of identified projects which capitalise on the strengths of ICTs to reach out to the broader educational community. However, it is as yet unclear how ICTs can promote creativity and innovation for human capital development in South African schools. This study aims to address this knowledge gap in the South African context.

2. Review of Relevant Literature

The purpose of a literature search is to broaden the researcher's ideas to the wider literature on the topic (Healey *et al.*, 2010: 16-17). A way of strengthen the operationalization of data collection is through triangulation. In general triangulation is application of several research methodologies to study the same phenomenon. It is a form of crosschecking data (de Jong, 2010: 178). A significant proportion of the research will deal with tools for the digital age the users are growing up with.

The best way to appreciate the merits and consequences of being digital is to reflect on the difference between bits and atoms. While we are undoubtedly in an information age, most information is still being delivered in the form of atoms: newspapers, magazines, and books. Our economy may be moving toward an information economy, but we still measure trade and we write our balance sheets with atoms in mind (Negroponte, 1998). This dichotomy is reflected in the diverse educational approaches being adopted in schools across South Africa today. On the one hand, learners are being exposed to traditional education via the use of textbooks, when they are available, while other learners are being fully prepared for life in a digital world to participate in the knowledge economy with the help of progressive educators and their respective institutions.

Transforming education into a modern system should address the digital needs of the learners from within the curriculum. If transformation fails to take cognisance of the Net Generation's ability to deal with information, amongst other characteristics, as described by Oblinger and Oblinger (2005: 2.4-2.5), then the system will fail to develop learners with digital-age literacy and other 21st century skills needed to cope with life in a technological world in which

they are growing up. This in turn may have a long-term knock-on effect of not producing enough knowledge workers who are able to operate effectively in a broader economy.

The world of knowledge-age work requires a new mix of skills. Jobs that require routine manual and thinking skills are giving way to jobs that involve higher levels of knowledge and applied skills—like expert thinking and complex communicating (Trilling *et al.*, 2009: 8).

Keeping pace with change is an essential element of producing successful learners exiting from the Grade 12 Examinations in South Africa. The thought of a school that can learn has become increasingly prominent during the last few years. It is becoming clear that schools can be recreated, made vital, and sustainably renewed—not by fiat nor by command, and not by regulation—but by taking a new learning orientation. This means involving everyone in the system in seeking to express their aspirations, in building their awareness, and in developing their capabilities together (Senge *et al.*, 2000: 5).

Schools across South Africa face a diverse learner population on both sides of the *digital divide*. Though a large majority may be limited through no exposure to technology, a growing number may be termed *Digital Natives* as they are *native speakers* of the digital language of computers, video games and the Internet (Prensky, 2001: 1) though Larkin (2007) and McKenzie (2007) are questioning the possible derogatory nature of use of such terms in education.

The intention of the introduction of OBE (Department of Education, 2002; Department of Education, 2003) has shifted the focus of the educational process towards one of skills development rather than the dated behaviourist paradigm of pure information transfer. Based on the researcher's own experience there are a growing number of more progressive educators who are grappling with the demands of introducing modern ICTs into the learning process. Providing these teachers with a better understanding of this environment may help them to take advantage of the strengths of a technology that facilitates the teaching and learning environment by capitalizing on the power of ICTs to create virtual classrooms which can digitally include remote learners in geographically separated classrooms.

The Young Engineers and Scientists of Africa (YESA) project initiated the development of a science, engineering and technology (SET) pipeline to nurture creative and innovative skills. This must be seen as a long-term investment in human capital development (HCD) to support the grand challenges of the Department of Science and Technology's (DST) ten-year strategic plan (Department of Arts Culture Science and Technology, 1996) to form the four-

dation stones of the National System of Innovation (NSI) for South Africa, ultimately contributing to the Millennium Development Goals of 2015.

Interventions that actively engage learners should be further investigated with the view to having an impact on all schools across the country. The *FabKids* and *Digital Kids* projects are just two such interventions which can provide a vehicle for the nurturing and identification of learners with talent. The outcomes of this investigation will potentially have implications for the following national projects:

- EduNet – interconnecting all schools in the country (Department of Education, 2004)
- National System of Innovation (Department of Science and Technology, 2004)
- Youth Into Science Strategy, Nurturing Youth Talent for a Stronger National System of Innovation: Department of Science and Technology (Department of Science and Technology, 2006)
- National Youth Strategy: Employment of unemployed Science graduates through the Department of Science and Technology (Department of Science and Technology, 2008)
- E-Caders: Employment of unemployed Computer Science graduates through the Department of Science and Technology (Mangena, 2006)
- E-Skills development: ICT skills for modern life, the work place and technical skills (e-Mzansi Information Society, 2009).

Computer literacy has to be the starting point to empower learners to access information, but far too often this is perceived as the end point—thereby stifling opportunities for creativity and innovation, while failing to promote entrepreneurial opportunities. To overcome this, teachers should be sensitised to the complexity of the learning environment, especially where ICTs are introduced for teaching and learning. This is a notion supported by John (2004) and Valcke et al. (2005: 13-17).

When dealing with computers in the classroom, teachers should first establish the level at which the learners are operating at before commencing with new work. Failure to do so may result on lost learning opportunities. Comprehending the level that learners are operating forms the basis of just about all education theories irrespective of technology but can certainly the effective use of modern technologies. The transition to an OBE model emphasises a learner-centred approach where individuals are expected to become central to the learning process (Schulze, 2003: 6-12) rather than the focus being the target of the content.

This study relies heavily on a constructivist approach in empowering learners to take ownership of the learning process by utilising the power of modern ICTs with a strong career guidance and entrepreneurial component. This should hopefully be able to add value to the spirit

of creativity and innovation. The availability of a broad range of commercial and open-source, freeware and shareware software solutions has expanded the options available for teachers to make more effective use of them in the classrooms across all the different subject and learning areas.

The introduction of YESA and the subsequent piloting of a range of interventions to address some of the above issues have identified the importance of massifying the project through the constitution of a national delivery vehicle. All NSI discussions should start with the SET pipeline from Grade 1. In this way one should be able to acknowledge the contributions of the formative years. In order for the pipeline to produce more learners with better qualifications in SET, it is proposed that these interventions should start working with learners from as young an age as is reasonably possible.

The following eight key concepts to be highlighted throughout the study include:

- Creativity and Innovation
- The Net Generation
- The Digital Divide
- Social Inclusion
- Constructivism
- 21st Century Skills development
- The National System of Innovation
- Human capital development.

2.1. Creativity and Innovation

Naiman (2007) defines creativity as the act of turning new and imaginative ideas into reality. Creativity involves two processes: thinking, followed by producing. Innovation is the production or implementation of an idea. If you have ideas, but don't act on them, you are imaginative, but not creative.

A more elaborate definition of the term *innovation* is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services (Harvard Business School Press, 2003: 2) . There are generally two types of Innovation: incremental innovation and radical innovation. Incremental innovation is generally understood to exploit the existing forms or technologies. It either improves upon something that already exists or reconfigures an existing form of technology to serve some other purpose. In this sense it is innovation at the margins. A radical innovation, in contrast, is

something new to the world, and a departure from the existing forms of technology or methods.

The terms break-through innovation and discontinuous innovation are often used as synonyms for radical innovation. More recently, Harvard professor Clayton Christensen has used the term disruptive innovation to describe a technical innovation that has the potential to upset organisations' or industries' existing business model. In almost all cases, these innovations are radical. Disruptive technologies displace the established technology and precipitate the decline of companies whose business models are based on them. In many instances, disruptive technologies create new markets (Harvard Business School Press, 2003: 3).

No other African country comes close to matching South Africa in even a single area of research and development (R&D). Based on a survey of recently published research papers, the country accounts for 64% of all research undertaken in Africa (Zachary, 2010). South Africa despite political transformations, has created opportunities for many professional and academic researchers to thrive. Yet the country has struggled to convert its stellar expertise into social and economic advantages—a troubling experience because millions of South Africans lack decent houses, reliable sources of water and electricity, affordable transport and household energy supplies.

The Johanna Solar Technology is an example what South Africans call their “innovation chasm,” or what the government’s Department of Science and Technology (DST) describes as “the gap between the local knowledge base and the productive economy.” The innovation chasm, represents a signal opportunity to respond by mobilizing and developing more of its “human capital”—the very South Africans who at once wish to raise their own professional standards and promote techno-scientific innovations that raise the living standards of a country where divisions between haves and have-nots, between rich and poor, stubbornly rank among the highest in the world, according to the State of the World’s Cities Report, released by UN Habitat in 2009 (Zachary, 2010).

The South Africa - Finland Knowledge Partnership on ICT Programme or SAFIPA (www.safipa.com) is a partnership between the Government of Finland and the South African Department of Science and Technology. The focus is an investment in research, development and innovation capacity which is critical to the successful building of a sustainable information society in South Africa both in a national and regional context. There are a number of innovative initiatives that are being funded by SAFIPA especially in e-education and e-health. Other examples of SAFIPA funded projects include the Nokia Maths Project which

deals with the issue of distance learning via mobile telephony; Virtual reality produced by the Naledi 3D factory concept; SAFIPA-Meraka Institute code-sprints program; and a mechanism to enhance the development capacity of emerging developers.

The establishment of YESA has provided an opportunity to encourage learners to allow their creativity to come to the fore, especially through the FabKids and Digital Kids programmes. The intention is to demonstrate that over a period of time it is possible to nurture this creative spirit to the point where individuals are able to see opportunities for incremental innovation and ultimately to move on to stimulate radical innovation in the different sectors in which they may find themselves. The My YESA Passport in one of the interventions that SAFIPA provided seed funding for.

2.2. The Net Generation

It is common to complain about the fact that kids no longer have activity hobbies, and, as they get older, how so few are interested any more in technical careers. These may have been temporary casualties of the digital revolution, artefacts of an overemphasis of bits over atoms, as young and old sat before their computer screens. Kids' toys emulate grown-up tools: a child's play with an erector set is not too far off from the work of an engineer (Gershenfeld, 2005: 251).

Throughout history, corporations have organised themselves according to strict hierarchical lines of authority. Everyone was a subordinate to someone else—employees versus managers, marketers versus customers, producers versus supply-chain subcontractors, companies versus the community. There was always someone or some company in charge, controlling things, at the "top of the food chain." While hierarchies are not vanishing, profound changes in the nature of technology, demographics, and the global economy are giving rise to powerful new models of production based on community-collaboration and self-organization, rather than on hierarchies and control (Tapscott *et al.*, 2008: 1).

These changes in society and the way children play should to be reflected in what happens in classrooms on a daily basis—if what goes on in the classroom is to be relevant to all learners exiting the education system, especially in the 21st century. Educators around the world are heatedly debating how to prepare students for living and working in the 21st century (Caspari *et al.*, 2007: 2).

Each generation has its own distinct set of values that is developed from the social environment in their early years. Different generations have different values and beliefs regarding

family, career, the work/life balance, training and development, loyalty, gender roles, the work environment and expectations of leaders (Jackson, 2010).

In 1997 Don Tapscott described those born after 1978 as the 'net generation', in 1999 Horst Opaschowski dubbed them the 'generation @', and in 2000 Neil Howe and William Strauss coined the term 'millennials' to refer to those born in 1982 and thus graduating from high school in the United States at the turn of the millennium. At the same time the successor to generation X was baptised generation Y. Since then, the terms 'generation Y', 'millennials', 'net generation' and 'internet generation' have been interchangeable. In 2001 Marc Prensky spoke of 'digital natives' and 'digital immigrants' and enjoyed a large amount of attention for rhetoric that was undefiled by the slightest brush with scepticism. In 2003 Rena Palloff and Keith Pratt used the characteristics of the net generation for their description of the 'virtual student'. In 2005 wife Diana and husband James Oblinger praised the net generation in Educause (Schulmeister, 2008).

We live in an era where the world is changing around us, and the current Net Generation—born after 1994—are growing up not knowing what life was like without technology. If the Net Generation values experiential learning, working in teams, and social networking, what are the implications for classrooms and the overall-learning environment? Brown (2005: 122), in dealing with learning spaces refers to these new classroom capabilities which have, in turn, sparked interest in new pedagogical approaches.

It is important to note that these approaches mesh well with educating the Net Generation habits of Net Gen students, such as their enjoyment of social interaction, their preference for experiential learning activities, and their use of technology. In these and other ways, technology acts as the lever that makes it possible to develop new and more effective pedagogies. Hence the classroom and the activities associated with it are evolving (Brown, 2005).

Alexander (2004: 26) summarized the requirement for change through the comments of a student: One student was saying that one should not be told the answer about the journey. He said that a learning journey should be one in which you don't know the answers until you yourself have thought about it, but that might not be the answer at all; it's just what you think at the time. The bottom line is this: if you understand the Net Generation you will understand the future. You will also understand how our institutions and society should change today (Tapscott, 2009: 11). The researcher was exposed to such learners from a variety of different school environments.

All parties associated with education today, including teachers, policy-makers, employees and parents in developing countries like South Africa have to take cognisance of this in order to bring about systemic changes in classrooms across the country. This has implications for the long-term economy of the country, as learners' progress into the real world to become economically active members of society.

There are, however, growing concerns about the hype of the net generation. Tapscott for instance is a prominent proponent of the Net Generation in many aspects of society. Bullen (2009) raises the question of the validity of the methodologies used in Tapscott's research indicating that because the results are not publically accessible they are not therefore verifiable and hence the questionable theoretical underpinnings for the claims made. Bennet, *et al.* (2008) eludes to the notion that not all learners arriving at tertiary educational institutions are said to have been immersed in technology all their lives.

With reference to this study the focus is more on the Net Generation per se as many of the learners were drawn from schools where learners would be classified into this category. On the other hand many learners were drawn from previously disadvantaged communities in Mamelodi, Atteridgeville and the Rustenberg areas and may not necessarily be classified into the Net Generation category due to lower exposure to technology.

Assuming a Net Generation perspective the paradigm of the teacher driving the knowledge bus has to change if the education system is to generate more effective knowledge workers for the future. The journey that the Net Generation are demanding implies that they want to dictate when and where they want to get on the bus; which route they wish to take; and in what sequence they want to undertake it. The starting point and end points of the journey are defined by the curriculum where it is assumed that the Net Generation utilise the resources available to reach their destinations and a different yet disciplined manner. The end goals remain the same, but the knowledge and life experiences gained by each individual may differ, depending on the technologies used, the social networks in which they participate, and the ways in which they construct meanings of the world in which they are growing up.

Within this research the researcher will highlight aspects of content generation for the Net Generation through the provision of opportunities to express their uniqueness. Added to this will be the use of ICTs amongst disadvantaged learners to enable them to share in the same opportunities. The principle followed that opportunities will be created to allow learners to find their niche beyond the digital divide, higher up the technological ladder, as part of

Human Capital Development (HCD) process. A more detailed explanation of the Technological Ladder will follow in articles 3 and 5.

2.3. The Digital Divide

Bridging the *digital divide* as early as possible has the potential to provide future economically active citizens with the necessary tools to cope with life in a technological world. It is imperative that a broad range of strategies be adopted to digitally include learners from both urban and rural communities, so as to ensure equal access to information and to unleash their creative and innovative talents, coupled to the promotion of e-literacy amongst the broader population. Certainly, the *digital divide* is not making the headlines in the way education, health, employment and crime do, but the researcher believes it has an underlying impact on all of these areas, and more (UK OnLine Centres, 2007).

Connecting people to ICT skills can connect them to new or better jobs, to new forms of communication and social interaction, to community infrastructures and government services, to information needed to help learners with their homework, to consumer power and convenience. It can save people time and money, open new doors and new worlds. Digital inequality matters because those without the right combination of access, skills, motivation or knowledge to make digital decisions are missing out in all areas of life. That does not just impact on individual lives, but on families, communities, on political processes, democracy, public services and the economic and social health of the nation as a whole (Milner, 2007).

Van Dijk (1999) distinguishes four kinds of access in the context of the *Digital Divide*:

1. *Insufficient digital experience* caused by a lack of interest, computer fear and unattractiveness of the new technology (psychological access)
2. *Insufficient computer and network connections* (material access)
3. *Insufficient digital skills* caused by insufficient user-friendliness and inadequate education or social support (skills access)
4. *Insignificant usage opportunities* (usage access) (Van Dijk, 1999: 23)

On the other hand, Norris (2001) sees the concept of the *digital divide* as one that needs to be understood as a multidimensional phenomenon encompassing three distinct aspects. The global divide refers to the divergence of Internet access between industrialised and developing societies. The social divide concerns the gap between the information-rich and the information-poor in each nation. And finally, within the online community, the democratic divide signifies the difference between those who do, and those who do not, use the panoply of digital resources to engage, mobilise, and participate in public life (Norris, 2001: 5).

This study will go on to propose an alternative to the *digital divide* which is often portrayed as a 'chasm.' This alternative is to view the situation as a technology ladder which makes it possible for learners to find their niche—ranging from access (first rung), to computer illiteracy (second rung), all the way up to ICT-enabled innovators at the top. This model will contextualize the ICT development strategy in order to feed the NSI process.

2.4. Social Inclusion

Helsper (2008) investigates the question of whether access to digital resources can promote social inclusion. If this is the case, it will be important for governments at all levels to support initiatives that promote digital inclusion. The research into these relationships is limited largely due to the complexity of unravelling what digital and social inclusion actually mean, and how they can be measured. Understanding the links between social inclusion and digital engagement can have an influence on implications for policy.

Although ICT has not created a parallel world into which one must leap at any cost, it has contributed to a profound change in the real world in which we live. While notions of cyberspace fade away, real-life applications of e-commerce, e-governance, and Internet-enhanced learning thrive. And while the current U.S. administration does not emphasise a *digital divide*, many governments around the world are stressing the importance of ICT for social inclusion (Warschauer, 2004: 12).

The shift from the focus on a *digital divide* to *social inclusion* rests on three main premises: (1) that a new information economy and network society have emerged; (2) that ICT plays a critical role in all aspects of this new economy and society; and (3) that access to ICT, broadly defined, can help determine the difference between marginalisation and inclusion in this new socio-economic era (Warschauer, 2004: 12). To achieve this in the long term, individuals at school level should experience the implications of this first-hand in order to be more in tune with the impact of social inclusion in the future workplace. Put simply, the seeds should be sown while learners are at school wherever possible and in whatever format.

Whitney (2007) refers to learners with Special Education Needs. These learners should be brought into mainstream education, as a part of social inclusion, but the researcher argues that mainstream learners can potentially also benefit from these encounters as part of a more holistic educational experience (Ben, 2007: 1).

2.5. Constructivism

Constructivism has specific implications for pedagogy. Firstly, it asks students to cope with very complex situations where the cognitive load is high. Perkins (1991: 19) explains that cognitive instruction aims to confront the learner with situations that make the inherent inconsistencies in the learners' native model plain and challenge the learners either to construct better models or at least to ponder the merits of the alternative models presented by the teacher. Therefore this conflicted path has very high cognitive demands. Complex situations are most effectively represented in authentic tasks, that is those that have real-world relevance and utility; are problem based and or related to community issues; draw on knowledge from across the curriculum; provide appropriate levels of complexity; and allow students to select appropriate levels of difficulty or involvement (Jonassen, 1991: 29).

Constructivism refers to a cluster of related views (radical constructivism, social constructivism, socio-cultural approaches, emancipatory constructivism, social constructionism). These all rest on the assumption that learning is an active process of constructing meaning and transforming understandings (Gravett, 2001: 18).

The key idea that sets constructivism apart from other theories of cognition was launched about sixty years ago by Jean Piaget. It was the idea that what we call knowledge does not and cannot have the purpose of producing representations of an independent reality, but instead has an adaptive function. This changed assessment of cognitive activity entails an irrevocable break with the generally accepted epistemological tradition of Western civilization, according to which the knower must strive to attain a picture of the real world. While the revolutions in the physical sciences in this century have led to the realization that such a picture seems impossible even according to physical theory, most philosophers hang on to the belief that the progress of science will somehow lead to an approximation of the ultimate truth (Von Glaserfeld, 2005: 3).

The theories and reasoning behind the constructivist views on learning have far-reaching implications on the methods and practices of teaching. The constructivist viewpoint sees the learner in quite a different light than that to which many of the traditional methods of teaching cater. According to the idea of constructivism, the individual plays a key role in actively constructing his or her own knowledge and understanding. In this way of thinking, information cannot be directly given to children and adolescents and put into their minds, but rather, they themselves need to discover knowledge through exploring their own world and thinking critically on the ideas presented to them (Schall, 2006).

If this is true for modern educators, then their job is much more than simply instructing children and passing information on to them. Instead, teachers should become facilitators and guides, rather than directors and moulders of traditional learning. They cannot force the information on their students, but rather they need to present the information to them and help them to explore and interpret it in their own way (Schall, 2006).

“If students can't learn the way we teach, we must teach them the way they learn”(Adams *et al.*, 2008: 19). This poses a real challenge for teachers to transform their methodologies to take into account the requirements of the generation of learners before them by applying a constructivist pedagogy. Understanding their requirements and the way they think and operate, while working in their digital world, should no longer be optional for a teacher in a developed or developing world.

The constructivist views, as influenced by Piaget, place the emphasis on the mental processes of individuals in meaning-making. An important proponent of this belief is Von Glasersfeld, whose view is termed *radical constructivism*. However, according to *social constructivists* (of which Vygotski was the father), the construction of individual meaning takes place in social contexts (Gravett, 2001: 20). Social constructivists therefore emphasise the roles of language, dialogue, and shared understandings (Schulze, 2003: 6).

Radical constructivism offers a radical break from the dualism of the positivist view, seeing perception and understanding as being part of a dynamic process. It also refutes the possibility of objective truth in any absolute sense, in that knowledge as a construction cannot be seen as something separate from the construer. However, this view raises the problem of the status of communication and of shared knowledge (Littledyke, 1998: 6).

Lundy (2007: 10) refers to the work of David Merrill who supports a more behavioural approach to instruction, discussing the basic assumptions that constructivists subscribe to in a 1991 *Educational Technology* article, “Constructivism and Instructional Design.” Lundy outlines this work as follows:

- Learning is constructed—people learn from experience
- Interpretation is personal—reality is not shared
- Learning is active—learners take an active role in developing knowledge through experience
- Learning is collaborative—conceptual growth comes from interacting with others and sharing multiple perspectives
- Learning is situated—learning should be placed in situations meaningful to students and relevant to the context in which the new information will be used

- Testing is integrated—testing should not be a separate activity, but integrated with the learning experience.

The lessons learnt from this have been applied by the researcher in the different projects reported on in this thesis.

One important missing issue in the main theories Behaviourism, Cognitivism and Constructivism is that none of them consider the educational technologies. That sounds obvious because only in the last four decades ICT was brought into the classroom and the main theories were developed long before the introduction of ICT, but what strikes is that the main theories seem to thrive by it just as a result of the use of these educational technologies (van der Zanden, 2009: 73). Connectivism as an upcoming learning theory supports such process-orientated knowledge-based acquisition on network learning behaviour. Students connect to persons and systems, thus treating them equally as virtual extensions, and use them for instant knowledge-on-demand when needed (van der Zanden, 2009: 75).

Though most of the discussions in this thesis will focus on the issues of Constructivism one must not lose sight of the importance of such concepts as Behaviourism and Instructivism. Behaviourism views knowledge resulting from a learning process whereas constructivism believes knowledge resulting from a natural consequence of a constructive process. The former considers learning as an active process of acquiring knowledge whereas the latter views learning as an active process of constructing knowledge. According to behaviourism, instruction is the process of providing knowledge, it may be said as 'instructivism', whereas for constructivism instruction is the supporting process in the construction of knowledge (Ahmed, 2009: 81).

2.6. 21st Century Skills

Education may be the most successful institution to emerge from the Industrial Age, First-world nations have thrived because they identified and employed effective strategies for educating the general populations so citizens were well prepared to succeed in the 20th century workforce and society. This strength may now become the downfall of education in these countries. The world is changing. Rapid advances in technology have changed the way services are provided and goods are manufactured. It's difficult, if not impossible, to find an industry that has not changed because of these advances, and many people now have access to myriad goods and services that didn't exist a decade ago. Experts predict that advances will continue to accelerate for at least the next ten to fifteen years. This growth will

continue to spur change in the worldwide workforce as economic globalization continues to spread (Brooks-Young, 2010: 5).

The world of Knowledge Age work requires a new mix of skills. Jobs that require routine manual and thinking skills are giving way to jobs that involve higher levels of knowledge and applied skills like expert thinking and complex communicating (Trilling *et al.*, 2009: 8). Preparing students for the workforce and being good, active participating members of society: that's what this is all about. It is about constant improvement (Oberg, 2004: 129). Children live in a global, digital world—a world transformed by technology and human ingenuity. Many of today's youngsters are comfortable using laptops, instant messaging, chat rooms, and mobile phones to connect to friends, family, and experts in local communities and around the globe.

Given the rapid rate of change, the vast amount of information to be managed, and the influence of technology on life in general, students should acquire different, evolving skill sets to cope and to thrive in this constantly changing society. These enGauge 21st Century skills can go even a step further. Advances in the cognitive sciences show that learning increases significantly when students are engaged in academic study through authentic, real-world experiences. The enGauge 21st Century skills build on extensive bodies of research—as well as on calls from government, business, and industry for higher levels of workplace readiness—to define clearly what students require in order to prosper in today's Digital Age (enGauge, 2003).

Trilling *et al* (2009) presents a similar set of 21st Century Skills, namely Learning and Innovation (Learning to create together), Digital Literacy Skills (Info-Savvy, Media-Fluent, Tech-Tuned) and Career and Life Skills (Work-Ready, Prepared for Life). Similar themes of Learning and Innovation Skills; Information, Media and Technology Skills; and Life and Career Skills are proposed by the Partnership for 21st Century Skills (2004).

Given the rapid growth in telecommunication Friedman's Flat World intimates that the world getting smaller, while being enhanced by technologies through the process of globalization. This raises the issues of an ever-increasing population being left on the wrong side of the *digital divide*, as new forms of collaboration are introduced. So schools had better make sure they are embodying these tools and concepts of collaboration into the education process to ensure that future citizens emerging from the educational process are better equipped. In order to succeed in a modern world an education system has to convey more than just information (Friedman, 2006: 315). It has to develop more learners with the right skills, attitudes and values to transform information and experience into knowledge. This process

requires an additional set of 21st century skills to be taught in the classroom—to enable learners to operate effectively in Friedman’s so-called *Flat World*.

2.7. National System of Innovation

Twenty-first century innovators do not need to behave like the Stone Age men who accidentally discovered fire. Scientists and technologists can now use existing knowledge and technology to generate new ideas and new products (Pandor, 2009a). In initiating a SET pipeline, the emphasis of the various interventions is on creating an Innovation Ecology. This is the work environment, a setting which can facilitate, encourage, foster, and catalyze the generation of ideas and the creation of values out of them. It supports individuals, teams, and the whole organisation in the journey towards sustainable growth and success that are based on on-going innovation (Dvir *et al.*, 2007).

As in a biological approach, Innovation Enabling Ecology in the work environment can facilitate, encourage, foster, and catalyse the generation of ideas and the creation of values out of them. It should ideally support individuals, teams, and the whole organisation in the journey towards sustainable growth and success that are based on the balanced portfolio of innovation—covering incremental, radical and disruptive innovation (Dvir, 2008).

This quite naturally assumes that an ecological approach allows for a process of interdependence, where the nurturing of the minds of the learners is enhanced through the interrelatedness of all contributing socio-economic, cultural, historical and other factors which are brought to bear on the child. The role of YESA is to engage the learners in this process—with the view to develop the feeder stock for the human capital needed for a NSI (Department of Science and Technology, 2009).

The “Innovate America” report identified the need for a new 21st Century innovation economy that focused on talent, the capacity to take risks, and the continuous renewal of an innovative infrastructure. Reports by the National Academy of Engineering and the Task Force for the Future of Innovation have all reached similar conclusions. Significant characteristics that must be addressed for industrial and societal competitiveness include: 1) the bar for innovation is rising; 2) innovation is diffusing at ever-increasing rates; 3) innovation is becoming increasingly multidisciplinary and complex; 4) innovation is becoming more collaborative, requiring thereby co-operation and communication among scientists and engineers, and also between creators and users; 5) workers and consumers are demanding higher levels of creativity; and 6) innovation is becoming global in scope, with mutual demands from centres of excellence and from consumers as well (Dismukes, 2005: 30). The

various interventions of YESA comprise an attempt to address these same issues by starting at the grassroots level with the intention of increasing the pipeline to feed the NSI.

Idea creation is no longer a question of finding a deep personal vision, where you dream of bringing forth new ideas. Idea creation is now a far more nomadic process that rests on seeing an opportunity in the moment and seizing it, long before you even know where the trail will lead. It is far more about being awake and alert, flexible and sensitive, than it is about being forceful and commanding. The well-worn advice of searching your soul for something you love to do may no longer be quite as relevant. It comes from a gardening mentality, and the new economy is the domain of hunters and gatherers (Tarlow *et al.*, 2002: 3).

The next logical step in the process is to go beyond idea creation. Using the Knowledge Funnel Concept Martin (2009) as depicted in Figure 1 creates a visual element that shows how knowledge progresses from mysteries to heuristics to algorithms. It all begins with a question at the top of the funnel, and at each stage transition, knowledge and execution can typically be transferred to lower cost labour (and possibly handled by a computer when they reach the algorithm level) (Kelley, 2010).

The Knowledge Funnel

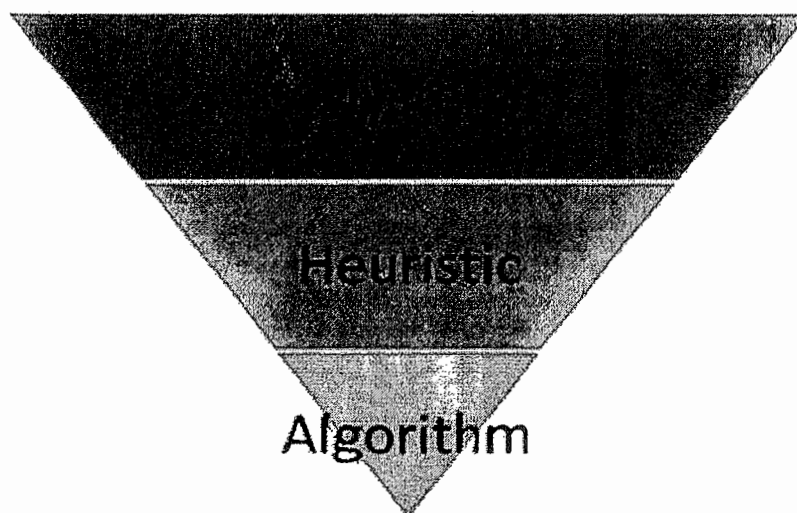


Figure 1: The Knowledge Funnel by Martin (Kelley, 2010)

Though this concept is set within the context of business it is of relevance in the HCD processes inherent in this research work as well.

The stimulation of a NSI will be central to the empowerment of all South Africans, as they seek to achieve social, political, economic and environmental goals. The development of

innovative ideas, products, institutional arrangements and processes will enable the country to address more effectively the needs and aspirations of its citizens. This is particularly important within the context of the demands of global economic competitiveness, sustainable development and equity considerations that are related to the legacies of our past. A well-managed and properly functioning NSI will make it possible for all South Africans to enjoy the economic, socio-political and intellectual benefits of science and technology (Department of Arts Culture Science and Technology, 1996).

There are a number of organisations that are operating in the NSI space. The objectives of the National Research Foundation (NRF), for example, are to support and promote research through funding, human resource development and the provision of the necessary research facilities, in order to facilitate the creation of knowledge, innovation and development in all fields of the natural and social sciences, humanities and technology. In doing so, it will contribute to the improvement of the quality of life of all the people of the country (National Research Foundation, 2009). Added to this, is the National Advisory Council on Innovation (NACI) which was created by legislation to advise the Minister of Science and Technology of South Africa, and through the Minister, the Minister's Committee and the Cabinet, on the role and contributions of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives (National Advisory Council on Innovation, 2009).

There are a number of school-based competitions which promote the spirit of innovation. The Federation of Engineering, Science and Technology Olympiads and Competitions (FESTOC) provides a management service for the various national Science, Technology, Engineering and Mathematics (STEM) Olympiads and competitions from Grades 1 to 12. The introduction of the *Digital Kids* and *Fab Kids* programmes as part of YESA has highlighted the prospects of adding value to FESTOC initiatives, such as the Eskom Expo for Young Scientists (<http://www.exposcience.co.za/>).

Key ingredients of these programmes include the nurturing of creativity and innovation through the adoption of a constructivist methodology within a non-traditional learning environment. These sessions have identified many talented learners who have gone on to compete effectively at international levels.

The production of PhDs features prominently among DST's priorities. Unlike capital equipment, including the most sophisticated of industrial machinery, you cannot get a PhD by completing an order form and passing it onto your procurement manager. The lead time for producing a PhD is protracted, even with the availability of high quality materials such as

good students, research mentors and supervisors. But once produced, a PhD adds value to our NSI by bringing in the services of a knowledge worker who possesses, amongst others, the potential to be an innovator and entrepreneur. To get closer to the realisation of this potential, there is a need for a major realignment of our applied sciences PhD curriculum to include innovation studies, technology management, product development, technology incubation, project management, and business management. This would produce a generally innovation-literate researcher, and contribute immensely to the strengthening of South Africa's competitiveness in the knowledge arena (Mangena, 2007).

Over the next ten years DST's innovation strategy aims to drive South Africa towards a knowledge-intensive economy, in which the production and dissemination of knowledge enriches all fields of human endeavour. This is not the time to cut back on South Africa's investment in the future. It's the time to invest in key sectors where South Africa is well placed to lead. Our policy is to protect and promote our investment in science, to make it easier for students and entrepreneurs to exploit their patents and to form companies, and to provide a regulatory regime in which enterprises find it beneficial to market their ideas. Our future growth—more jobs, greater wealth—lies in increased research and development, developing new patents and trademarks, and developing new technologies for transforming traditional industries (Pandor, 2009b).

To increase capacity in the PhD pipeline it is necessary to return to the source and make a long-term investment from an early age in order to grow the human capital feeder stock. YESA is the start of such an initiative, and it will feed into the South African government's awareness of the requirement needed to stimulate entrepreneurship, innovation and growth amongst knowledge-intensive businesses.

Science and technology education, innovation and commercialisation are integral components of our NSI. The key challenges are adequate funding, skilled human resources, improved private sector R&D, protecting and exploiting intellectual property, and integrating a fragmented government science and technology system (Comins, 2009).

Baskaran and Muchie (2006: 238), in a study involving Innovation Systems for ICT in Brazil, China, India, Thailand and Southern Africa, have shown clearly that the context of the NSI, whether it exists in a weak, strong, bifurcated, lopsided and uneven way, or whether it is in a state of birth, emergence, consolidation, maturity or decline, has serious consequences on the manner in which ICTs are created, appropriated, diffused and used in many of the economies. For the economies in the developed world, ICT develops as industrial sectors and promotes economic growth which is essential for daily life and society. It has become

central to the existence and reproduction of society, economy and various institutions. This reinforces the notion of learners being encouraged to go beyond the confines of computer literacy, as well as the school curriculum, in order to become highly sought-after ICT practitioners and innovators.

2.8. Human Capital Development

In order to comprehend the essence of this research, it is necessary to place the emphasis on the nature of human capital. O'Sullivan and Sheffrin (2003: 5) refer to *human capital* as the stock of competences, knowledge and personality attributes embodied in the ability to perform labour so as to produce economic value. Human capital comprises the attributes gained by a person through education and experience. The development of a Human Capital and the knowledge base is one of the National Advisory Council on Innovation's (NACI) five strategic thrusts, together with the necessary infrastructure for innovation, competitiveness, the social dimensions of innovation, and NACI's position, role and functioning in the NSI (National Advisory Council on Innovation, 2006).

This has to be viewed within the context of the White Paper on Science and Technology – Preparing for the 21st Century (Department of Arts Culture Science and Technology, 1996) specifically within the establishment of EduNet and the effective use of ICTs in promoting human capital.

Innovation, on the other hand, is considered as one of the most important factors enabling organizations to effectively compete (Christensen, 1997). It is this factor that the researcher believes is initiated during the formative years and should be nurtured from a grassroots level, since it is not something that can be 'taught' at a higher level. In essence, it needs to be embodied in the SET pipeline designed to feed the NSI.

3. Research Aim, Objectives and the Purpose of this Study

The main purpose of this research will be focused on establishing 'proof of concept' for all the different interventions. In essence, there were many lessons learnt by the researcher based on experiences in a constructivist environment. These experiences could influence the methodologies of the future YESA interventions. These experiences included local and international experiences, such as the Formula One in Schools Project and other international projects, such as the World School Forum and the International Student Project for Gifted Children. These could all be brought to bear on education *within a South African context*.

This has to be contrasted with the under-resourced schools in South Africa in which YESA is mandated by the Meraka Institute to operate. It is anticipated that the types of problems to be encountered will focus more on the human side (*warmware*) issues of administration, getting permission to proceed, and obtaining the buy-in from the teachers. This is expected to be in stark contrast to the willingness on the part of the learners to actively engage in the new learning process.

The main problem to be investigated is how a SET pipeline for Science, Engineering and Technology at school levels can be established that can initiate human capital development from an early age where ICT will form an integral component.

In a post-apartheid society South Africa, meeting the requirements of the people cannot be solved simply by throwing money at the problem. To bring about effective social transformation is a complex process involving the management of many variables. This study will focus largely on learners in the educational sector. The problems that were identified as influencing the direction of the investigation included:

- Gearing teachers up to adapt to the new demands and expectations of teaching in a digital age
- Teachers with low or no educational qualifications, especially in the science and technology fields
- Poor quality of teachers in township and rural areas
- Low penetration rates for technology in schools
- Low emphasis of creativity and innovation and other 21st century skills in schools—even within the newly introduced OBE system
- Learners being ill-prepared for life in a technological world.

This study will have the following key objectives:

- To investigate a small-scale intervention into digitally-including remote learners in geographically separated virtual classrooms
- To conceptualise a multi-layered approach for the provision of a range of community-focused solutions—on top of a communications network infrastructure
- To conceptualise an alternative educational model which highlights the similarities and the differences between teachers and learners, where ICTs are used in the classroom
- To pilot a *FabKids* intervention, which utilises a rapid-prototyping environment to promote creativity and innovation, and

- To pilot a Digital Kids intervention, within the context of Technology Clubs that focuses on the development of digital literacy amongst learners using open source software.

3.1. Main Research Question

How can technology in education promote creativity and innovation for human capital development at school level to teleport more learners up the technological ladder?

3.2. Sub-questions

The following sub-questions are based on the main research question:

1. What are the implications for using broadband communication technologies to digitally link two geographically separated classrooms?
2. How can the development of a new educational model assist in identifying the complexity of the learning environment needed to inform teachers of the diverse nature of an ICT-enabled classroom?
3. What are the implications for human capital on the development of a multi-layered solution to address the requirements of rural communities?
4. How can a rapid-prototyping environment be used to stimulate human capital development, creativity and innovation?
5. How can digital literacy be taught as part of Technology Clubs at schools?

4. Research Design and Methodology

The contrasting of ontological and epistemological models of humankind all demand different research methods. Investigators adopting an objectivist (or positivist) approach to the social world—and who treat it as if the world of natural phenomena were hard, real and external to the individual—will be obliged to choose from a range of traditional options: surveys, experiments, and the like. Others, favouring the more subjectivist (or anti-positivist) approach and who view the social world as being of a much softer, more personal and man-created kind, will be required to select from a comparable range of recent and emerging techniques—accounts, participant-observation and personal constructs (Cohen *et al.*, 1985: 8).

The field of education lends itself to both quantitative and qualitative research. The research methodology followed in this study was influenced to by the nature of the data and the research problem. Qualitative research methodologies are methodologies dealing with data

that are principally verbal, while quantitative research methodologies are those dealing with data that are principally numerical (White, 2005: 80). It could be said that all science is organized around two activities: measurement and interpretation.

Social researchers measure aspects of social reality and then draw conclusions about the meaning of what they have measured (Babbie *et al.*, 2007: 2).

4.1. Design Research

Design research was the main methodology adopted for this research. Design research (Bannan-Ritland, 2003; The Design-Based Research Collective, 2003; Kelly, 2003), also known as *development research* (not *developmental*) by van den Akker (1999), has the following characteristics:

- The focus is on broad-based, complex problems critical to higher education
- The integration of known and hypothetical design principles with technological affordances to render plausible solutions to these complex problems
- It requires a rigorous and reflective inquiry to test and refine innovative learning environments, as well as to reveal new design principles
- Long-term engagement involving continual refinement of protocols and questions
- Intensive collaboration amongst researchers and practitioners
- A commitment to theory construction and explanation, while at the same time solving real-world problems (Reeves *et al.*, 2005).

Barab and Squire (2004) broadly define educational design research as "a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings." Further clarification of the nature of design research may be helped by a specification of what it is *not*. The most noteworthy aspect is probably that design researchers do *not* emphasise isolated variables. While design researchers do focus on specific objects and processes in specific contexts, they try to study those as integral and meaningful phenomena. The context-bound nature of much design research also explains why it usually does not strive towards context-free generalisations.

Design is a complex activity, involving artefacts, people, tools, processes, organisations and the environment in which this takes place. Design research aims at increasing our understanding of the phenomenon of design in all its complexity and at the development and validation of knowledge, methods and tools to improve the observed situation *in design*. A de-

sign research methodology should help in identifying research areas and projects, and in selecting suitable research methods to address the issues (Blessing *et al.*, 2009: vii).

Lunenfeld (2003: 10-11) suggests that in the Design Cluster, pluralism and serendipity define ways of thinking by, with and through the idea of design research. Design research can fashion singularities that will allow theory to morph into practice and come back again through the wormhole—as something entirely new. Design research creates a place to braid theory and practice to make the work stronger.

It establishes a demilitarized zone between makers suspicious of discourse and critical intelligence disdainful of the negotiations between designer and client. Design research is a method of invention that sides with finding out rather than finding the already-found. Design research is not inherently good, nor is it inherently bad, but that doesn't mean it's neutral either. Obviously, design research will draw polling methodologies of the social sciences and the niche analysis of marketing surveys when it is appropriate (Lunenfeld, 2003: 10-11).

For the researcher the application of design research was not about the design process of a single stand-alone object, but rather about the integrated system (Lunenfeld, 2003: 10-11) that was to prove more important. The research highlighted the importance of dealing with human capital development—not just as a single isolated entity—but one that should focus on a much broader approach to cater for a diverse range of skills development. Examples of this would include promoting digital literacy versus computer literacy, promoting creativity and innovation versus information transfer, targeting whole communities versus single entity projects.

The use of a combined quantitative and a qualitative approach assisted in making use of the different strengths and weaknesses of each to complement each other. In most cases, researchers fall into one of the two camps—either relying exclusively upon "objective" survey questionnaires and statistical analyses, while eschewing warm and fuzzy qualitative methods, or using only qualitative methodologies, rejecting the quantitative approach as decontextualizing human behaviour. However, social marketing researchers recognise that each approach has its positive attributes, and that combining different methods can result in gaining the best of both research worlds (Weinreich, 2006).

4.2. Population and Sample

For the purposes of this research, schools in the greater Tshwane area were used. The primary target was the senior grades from Grades 8 to 12 and included learners from other

grades, as well as some learners with learning difficulties. The selection of the schools included private and government schools in Pretoria, Mamelodi and Soshanguve. In terms of the gender issues, roughly an equal number of male and female students participated, where the selection of the learners was left entirely to the schools that were invited to participate.

Some of the work was conducted in a traditional computer laboratory environment, while other research was moved to the Fabrication Laboratory environment based at the Innovation Hub in the Pretoria and Soshanguve areas.

4.3. Data Collection

An elementary questionnaire was used to identify simple frequency counts from the sample population, taking into consideration such variables as race, age and gender. The researcher personally administered and analysed the data gathered. A copy of the Questionnaire used can be found in Addendum A.

Permission to use schools based in the Gauteng Province was obtained from the Gauteng Department of Education. A copy of this approval can be found in Addendum B

Table 1 represents the data collection matrix used in this research covering all 5 articles.

Table 1: Data Collection Matrix

	The Ulwazi Concept	The Hub School Concept	5 Dimensional Education	Fab Kids	Digital Kids
Questionnaires	X			X	X
Participant observation	X		X	X	X
Interviews	X			X	X
Focus Group				X	X
Document Analysis					
• Technical Report	X	X	X	X	X
• National Policies	X	X	X	X	X
• Reference Material	X	X	X	X	X

4.4. Data Analysis

The research methodology used was adopted with a greater emphasis on qualitative investigations to produce low-level analysis in terms of frequency counting to highlight basic trends. The intention was to establish a proof of concept for the various interventions with the express view of creating a massification strategy for YESA as a national delivery vehicle. One of the goals of YESA is the establishment of Technology Clubs at various schools to supplement the traditional education curriculum spelt out in the National Curriculum Statements (NCS).

4.5. Paradigms

How one sees the world is largely a function of where you view it from, what you look at, what lens you have used to help you see, what tools you use to clarify your image, what you reflect on and how you report on your world to others. Thus, an empirical researcher will see only those things which are conveniently measured in empirical ways. A sociologist will only be concerned with patterns affecting groups and will have little chance of learning about individual motivations—except as they relate to group behaviour. The behaviourist will focus on reporting and controlling behaviours, whereas the anthropologist's concern will be on the underlying meanings of phenomena (Anderson *et al.*, 1998: 3).

Thus, research reflects the values, beliefs and perspectives of the researcher. This is not the same, however, as saying that research is subjective. For valid research, similar approaches should lead to similar conclusions, but different approaches can hardly be expected to lead to exactly the same conclusions. These different approaches cannot be expected to ask the same questions, let alone realise similar answers. Thus, few researchers are truly unbiased or value-neutral, obviously carrying a baggage of beliefs, assumptions, inclinations and approaches to reality (Anderson *et al.*, 1998: 3).

According to Burrell and Morgan (1979: 22-23), the functionalist paradigm views the social world as consisting of concrete artefacts and relationships that can be identified, studied and measured through natural sciences from an objectivist point of view. The interpretive paradigm is concerned with understanding the world as it is. Interpretivism views the social world from the subjective experiences of individuals. The radical humanist paradigm also views the social world from an ideographic perspective, as does the interpretive paradigm, but the frame of reference focuses on overthrowing the limitations of existing social structures.

complete a PhD through this institution and was once again required to seek ethical clearance (Addendum D).

The Ethics Clearance covered aspects of willingness, informed consent, etc. The participants were asked to sign an informed consent form before any interventions were conducted and were to be allowed to withdraw from the study at any time, though none did so.

6. Presentation of this Research

This thesis does not follow a traditional thesis format, but is presented as a series of five journal publications submitted to and published in internationally accredited journals. Each article was compiled as a stand-alone publication, containing its own domain of new information. This broad research introduction poses the overarching research question of whether it is possible to establish a pipeline for Science, Engineering and Technology at school levels that can initiate human capital development from an early age where ICTs form an integral component of the education process. Each of the sub-questions were addressed through the relevant articles. The following is the initial framework for the planning of the five articles presented in this thesis (Table 2).

Table 2: Planning of Concepts Unpacked in the Articles According to the Different Projects

	The Ulwazi Concept (Article 1)	The Hub School Concept (Article 2)	5 Dimensional Education (Article 3)	Fab Kids (Article 4)	Digital Kids (Article 5)
Digital inclusion	X	X			
Virtual classrooms	X	X			
Social transformation	X	X			
Interactive Whiteboards	X	X			
Net Generation	X	X	X	X	X
Digital literacy				X	X
Digital Natives and Digital Immigrants	X	X	X	X	X
National System of Innovation		X		X	X
Personal fabrication				X	
Authentic learning				X	X
Educational Models			X		
Rapid Prototyping				X	
Team work				X	X
Technological Process				X	
Learning theories			X	X	X

6.1 Preliminary Structure of Articles

This section lists the five articles presented in this thesis as a body of contributions to the long-term impacts on a number of key national interventions at a macro-level (as mentioned in section 2.0 above), as well as providing an understanding of how teachers and learners can make better use of ICTs in the classroom at the micro-application level for the promotion of 21st century skills.

Article 1: The Ulwazi Concept – Virtual Interactive and Collaborative Classrooms of the Future

The focus of this article is to report on a project which was initiated in 2001 as an outreach project between St Alban’s College, a private school on the eastern side of Pretoria and Ga-tang Comprehensive School in Mamelodi, a local township more than fifteen kilometres away. Virtual interactive classrooms were established to digitally include learners from remote classrooms using broadband radio connections, SMART Interactive Whiteboards, microphones, speakers and web cams to create a common digital interactive curriculum inter-

face. By using these technologies, it was demonstrated that learners in geographically separated classrooms could be digitally included in science lessons and experiments.

Article 2: A Five-Dimensional Model for Educating the Net Generation

The purpose of this article is to introduce a philosophical model of education to comprehend the complexity of teaching/learning environments, especially where ICTs are introduced. The model will motivate the need to view education as a five-dimensional environment, where each level has a different set of key characteristics which all take into account the differences of the net generation. This article will go on to propose the development of a tool to plot where learners are located within the model and compare this with where the teachers assume them to be. Understanding what these differences are may help the teachers to better manage the effective use of technologies in their subject environment.

Article 3: Extending the Education and Social Benefits through 'Hub Schools'

It is not always economically viable to deploy resource-hungry facilities to many schools in a single community. This article proposes the use of a Hub School Concept to extend the effectiveness of an investment to the wider community to include more participants. A number of Meraka Institute-based innovative projects and other technologies are included to establish the layering of additional services on top of an established radio network to facilitate a range of e-services. Based on the experience of the FabKids project, this may provide for the demonstration of such concepts as digital manufacturing.

Article 4: Nurturing Creativity and Innovation through Fabkids—A Case Study

The Young Engineers and Scientists of Africa (YESA) project was incubated within the Meraka Institute over a period of three years. During this time, the FabKids projects emerged as a key component to enable learners to express their creative and innovative talents within the high-tech rapid-prototyping environment of a FabLab. This article will report on a pilot project that was conducted which highlighted the requirements needed to massify the process to more schools across the country as an integral component in expanding the FabLab concept.

Article 5: The Broader Issues of Introducing a Digital Kids Programme

21st Century skills development includes Digital Literacy, High Productivity, Effective Communication and Inventive Thinking (enGuage, 2003). The Digital Kids programme caters for

the development of all these skills, while using Open Source, Freeware and Shareware software, where available, within Technology Clubs as extra-curricular activities. Topics covered included the development of 2D/3D graphics and animations to video-editing, Wikis, Blogs and the introduction of Fischer-Technik technologies, etc. This article will report back on a pilot project that was conducted under the banner of YESA.

The articles have been submitted to internationally accredited journals, primarily in the field of education. The status of the five articles as reflecting on the submission of the thesis is reflected in Table 3. The articles are also available on the compact disc in electronic format.

Table 3: Status of the Articles Submitted to National and International Journals

Title	Journal	Status at time of Thesis submission	Addendum	Permission to Reprint
The Ulwazi Concept –Virtual Interactive and Collaborative Classrooms of the Future (Beyers, 2007)	South African Journal of Higher Education, 21(6):748-760	Published	Addendum E	Addendum J
A Five-Dimensional Model for Educating the Net Generation (Beyers, 2009)	Journal of Educational Technology & Society, 12(4):218–227	Published	Addendum F	Addendum K
Extending the Education and Social Benefits through 'Hub Schools' (Beyers, 2010a)	Progressio: South African Journal for Open and Distance Learning, 32 (1):74-93	Published	Addendum G	Addendum L
Nurturing Creativity and Innovation through FabKids — A Case Study (Beyers, 2010b)	Journal of Science and Technology.04 March 2010	Published	Addendum H	Addendum M
The Broader Issues of Introducing a Digital Kids Programme	Journal of Science and Technology	Submitted – 17 March 2010 Resubmitted 02 April 2010	Addendum I	

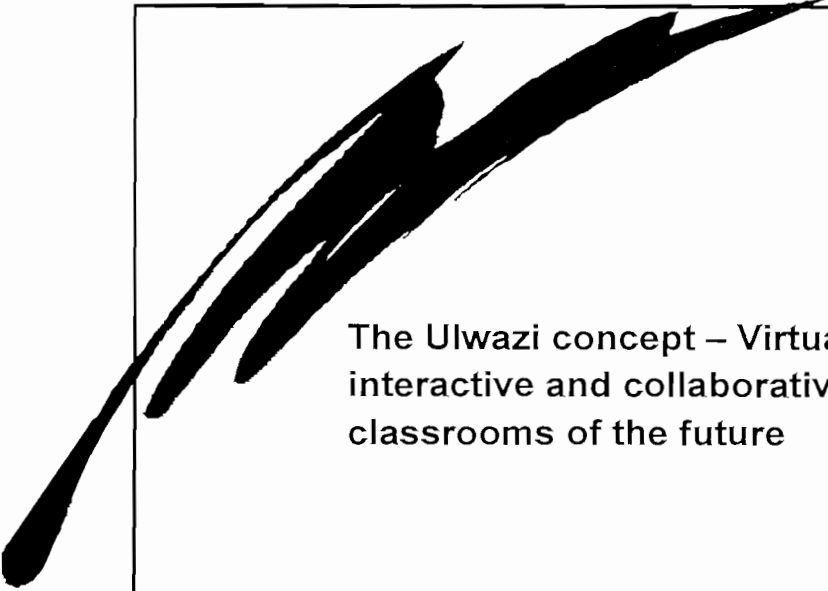
Each journal imposes a different format and writing style, with a limit to the number of words and the extent of reference citations, according to the journal article's prescribed formatting style. For the published articles, these were retained—as the copyright of the articles no longer resides with the researcher. Permission to use those articles published at the time of submitting this thesis is included in Addendum J, K and L. The final article under review is presented in a style in accordance with the journal it was submitted to. The articles listed are not necessarily in the order in which they were submitted to the respective journals, but are arranged in an order to represent a logical progression of thinking. They form the tools and framework required to create the enabling environment of YESA.

The synopsis, reflections and contributions conclude this thesis in dealing with the analysis and recommendations of the study through a meta-analysis of the articles, the value of the study and the personal reflections of the researcher.

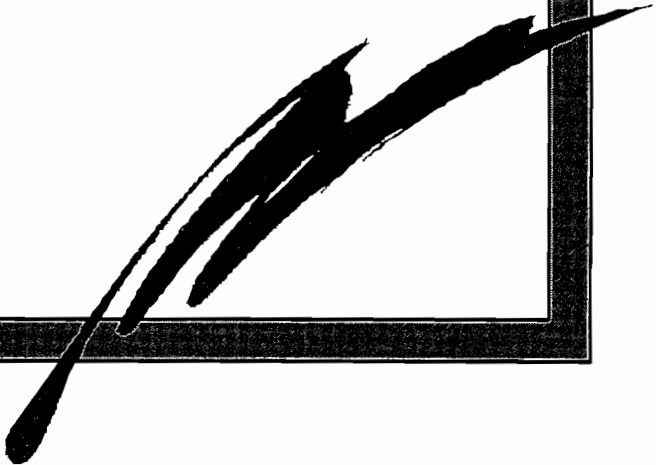

The addressing of the sub-questions will be highlighted through the different articles presented in Table 4.

Table 4: Listing of the Research Sub-questions and the Articles that Address these Questions

Sub-question Number	Question Addressed in Article
1. What are the implications for using broadband communication technologies to digitally link two geographically separated classrooms?	Article 1 The Ulwazi Concept—Virtual Interactive and Collaborative Classrooms of the Future
2. What are the implications for the development of a multi-layered solution to address the requirements of rural communities?	Article 2 A Five-Dimensional Model for Educating the Net Generation
3. How can the development of a new educational model identify the complexity of the learning environment to inform and provide practical experience thereof to the teacher of the diverse nature of an ICT-enabled classroom?	Article 3 Extending the Education and Social Benefits through 'Hub Schools'
4. How can a rapid-prototyping environment be used to stimulate creativity and innovation?	Article 4 Nurturing Creativity and Innovation through Fab-Kids—A Case Study
5. How can digital literacy be taught as part of Technology Clubs at schools?	Article 5 The Broader Issues of Introducing a Digital Kids Programme



The Ulwazi concept – Virtual
interactive and collaborative
classrooms of the future



The Ulwazi concept – Virtual interactive and collaborative classrooms of the future

R. N. Beyers

Council for Scientific and Industrial Research
Pretoria, South Africa
e-mail: rbeyers@csir.co.za

Abstract

The purpose of the study was to demonstrate that two schools which were geographically separated could be digitally included using broadband radio connections, interactive whiteboards and other technologies to enable virtual interactive and collaborative lessons. The project was established to overcome a transport problem of bussing learners from Mamelodi to St Alban's College in the Tshwane area as part of an outreach project for them to receive supplementary tuition. The most significant finding was that the results of Grade 10 Science learners in a remote school improved over time.

INTRODUCTION

The Education Minister Naledi Pandor reiterated that: 'It is our view that proficiency with, and understanding of, information communication technologies should join reading, writing and arithmetic as one of the basic learning processes' (*Sunday Times* 2006),

The Minister went on in the same article to state that: 'I believe the task of bridging the digital divide is a crucial challenge because information technologies are emerging as the key driver of economic growth and social development. Failure to bridge the divide leaves those without access to information communication technologies in a developmental cul-de-sac.' This is further compounded by the fact that a significant number of schools do not have access to electricity as a basic requirement, let alone other infrastructure such as toilets or even text books.

Director-General Duncan Hindle (2005) also highlighted that reports of significant absenteeism on the part of teachers in some communities with pay-day syndromes and in some case extended absence without consequences, has a demoralizing effect on the educational community leaving the learners ill prepared for examinations and the lack of a culture of learning in general. Thirty one schools across South Africa did not have

a single matriculant pass in the 2005 senior certificate examination, while another 148 schools obtained a pass rate of below 20 percent, which, although down from 2004's figure of 183 was cause for concern and remained at an 'unacceptable level'.

To add further woes to the developmental cul-de-sac Seepe and Sibanda, (2006) in a recent study by the Human Sciences Research Council that was commissioned by the education labour relations council last year indicated that a minimum of 10 000 teachers living with Aids urgently need to be put on antiretroviral drugs. The Aids endemic in South Africa could see a growing number of classes losing out on a basic level of education because teachers are dying on a daily basis compounding the problem of a lack of delivery in the educational sector.

The South African Education Department has produced a modern Outcomes Based Education curriculum which assumes that the approximately 12 million students have access to quality educational resources and highly qualified teachers. There can be little doubt that the current educational sausage factory is merely perpetuating an old paradigm where the vast majority of learners are being exposed to pure information transfer and regurgitation of factual information. The benefits that modern Information Communication Technologies (ICTs) have to offer is restricted to a minority of learners and even where there are computer centres these are clogged up with Computer Studies learners. Those learners who are provided access are therefore restricted to single lessons which may in some cases be once every two weeks.

THE PROBLEM IDENTIFIED

Over the past few years there have been a growing number of schools who have been willing to share their expertise and resources with those less fortunate than themselves. Whatever the motives of the well resourced institutions, many teachers and learners across the country have benefited from such interventions covering a wide range of subject areas. There were a variety of interventions ranging from extra lessons and training sessions in the holidays, etc. but the primary method of making contact was based on bussing learners and teachers to city school campuses.

St Alban's College, located on the eastern side of Pretoria, was one such organization where a number of interventions were arranged to meet the needs of the Mamelodi and Atteridgeville Communities. Mnguni (2006) reported that he Top Matric project bussed students to the campus for Mathematics, Science, English and Biology five days a week. This project produced a total of 107 students out of 126 who passed the Senior Certificate 2005 examinations. Fourteen A aggregates were obtained in the four subjects (i.e. English, Mathematics, Biology and Physical Science). In previous years some of the students who attended the outreach programmes on the College campus received tuition in certain subjects as their only form of formal lessons due to the absence of subject teachers in the township schools.

Apart from the fact that the supplementary tuition which these students received, it came at a huge price. Many students could barely afford the course fees but more

importantly they were prepared to sacrifice many hours spent travelling the 15 to 20 km to receive an education. Their desire to be given access to better education outweighed the personal sacrifices they had to make.

The problem statement: Geographically separated classrooms linked by broadband radio connections to enable virtual interactive and collaborative lessons using SMART technologies (<http://www.smarttech.com/>) can provide a platform to explore solutions to digitally include remote learners.

The type of research for this intervention was based on a qualitative approach to this case study. The participating schools were selected on the basis of their long standing relations with St Alban's College. Data collections were based on interviews and observations which were conducted during the lessons.

THE BIRTH OF THE ULWAZI CONCEPT

In April 2003 a workshop was held between Richard Gerber from the Department of Communications, Leslie Hlengani and two pupils from Gatang Comprehensive, Ron Beyers and three pupils from St Alban's College. The meeting discussed theoretical possibilities of digitally connecting two classrooms and by chance Ronnie Seeber from Motorola South Africa happened to drop in.

The outcome of the meeting was a proposal to deploy a broadband Motorola Canopy network between the two schools which were situated 15 km away. A formal proposal was submitted to Independent Telecommunications Authority of South Africa (ICASA) and eight months later the Ulwazi project was given a three month temporary licence to transmit lessons. Application was made to renew the licence on a regular basis thereafter.

Technically the creation of the virtual interactive and collaborative classrooms was based on the deployment of the following equipment in each venue:

- Motorola Canopy – providing 11 Meg Broadband wireless connectivity
- SMART Interactive Whiteboards – providing the digital interface for the curriculum and other interactions
- 5 Channel sound card and speakers – to be able to hear lessons delivered
- Web Cam – to be able to see each other
- Microphone – to enable voice communications
- NetMeeting – standard on all Windows Platforms to facilitate the video conferencing.

The Motorola Canopy operates in the frequency band 5.725-5.875 GHz, that is allocated globally, in the ITU Table of Frequency Allocations (ITU Radio Regulations 2003) for use by industrial, scientific and medical (ISM) equipment. The band was originally opened up by the FCC (Federal Communications Commission) in the USA for so-called Unlicensed National Information Infrastructure (U-NII) devices (FCC Report

and Order No FCC 97-5 1997), of which Canopy is an example. The band in the US is for shared-spectrum use and there is no requirement for doing frequency coordination for telecommunications equipment, neither by the user or the telecommunications regulator. However, the equipment needs to meet certain technical criteria, such as maximum levels of radiated power. This shared, uncoordinated and unlicensed use has been so successful that this ISM band has now come into use for telecommunications in many other countries.

To overcome the requirement of direct line of site, Lynnwood Ridge Shopping Centre had to be used as a relay station between the valley in Lynnwood Glen and the township of Mamelodi. Using a combination of Access Points and Subscriber modules, a broadband radio communications network was established between two classrooms which was donated by Motorola. Seed funding in the amount of R44 000.00 from the Department of Communications provided the means to equip the second classroom and to provide for the development of the initial web based learning materials. See Figure 1 for a schematic representation of the Ulwazi network.

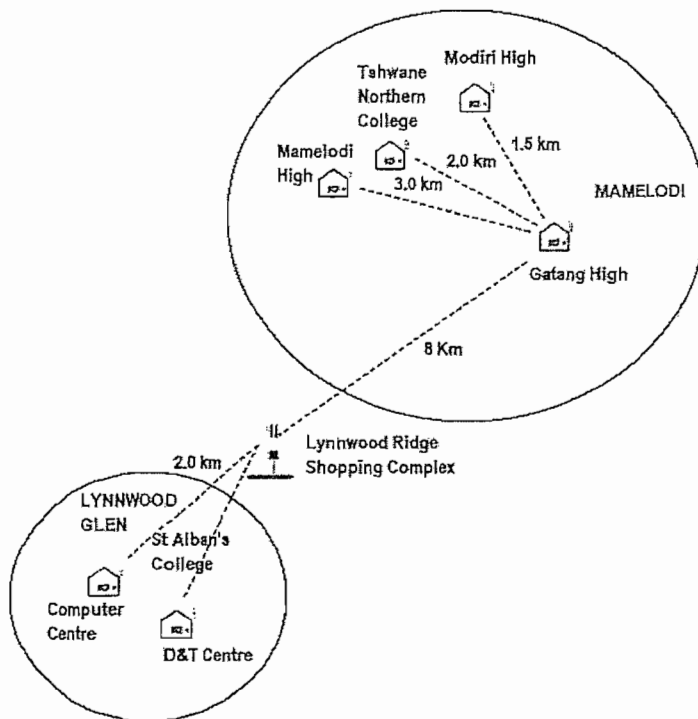


Figure 1: A schematic representation of the Ulwazi Network Diagram

The initial aim of the project was to demonstrate that it was technically possible to connect two schools using a wireless broadband backbone. Lessons were delivered to students at Gatang on a weekly basis as supplementary education where each group of approximately 30 students were invited once every three weeks in order to increase the exposure of the educational approach to more learners.

It soon became evident that the learners readily adopted the extra lessons even though they were voluntary. Application was made to the Motorola Foundation for US\$30 000.00 which enabled the project to be expanded to Mamelodi High, Modiri High and Tshwane North College. A server was also added to the network to enable the Ulwazi Project Web Site (www.ulwaziproject.co.za) material to be shared by the local community as the IP based network operated as a closed loop with no external internet access.

In describing the Ulwazi Concept, it is based on the following principles

- A community that is ready to adopt technology to help uplift its members
- A champion from the community who will coordinate and drive the project
- Connecting of schools and homes in a local geographical area which can provide the benefits of a connected learning community (Connected Learning Communities 2007)
- Broadband with greater than 5–10 Meg interschool connectivity which is preferably IP based
- Access to 'video conferencing' equipment that can facilitate virtual interactivity and collaboration
- Access to shared resources
- Options of providing email and internet access.

Pinder (2004) emphasises that: 'digital inclusion is not about computers, the internet or even technology. It is about using technology as a channel to improve skills, to enhance quality of life, to drive education, and to promote economic well-being across all elements of society. Digital inclusion is really about social inclusion, and because of this, the potential for technology to radically improve society and the way we live our lives should not be underestimated.' To put this into perspective, the total cost to the employer for running the project in terms of man power was virtually zero. The reason for this was that during the normal course of the week extra lessons for the fee paying students at St Alban's College were available. Through a process of digitally including the learners from Mamelodi there were no additional expenses in terms of man hours as well as no 'transmission time' costs usually associated with satellite connections.

A suitable definition of the Ulwazi Concept could be reflected in 'Connecting geographically separated schools using wireless broadband technologies to enable remote and interactive teaching and learning'.

SOME OUTCOMES OF THE PILOT PROJECT

The advantages of digitally including additional classes were astounding and included:

- More 'cost effective' use of the presenter's time whereby the learner to teacher ratios were increased
- Quality education was available to both groups of learners
- Both groups of learners reported that they felt included in the lessons
- High levels of virtual interactions were achieved
- The SMART Interactive Whiteboards provided an invaluable digital curriculum interface
- Lesson material that was developed after hours, including animations and clip art, was able to capture the imagination of both groups of learners and delivery of captivating lessons
- A 'hidden curriculum' provided a cultural bridge for learners on opposite sides of the digital divide to meet and exchange ideas
- Many concepts embedded in the teaching of computer skills were smuggled in the lessons without the learners being aware of it.

What started out as a simple connectivity project has provided an invaluable proof of concept that it is technically possible to use broadband wireless connections linking two virtual interactive and collaborative classrooms which are geographically separated. The exciting part of the exercise is that the Ulwazi Concept has evolved into some form of social transformation process with further potential for not just the classroom environment.

TRANSFORMATIONAL OUTCOMES

This paper focuses mainly on the pedagogical aspects of the Ulwazi Concepts which certain aspects of social transformation were also noted. Although the project did not set out to measure the effect of the impact in any way as the main focus was on connectivity, Hlengani (2005) in an interview reported that there were improvements of up to 15 per cent in the Science results of many of the students attending the extra lessons in comparison with other learners in the same grade. These results were attributed to the application of the Ulwazi Concept between these two virtual classrooms.

South Africa in general is undergoing a process of social transformation which has accelerated in the post apartheid era. The education system has seen significant change at the policy level in order to align it with current international standards as well as providing equal access to all citizens. One of the critical challenges is to implement this across the broad range of schools, especially in the township and deep rural areas.

Ensor (2006) indicates that current thinking even raises the issue of teachers needing licences renewable every five years to overcome the problem of poor quality of teachers. The basic intention is to introduce a framework to develop teachers' competence and ensure that they had the ability to perform in their profession. Needless to say, the relevant teacher unions rejected the suggestion.

In the process of social evolution the power of ICTs in education hold enormous potential if it can be successfully unleashed. Earley suggests that 'since fundamental change is needed, social change activities must go far beyond traditional political activism'. He goes on to add that 'a spectrum of social change activities are needed, including confrontation of destructive policies, personal growth, public education, community organizing, reform, creating alternative institutions and technologies, and much more'.

Earley adds that 'To build a healthy society we need change at both the personal and societal levels. Without personal growth, we won't have enough citizens who have the consciousness required to co-create a healthy society. However, some of our social structures, especially our current global corporate economy, are not only destructive to our society but also tend to constrain our consciousness and drive it into certain narrow ways. Therefore we need to work for change at all levels simultaneously.'

Although the Ulwazi project initially focused on connectivity by 'chasing champions', the resultant positive incidental changes were noticeable. In a video interview one learner summed up the situation when he stated that the students had access to technology, access to a good educator and access to information. They no longer had an excuse to fail. Fundamental changes in society must begin within individuals and the biggest change must certainly be in personal attitudes. A positive attitude of 'I can do Science' was very evident and a significant number of learners who participated in the project were intimating that they were considering careers in the hard sciences.

The old model of Outreach programmes is losing flavour rapidly as more companies would like to see greater returns on the corporate social investments. Fund raising for Outreach projects over the years showed a decline from many institutions. The impact of channelling scarce resources into a bussing model sees a significant proportion of the budget being consumed rapidly even before any education starts and the process is certainly not sustainable. The Ulwazi Concept negates this effect immediately by reducing the 'transport' cost to zero. The added advantage of digitally transporting learners and educator to remote classrooms is that it can be achieved virtually instantaneously and can operate 24 hours a day at virtually no additional cost. It also overcame an inherent fear that learners and teachers from the cities being reluctant to travel into local townships. There is no longer an excuse for not reaching out to disadvantaged communities as the hardware and software barriers are dwindling rapidly. Beyers (October 1998) states that the biggest problems are the warmware issues or human factor.

An issue of strategic importance to the educational use of the Ulwazi Concept must certainly be the regulatory issues surround the use of the operating frequency band. Dasgupta (2005) sums up the situation. 'If you think education is expensive, try igno-

rance!' The regulation of the airwaves is important but the Ulwazi Concept is based on the principle of a zero-rated education licence as not many schools can afford a monthly fee to access the wonderful resources that the internet has to offer, let alone an additional expensive of connectivity to receive supplementary tuition. The engine room of a developing world countries economy has to involve an investment in future generations. A system that does not promote free access to information and information services will severely hamper any development of human capital especially in the science, engineering and technology sectors. The knock-on effect will be individuals who are unable to cope with life in a technological world.

RECOMMENDATIONS

The pilot phase of the Ulwazi project is now complete and plans for the next phases are already on the drawing boards. As has been mentioned previously, access to technology and more importantly, information are critical, but a common problem with the deployment of any computer laboratories is the question of security. The 'theft' value of computer equipment unfortunately demands that a significant portion of scarce financial resources have to be allocated to securing the laboratories. In essence, this translates to poor physical access to the equipment on the part of the teachers and especially the learners. Computer laboratories in general, remain locked up for a significant proportion of the school term for fear of losing the equipment.

An initiative that has been launched by the Meraka Institute (www.meraka.org.za) at the CSIR involves the development of a community network and to empower locals to deploy and maintain a mesh network (http://en.wikipedia.org/wiki/Wireless_mesh_network) as part of an entrepreneurial opportunity. The network is part of the community and must therefore be owned by the community. A classic example of this is the use of cantenna (<http://en.wikipedia.org/wiki/Cantenna>) which is a directional waveguide antenna for long-range WiFi used to increase the range of (or snoop on) a wireless network. Originally built using a Pringles potato chip can, a cantenna can be constructed quickly, easily, and inexpensively using readily obtained materials. The use of tin cans to make the antennas reduces the cost of the equipment as well as the expertise needed to maintain it in such a community network. A group of learners from Gatang High have displayed an interest in taking on the challenge of developing a business in the local community. Currently there are plans to provide two teachers and two learners with access to the Ulwazi network from their home PCs and to explore the education possibilities of such a community network linked to educational resources.

As part of the shared resources the server will house a version of the Wikipedia as internet access will not be provided due to cost factors. Coupled to this will be the inclusion of:

- a Wiki
- Wikipedia

R. N. Beyers

- Content management and delivery system
- Pod casting capabilities.

The use of the mesh network is in line with the Wireless Africa's (<http://www.meraka.org.za/wireless.htm>) initiative to implement ways in which technology barriers can be removed or minimized to enable bottom-up creation of wireless access infrastructure. The group is performing research in the areas of mesh networking, low cost voice/messaging devices, low cost access points and antennas, and network security. Mesh networking research is particularly interesting in that a community can grow a wireless network in an ad-hoc manner without the need for large capital investment in radio masts. Two experimental test bed mesh networks have been installed in Pretoria and Mpumalanga and are continually increasing in size to understand issues such as scalability and quality of service as stated by Wireless Africa.

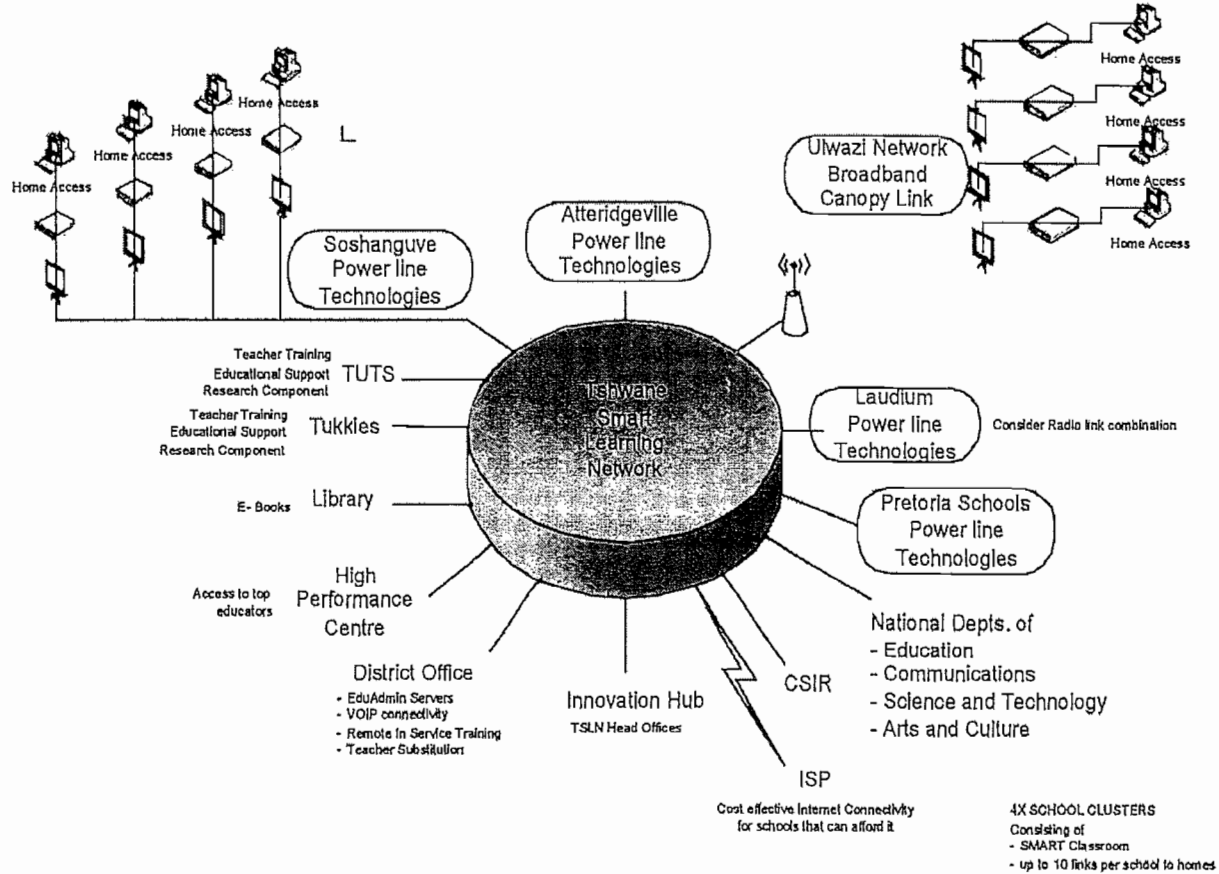
The proposed Ulwazi Tshwane Smart Learning Network (TSLN) is the next expansion step in the process. It is intended that the Tshwane Global Digital Hub (<http://www.tshwane.gov.za/business.cfm>) will provide access to the fibre optic backbone covering the whole of the Tshwane area providing access to all the schools in the metropolitan area. The educational implications of such a digital network are enormous and can play a significant role in addressing many of the negativities that are hindering progress in the educational sector. See Figure 2 for a proposal on Ulwazi Tshwane Smart Learning Network Diagram.

The following are just some of the educational advantages that could emanate out of such a proposed network. Some of the following recommendations could be turned into further areas of research.

- E-enabling additional processes in order to maximize on the deployment of expensive equipment. This would include connecting all the health clinics to enable the realization of an e-health strategy as well e-municipality and e-government.
- In setting up a metropolitan wide network it is important to identify the champion individuals and schools to act as change agents. The first phase will be to roll out to them in order to facilitate an organic growth model for the dissemination of best practices. By investing in champions it is possible to empower them to act as catalysts and to overcome the 'ignorance is bliss' syndrome that prevails in many schools which is hampering the early adoption of technologies in classrooms.
- The deployment of low cost mesh types of technologies has the potential to spawn entrepreneurial opportunities for groups within the community to maintain and deploy such a network. This community empowerment process can go a long way to initiating additional components of sustainable social transformation through digital empowerment. An extension of this concept could be the initiation of a call centre on the network which uses Voice Over Internet Protocols (VOIP). This service to the educational community would be a value added service and could also be extended to the e-health and e-municipality concepts as well.
- Another key concept that the deployment of the proposed TSLN can demonstrate

754

APPENDIX A : Ulwazi Phase 2 - Tshwane Smart Learning Network – Concept Diagram



The Ulwazi concept – Virtual interactive and collaborative classrooms of the future

is the distribution of internet access to multiple schools using a single entry point. This could provide the benefits of free district wide interschool connectivity with access to shared resources anywhere on the network. The expensive part of connectivity could be shared through a managed entry point which is scalable depending on the demands. It is foreseeable that as the Ulwazi Concept is deployed in other cities with centres of excellences as the main hubs, it is conceivable that the role out of national schools educational network or EduNet would be greatly enhanced without the need to connect individual schools. The Telecommunications Act 103 of 1996 and amended in 2001, as stated in the Draft White paper on e-Education (2003), makes provision for the development of a network for education (EduNet) that will connect all schools to each other and to the Internet through multi-media laboratories. There is growing pressure to ensure that EduNet is deployed early in the next century which is an enormous task given the remoteness of many of the schools as well as the lack of basic facilities in many institutions.

- An important consideration when creating the proposed learning communities that are connected, it to deploy the appropriate technologies which may range from ADSL, ISDN, V-SAT, Wifi, WiMax, etc. While addressing the issue of connectivity the policy makers must also take into consideration the importance of defining the bandwidth for such connections. With the rapid escalation in hardware and software innovations, coupled to the variety of formats that digital information can be captured and delivered, it is imperative that the connections do not restrict future information pipelines by allocating poor bandwidth. The Ulwazi pilot project operated with a bandwidth of approximately 10 Meg which enabled the establishment of a virtual interactive and collaborative classroom. It is for this reason that connections should aim for an interschool bandwidth associated within a given closed network to be in the region of 20 Meg. Internet connectivity can then be chocked down to an affordable level.
- Access to a metropolitan wide school administration package can greatly enhance the management of a key administrative function of all schools. It is proposed that such a system is browser based with the server residing at the head offices of the local educational district offices. The system should make provision of such essential elements as learner and teacher administration, basic financial administration, capturing and process of marks, printing of reports, etc. District offices should have access to the database in order to data mine the information on a daily basis in order to make more rapid and informed decisions based on the patterns of information that emerge.
- The TSLN proposal also takes into account providing universities with access to the network. The motivation for their inclusion is based on providing the in service teacher training departments with the opportunity of exposing the teachers to a living laboratory to gain invaluable hands on experience. The real value lies in the contextualization of learning for the would-be teachers while providing learning opportunities for the learners in the schools as well. The proposal is therefore based on a move away from thumb-suck education to real education which is relevant.

CONCLUSIONS

Given the scenario described previously with teacher absenteeism, coupled to poor teacher training and a lack of delivery, it is conceivable that classrooms in different parts of an educational district could be digitally merged for varying periods of time. There would no longer be the excuse that no teaching was taking place or that the quality was not up to standard. Modern technologies are mature enough to provide stable broadband connectivity which could digitally transport the best educators to any school in the district. It is also conceivable that with further enhancements in the internet connectivity that top educators could even be available digitally to any school in the country in the near future. The mind boggles at the educational opportunities that could be leveraged in such scenarios.

There are many more permutations of the TSLN proposal that could have a dramatic influence on the educational outcomes should such a network be deployed, including the open source debate. The challenge must therefore be to provide a holistic solution to digital inclusion for communities in disadvantaged areas. The Ulwazi Concept is one possible solution that has demonstrated proof of concept on a small scale and with further piloting could play a significant role in the deployment of EduNet in the coming years while providing more learners to draw benefits from a learning community that is connected.

This paper clearly adopts the position that argues that the latest generations of ICTs are a panacea not for all the problems facing education but certainly has the potential to circumvent some of the critical stumbling blocks that are hindering progress, especially in the areas of content and teaching where there is a lack of delivery. It has been clearly demonstrated that it is possible to establish a learning community that is connected which can lead to social transformation which could lead to long terms effects on the economy.

References

- Beyers, R. N. 1998. Warmware issues in education. Available at: <http://ulwaziproject.co.za/ronbeyers/warmware.htm>.
- Connected Learning Communities. 2007. Available at: <http://www.microsoft.com/uk/education/learning/learning-communities/>.
- Dasgupta, B. 2005. With a grain of salt. Available at: <http://piquancy.blogspot.com/2005/05/if-you-think-education-is-expensive.html>. Accessed on 5 May 2005.
- Draft White Paper on e-Education. 2003. Transforming Learning and teaching through ICT. Available at: <http://www.info.gov.za/whitepapers/2003/e-education.pdf>. Accessed during August 2003.
- Earley, J. No date. Principles of social transformation. Available at: http://www.earley.org/Transformation/principles_of_social_transformat.htm.
- Ensor, L. 2006. Plan to give teachers five-year 'licences'. *Business Day* 12

R. N. Beyers

- July 2006. Available at: <http://www.businessday.co.za/articles/topstories.aspx?ID=BD4A231124>.
- FCC Report and Order No FCC 97-5. 1997. 'Amendment of the Commission's rules to provide for operation of Unlicensed NII Devices in the 5GHz frequency range.' Released 9 January 1997.
- Federal Communications Commission. Available at: <http://www.fcc.gov/>.
- Hindle, D. 2005. Thirty-one schools report zero pass rate. *Independent Online*. 29 December 2005. Available at: http://www.iol.co.za/index.php?set_id=1&click_id=13&art_id=qw1135862100540B253.
- Hlengani, L. 2005. Interview. Gatang Comprehensive School. February 2005.
- ITU Radio Regulations. 2003. Available at: <http://www.austlii.edu.au/au/other/dfat/nia/2005/7.html>.
- Mnguni, P. 2006. Interview. St Alban's College, February 2006.
- Sunday Times*. 2006. Schools languishing in digital dark age. 22 March 2006. Available at: <http://www.sundaytimes.co.za/zones/sundaytimesNEW/basket16st/basket16st1143031926.aspx>
- Seepe, J. and M. Sibanda. 2006. There's no govt Aids crisis. Available at: http://www.news24.com/News24/South_Africa/Aids_Focus/0,,2-7-659_1888694,00.html. Accessed on 26/02/2006.



A five dimensional model for
educating the Net Generation

A Five Dimensional Model for Educating the Net Generation

Ronald Noel Beyers

Young Engineers and Scientists of Africa Programme, Meraka Institute, Pretoria, South Africa // ron@yesa.org.za

ABSTRACT

This paper proposes a multi-dimensional concept model of an ICT enabled classroom to highlight potential similarities and differences between where teachers perceive themselves relative to their learners. Some teachers and learners may be at the two dimensional text-book level, while others are operating in at a globalization level. Being armed with this type of information, educators may be empowered to rethink their educational strategies especially where ICTs are employed in an educational context.

Keywords

Net generation, Model of education, Knowledge society, Digital divide, Globalization

Introduction

The world in which our children live is significantly different from that of yesterday. Today's youngsters use laptops, pagers, instant messaging, and cell phones to connect to friends, family, experts, and others in their community and around the globe. They are bombarded with visual messages from the media – messages specifically targeted to tap into the billions in discretionary spending they control and/or influence. This is a generation that expects to actively participate in and through their media, hence the decrease in time spent by teens in viewing television and the corresponding increase in time spent on computers, gaming, and the Internet. Our children now have at their fingertips a virtual world – with all its promises and pitfalls (Lemke, 2003:5).

Schooling today is an attempt to make mini-scholars out of students by giving them doses of what was meant by scholarship in the eighteenth and nineteenth centuries. The theory of knowledge implicit here is that the educated person knows something about all the great books. This idea works when there aren't that many books in print (or at least it seems to work). But in an age when no one could possibly know something from every book that has been written, when there are enough books to go around, and when there are so many other forms of knowledge available to students, these ideas are outmoded. We must look to concepts that relate to today's world, one where there's so much to know that it is likely that students will have to direct their own education out of practical necessity (Schank & Cleary, 2008).

Public education is struggling to adapt to an intellectual, social and cultural transformation that has begun to emerge during the last thirty or forty years. New understandings on the frontiers of science, a growing awareness of the threats to planetary ecology, and a disruption of local communities and economies by the rise of globalization have made it necessary to rethink many of the basic assumptions that guided the development of modern industrial culture. It is increasingly evident that humanity faces the task of moving from an age of modernity into an uncharted post-industrial or post-modern future (Miller, 2000).

Figure 1. presents a diagrammatic representation of the relationship between an education system and on society in general. The formative years of schooling are aimed at preparing learners for an exit point into society after they successfully complete up to twelve consecutive grades. A mechanistic view of the education system demands that a feedback loop is essential to ensure that the needs of society are met through the system and is embedded in the contents of the formal curriculum which is managed by the government of the day. Change in society is inevitable resulting in a demand for learners with a new set of skills implying the need for these changes to be reflected in the curriculum of the day.

The curriculum in any contemporary democratic society always reflects the definition of democracy which that society has accepted as legitimate and true. Similarly, attempts to challenge the validity and legitimacy of a society's dominant definition of democracy always find expression in attempts to challenge the form and content of the curriculum of that society's schools. In this sense, the debates about the curriculum that occur in a democracy at any given time will reveal both how that democracy interprets itself, *and* how that interpretation is being challenged and revised in order to bring into being a more genuinely democratic form of life than that which currently exists. The curriculum in a democracy is thus always a curriculum for democracy, incorporating both a record of its past and a message for its future (Carr, 1998).

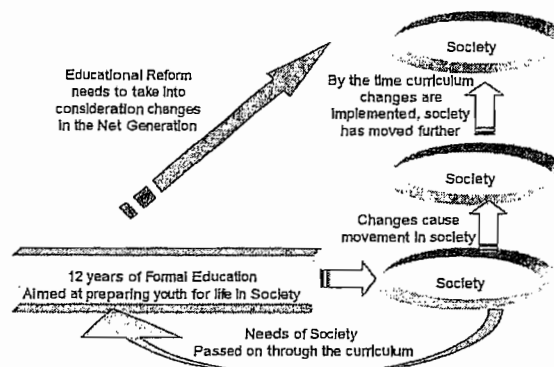


Figure 1: The education system, society and the curriculum

One of the primary functions of an education system is to convey and ensure a mastery of a set of knowledge, skills, attitudes and values that a particular society regards as desirable. During the formative years an individual will also be exposed to a cultural framework, which will supplement their survival strategies for the rest of their lives in a given society. One of the problems that many societies are facing especially where there is a transition from an industrial and manufacturing based economy to a knowledge society, is the rate of change. The reform processes in education, as portrayed through the curriculum, are seldom able to keep pace with the change resulting in students exiting the formal education system being inadequately prepared as the world that they were prepared for may no longer exist. To address this problem it is proposed that curriculum changes need to be visionary and project the activities within the classroom to intersect with the future needs of society as portrayed in Figure 1.

Teachers in the classrooms of today are facing an educational dilemma. The world that they grew up in and were trained in is also rapidly evolving around them. In a third world country like South Africa, these permutations are even more exaggerated by such a diverse variety of schools ranging from classrooms under trees with no running water, toilets or electricity in deep rural areas to modern digital classrooms with laptops and campus-wide radio networks found in the more affluent private institutions. The apartheid era has left a legacy which will take generations to rectify leaving many learners with very little chance of crossing the digital divide. The net effect for these individuals is a life of economic misery where they are excluded from many benefits that a technological world has to offer.

On the other hand 'wiring the schools and populating them with computers is necessary but insufficient to ensure equal opportunity to share in the digital revolution' (Tapscott, 1988:262). They need a redesigned education system and teachers who have been retrained and reoriented. Innovative technologies cannot make up for educational professionals who lack innovative methods and merely replicate learning models that don't work (Hooper, 2002).

A lack of sustained and meaningful professional development for teachers coupled to a stagnant curriculum can leave learners uninspired and unmotivated to extend themselves. This phenomenon is common as some teachers may not have, for whatever reason, had any in-service training or been exposed to new teaching methodologies and a phenomenon of 'ignorance is bliss' is perpetuated. The learners at the end of the day loose out on the benefits that educational reform has to offer such as the recently introduce Outcomes Based Education in the fledgling democracy of the South African education system.

A learner growing up in a first world environment has a very good chance of being nurtured on a digital diet acquiring the necessary skills to cope with life in a technological world. Children may be developing greater digital literacy than siblings who are just a few years older. For example, over two million American children (ages 6–17) have their own Web site. Girls are more likely to have a Web site than boys (12.2 percent versus 8.6 percent) (Oblinger & Oblinger, 2005). Individuals raised with the computer deal with information differently compared to previous cohorts: they develop hypertext minds, they leap around (Prensky, 2001).

Learning Theories

Gone are the days of working with the unformed, featureless minds of learners of the philosopher of John Locke's 'tabula rasa'. Pavlov's classical conditioning as part of behaviourism together with Thorndike, Watson and particularly Skinner's operant conditioning have been superseded by Jean Piaget's constructivism. Though their relevance has been surpassed by constructivism previous philosophical underpinnings laid the foundation for the new paradigm to understand the nature of learning.

Constructivism is a philosophy of learning which articulates mechanisms by which knowledge is internalized by learners. Constructivism is an epistemological view of knowledge acquisition emphasizing knowledge construction rather than knowledge transmission and the recording of information conveyed by others. The role of the learner is conceived as one of building and transforming knowledge (James, Applefield, & Mahnaz, 2001).

Constructivism has multiple meanings. In philosophy it is an epistemological theory, in cognitive psychology it describes human learning, and in curriculum it is a set of design principles. Constructivism is an overarching theory that can incorporate a number of teaching practices such as co-operative, collaborative and inquiry-based learning... Constructivism is basically a theory based on observation and scientific study about how people learn. It says that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. When we encounter something new we have to reconcile it with our previous ideas and experience, may be discarding the new information as irrelevant. We are active creators of our own knowledge (Mechlova, Konicek, & Balnar, 2003).

Constructionists believe that knowledge is constructed and learning occurs when children create products or artefacts. They assert that learners are more likely to be engaged in learning when these artefacts are personally relevant and meaningful (Bhattacharya & Han, 2001). In a more traditional teacher-centric classroom where information transfer is prevalent learners are less likely to be engaged as the meaning is being interpreted for them by the teacher. Modern youth often find themselves immersed by a range of technological devices that provide them with access to information through a broad range of media. The challenge for the teacher is to capitalize on this by engaging the in the content of the curriculum through the use of the 'tools' of the Net Generation.

The Net Generation is defined as the population of about 90 million young people who have grown up or are growing up in constant contact with digital media (Tapscott, 1988). Born between roughly 1980 and 1994, the Millennials have already been pegged and defined by academics, trend spotters, and futurists: They are smart but impatient. They expect results immediately. They carry an arsenal of electronic devices - the more portable the better. Raised amid a barrage of information, they are able to juggle a conversation on Instant Messenger, a Web-surfing session, and an iTunes playlist while reading Twelfth Night for homework. Whether or not they are absorbing the fine points of the play is a matter of debate

Millennials expect to be able to choose what kind of education they buy, and what, where, and how they learn. To meet the demands of these new students, they say, colleges must rethink how they operate. Imagine classrooms that incorporate more videos and video games, classes that meet electronically to fit students' schedules, students who choose to learn from each other rather than a professor, and courseware, search engines, and library databases that are animated, image-based, and interactive (Carlson, 2005).

By contrast many practicing teachers grew up without computers and the chances of them being formally trained to use them in the classroom as slim. Teacher training programmes are having to be implemented for both in-service and teacher training institutes to bring them up to speed.

A Proposed Conceptual Model

It is easy to criticize an education system which is inherently about learning but at the same time it is critical to look at the teachers who form the engine room of the system. This proposed Five Dimensional Model suggests a contextualization of possible differences between the traditional teachers in the classrooms who may be unaware of the needs of the net generation that they encounter. The model proposes a multi-dimensional perspective of

comprehending possible similarities and differences which could be used to empower teachers to make greater use of technology in the classrooms while addressing the needs of the learners.

These learning theories fall short of encapsulating the complexities of the net generation. The need is to present a model which may provide for a differentiation of a multitude of dimensions which is indicative of the ability of the modern learner to operate on a number of different levels and their ability to multitask within such an environment. This model is a new approach and must not be seen as being in conflict with such theories as constructivism but rather supplements them. The model was based on a number of years of exposure to innovative learners including a variety of information communication technologies (ICTs) and educational pedagogies ranging from drill and practice to blended learning, teacher training and e-learning opportunities. It is envisaged that the model could provide educators with the means to comprehend the 'differentness' and 'complexity' of the net generation. A tool to graphically plot individuals within this 5D model is being developed which will serve to highlight similarities and differences between teachers and pupils especially where ICTs are deployed in the classroom. The intention is sensitize teachers to this information so that they are encouraged to grapple with these issues to better understand them for the benefit of their learners.

The prevailing technologies of a particular place and time have always been intimately linked with education, because a society's tools are both the subject and the means of its learning. Today, the fact that technology pervades almost every sphere of life – from home to work to play – results in profound implications for learning, both in schools and throughout life (Partnership for 21st Century Skills, 2007:6)

The challenge of evolving pedagogy to meet the needs of Net-savvy students is daunting, but educators are assisted by the fact that this generation values education. These students learn in a different way than their predecessors did, but they do want to learn (Barnes, Marateo, & Ferris, 2007).

This five-dimensional model of viewing an educational system suggests that education is no long a linear process of information transfer, but rather that it has dimensions which can range from two dimensional textbook scenarios as well as a time and space dimension where ICTs are concerned. Each of the five dimensions have a predefined characteristics. The model is a mental picture that helps us understand something we cannot see or experience directly (Dorin, Demmin, & Gabel, 1990).

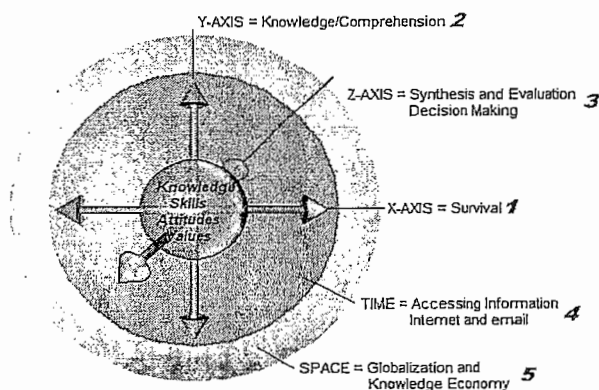


Figure 2: Five Dimensional Model of Education

The First Dimension – X Axis (Survival Strategies)

This dimension is characterized by the hunter-gatherer leading to the period of farming which brought about an improvement in the quality of life during the agricultural era. The young were trained to fulfil the roles needed for this agrarian society. Education outside the farming community was limited to a small population of chosen people and selected professions, such as the Clergy (Miller, 2000b).

One of the main functions in life was to scan the immediate environment to find food and these basic skills had to be handed on by word of mouth. Survival of the fittest was the order of the day and it provided an essential platform for youth to acquire essential skills for life. This is characterized by the stone masons who were able to pass on the skills from generation to generation often with sons completing the work on a cathedral which their fathers had started. The Three R's of Reading, Writing and Arithmetic form the foundation stones of all education and learners are expected to have a firm grounding in these basics in order to progress successfully through the grades.

The Second Dimension –Y Axis (Knowledge and Comprehension)

During the Industrial Era the economic power of a person, city or country came from the capacity to manufacture products. With the Industrial Revolution and vast numbers of inventions especially in the areas of mechanics, huge factories were erected everywhere to manufacture all kinds of products (Miller, 2000b). This era needed a class of citizen who was equipped to deal with the monotony of operating machinery resulting in a simplistic 'factory model' of education.

A characteristic of this dimension is rote learning based on a Pavlovian behavioristic model which required an education system to equip the masses with a fundamental education. The observable changes required that new behavioral patterns were repeated until it became automatic (Mergel, 1998). Society needed a cheap labour force to operate the machines for the capitalistic society. The 'thinking' was left to the people in power and education was simply a sausage factory where individuals were not encouraged to rise above the masses and where conformity was the order of the day. Teachers in such a system were viewed as gatekeepers and the source of all knowledge and where text books were regarded as all important.

Education is generally aimed at providing efficient and effective schooling for the masses who could perform a minimal set of skills on command in the factories. Creative thinking, problem solving skills and entrepreneurial endeavours were not required nor envisioned for an educational outcome in the industrial based economy and world picture (Miller, 2000c).

The Third Dimension –Z Axis (Spatial Orientation)

The third dimension raises an interesting possibility. If one had to compare the former two dimensions to travelling along a road, the curriculum would offer learners with choices at key stages in their development. The rest of the time would be spent following a predetermined, well-trodden paths which would lead to a possible reward system at the end of the road. It can be argued that many teachers are unable to make the transition to the third phase due to the nature of their own training as well as a lack of exposure to broader educational issues. Many teachers remain at the second level as they tend to operate at a two-dimensional level relying heavily on the 'security blanket' of the syllabus bound prescribed text book.

Adhering to the first two levels of the model can produce outstanding results but there is still the need to allow learners to expand their minds into the realms of creativity and innovation which may only be possible in the third, fourth and fifth dimensions. The transition to the third dimension also implies the ability to convey a richness to the educational journey that was not previously possible. By having the ability to fly as opposed to driving, learners are encouraged to transcend the two-dimensional mode of the text book. Such systems encourage a learner-centered approach by pushing the boundaries in which the students are able to safely discover far more of their own talents. The principal goal of education is to create men who are capable of doing new things, not simply of repeating what other generations have done (Burkhalter, McLean, & Jones, 2004:50)

The term learner-centered refers to environments that pays careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the educational setting. This term includes teaching practices that have been called "culturally responsive," "culturally appropriate," "culturally compatible," and "culturally relevant" (Ladson-Billings, 1995:465-491). The term also fits the concept of "diagnostic teaching" (Bell, O'Brien, & Shiu, Designing teaching in the light of research on understanding, 1980): attempting to discover what students think in relation to the problems on hand, discussing their misconceptions sensitively, and giving them situations to go on thinking about which will enable them to readjust their ideas (Bell, Diagnosing students' misconceptions, 1982:6-10) Teachers who are learner-

centered recognize the importance of building on the conceptual and cultural knowledge that students bring with them to the classroom (Bransford, Brown, & Cocking, 1999).

The third dimension favors a constructivist approach to learning based on the premise that learners all construct their own perspective of the world, through individual experiences and schemas. Constructivism focuses on preparing the learner to problem solve in ambiguous situations (Mergel, 1998). Taken a step further this includes the concept of constructionism in its simplest form one only knows something if one can explain it (Yager, 1991:52-57).

Intimately connected with experience is a more educationally descriptive meaning of constructivism. Students come into a classroom with their own experiences and a cognitive structure based on those experiences. These preconceived structures are either valid, invalid or incomplete. The learner will reformulate his/her existing structures only if new information or experiences are connected to knowledge already in memory (Hanley, 1994). It is therefore imperative that educators must provide a richer learning environment for learners to attach meanings to new learning experiences.

Modern ICT intensive organizations expect employees to have a new set of digital skills. These skills are often not promoted in an information overloaded curriculum to the detriment of many prospective employees. On the other hand programmes like Formula One in Schools, Green Power and the 4X4 Challenge (4x4 Challenge Project, 2009) actively promote the use of ICTs to supplement the curriculum through extra mural activities.

The transition to the third level implies that the country as a whole is making or has made the transition to a knowledge-based economy. Organizations at the same time need to embrace this change and encourage the educators in the classroom to catalyse this reform process from a grass-roots level.

The dilemma facing outcomes based education is that employers of today are dissatisfied even with the high achieving graduates who have passed through the school system. Graduates tend not to be adequately prepared for the demands of today's more complex society which requires such competencies as creative thinking, group problem solving and decision making, as well as the capacity to learn more and more efficiently and effectively which is inherent in 21st century skills. This means that a more sophisticated view of knowledge and learning is required than the one held in the previous industrial era because the economy is now based on selecting, processing and applying information and creating new knowledge and applications (Miller, 2000a).

The Fourth Dimension – Time

Extending the learning process beyond the confines of the core curriculum and the walls of the classroom should be the goal of all educators to overcome the time constraints imposed by traditional classes and restrictive timetables. Many teachers have personal limitations which may inadvertently restrict the natural progress of many learners. By employing such educational tools as the internet, CD Roms, email and other modern technological teaching aids, these technologies may, if carefully planned, have the potential to circumvent some of these personal limitations. By applying creative methodologies the teacher can empower learners to internalize the learning process and embark on a journey of self-discovery well beyond the confines of the minimum standards imposed by the prescribed curriculum.

Exposure to other curricular material, searching for information to supplement lessons through collaborative projects and web publishing can transform dull lessons into stimulating educational encounters that may motivate students to extend themselves beyond what was achievable in a two-dimensional traditional teaching environment.

In such a four-dimensional environment the emphasis is on communications including both synchronous and asynchronous methods. Students are able to access the wisdom of experts around the world and receive an answer in a relatively short period of time. This feature can go a long way to allowing students to become motivated to actively utilize the power of such things as Text Messaging, Blogs, Wikis, etc. Access to mobile learning devices and educational portals may suite the learning styles of many more learners in relation to face-to-face traditional teaching. This is embedded in the Web 2.0 phenomenon where learners are able to combine their collective intelligence through the use of social software (O'Reilly, 2005).

The Fifth Dimension – Global vision

It is necessary to highlight a fundamental difference between the use of the term ‘teacher’ and an ‘educator’ in this paper. Anyone can teach through a process of information transfer and reinforcement strategies but not everyone has the ability to turn a teaching situation into a life-long learning experience. Teachers acting as gatekeepers of knowledge are threatened by the perception that learners may know more than them. Educators on the other hand strive to release these learners to construct their own knowledge so that the educator can focus on those individuals who really need their attention.

It is suggested that the transition to the process of life-long learning can take place without students being exposed to all the facets of the other dimensions. However, it is suggested that educators should also make this transition themselves. By actively promoting the process of life-long learning, educators may be able to make a greater impact on the lives of the students that have been entrusted to their care. Adaptability is a key facet of this stage for without it teachers are doomed to remain in a two-dimensional text-book bound world.

At its most fundamental level, globalisation is about the monumental structural changes occurring in the processes of production and distribution in the global economy. These structural changes are responses by many global enterprises that confront tremendous pressures and fantastic opportunities presented by the increased application and integration of advanced information and communications technologies (ICTs) into their core business processes. Through the application of information and communications technologies, enterprises have the ability to diminish the impact of space, time and distance (Cogburn, 1998).

Our children live in a global, digital world—a world transformed by technology and human ingenuity. Given the rapid rate of change, the vast amount of information to be managed, and the influence of technology on life in general, students need to apply current skill sets, as well as develop new skill sets to cope and to thrive in this changing society (enGuage, 2003:3).

In order for learners entering the market place to be able to flourish in a global society they need to have acquired an essential set of skills which can only come about through exposure to the concepts of globalization. Traditional education has the teacher as a gatekeeper of information but the net generation is demanding not the raw information but rather the tools to sift through large volumes of data in order to synthesize new knowledge. This shift from broadcast to interactive is the cornerstone of the N-Generation (Net Generation). They want to be users-not just viewers or listeners (Tapscott, 1988:3).

A key characteristic of the fifth dimension also involves group work and a division of labour where learners are challenged to explore lateral thinking, creativity, problem solving and innovative types of challenges. It is essential that learners are provided with real-world tools and real-world scenarios such as those that are embedded in the following types of competitions that promote science, engineering and technology.

- Formula One in Schools (F1 in Schools, 2008)
- Green Power (Greenpower, 2008)
- 4x4 Challenge (4x4 Challenge , 2008)

Implications for Teacher Training

Too many teachers, too few educators

- As technologies penetrate the classroom environment and are embraced by net generation students, what is the new role for the teacher? Since the new media is drastically changing the learning milieu, so must the teachers change their roles and become more adapted to the new system of learning (Tapscott, 1988).
- There is a need to transform education from a teacher-centered behaviouristic to a learner-centered constructivist model by empowering the teachers to empower the learners through the integration of modern ICTs into all aspects of the learning process as depicted in Figure 3.

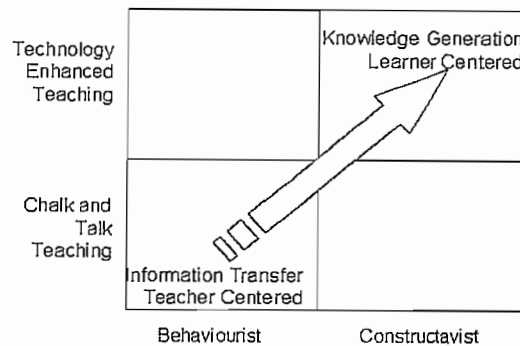


Figure 3. Moving from a teacher-centered to a learner-centered approach

- There is an opportunity to develop a system to plot teachers and learners on a grid indicating their relative position in terms of this model of education. A prototype tool is being developed and tested for self-assessment to plan personal growth rather than for formal evaluation purposes. By indicating the relative position of the teachers, coupled to specific professional developmental strategies, it is conceivable that teachers will be able to manage their own upliftment programs. In this respect, the skills development process will have a meaningful context.
- Re-skilling of teachers is needed to bring the vast majority of them up to date regarding modern pedagogies involving ICTs. Collaboration, group work, project and theme-based learning, and the integration of ICTs into all subjects are but a few examples of the processes that need to be conveyed. It is recommended that policy makers acknowledge that the vast majority of teachers are becoming burdened with administrative matters and are unable to find the necessary quality time for personal professional growth. If they are not exposed to the benefits of new approaches to education, they will continue to practice teaching in the tried and trusted armchair approach and not actively encourage learners to develop essential 21st century skills.
- The development of management skills need to be given a higher priority. This includes the management of people and information with the view to knowledge sharing in an open learning environment.
- The concept of Learning Communities that are connected to a National Grid of Learning needs to be cultivated. Far too often teachers assume that they are the only resource when the classroom door is closed. The sharing of teaching and learning material can be a powerful method of uplifting teachers to the status of true educators or learning facilitators especially with the availability of on-line learning materials.

Learning Communities are not simply another educational fad or a modest type of school reform but an attempt to rebuild society's educational system on a post-modern cultural foundation that is democratic and person-centered rather than mechanical, as well as ecological and life-centered rather than driven exclusively by economic forces. We offer the idea of the "cooperative community lifelong learning center" as a seed for social and cultural renewal - a form of education that reclaims the organic qualities of learning from pre-mechanistic times for a post-modern culture in the making (Miller A., Differences between the 'Traditional' and 'Outcomes Based' Education, 2000a).

- Understanding the needs of the net generation especially as far as providing e-learning opportunities is concerned.

Implications for Schools

- Access to the internet is no longer a nice to have but an absolute necessity for all schools. A telecommunication infrastructure needs to be developed to provide connectivity for all schools as outlined in the EduNet Concept for South African schools. Provision is made for this in the South African Telecommunications Act 103 of 1996 and amended in 2001 (Department of Education, 2004). Until the real cost of access to the internet is brought down to an affordable level, the information gap is going to widen, placing more and more learners at an even greater disadvantage with no real means of deriving benefits from the technology revolution.

- Schools in South Africa are facing large class sizes as a fact of life. New methodologies coupled to access to modern technologies, can be employed to allow the more able students to circumvent the limitations that such a system usually places on the teacher. Given the appropriate training, it is conceivable that an innovative educator may be able to 'reduce the class size' to a more manageable size while enabling the more able students to meet the requirements of their subject by employing open learning strategies and sound classroom management.
- The Ulwazi Concept (Beyers, 2007) has demonstrated the potential of providing virtual interactive connected learning classrooms with the means to share educational resources including access to top educators who are in geographically separated schools.

Implications for Learners

- Education is what is left over when you forget all the facts that your teacher made you memorize when you were in school - Quote by Mark Twain. This implies that learners can and must take greater responsibility for their own learning. Leaving learners to their own devices is not being advocated. On the contrary. The educator must still be in control of the process, but their role is more a facilitator rather than physically dictating what happens at the learning interface where there is greater emphasis on self-discovery after the basic skills have been acquired.

Conclusions

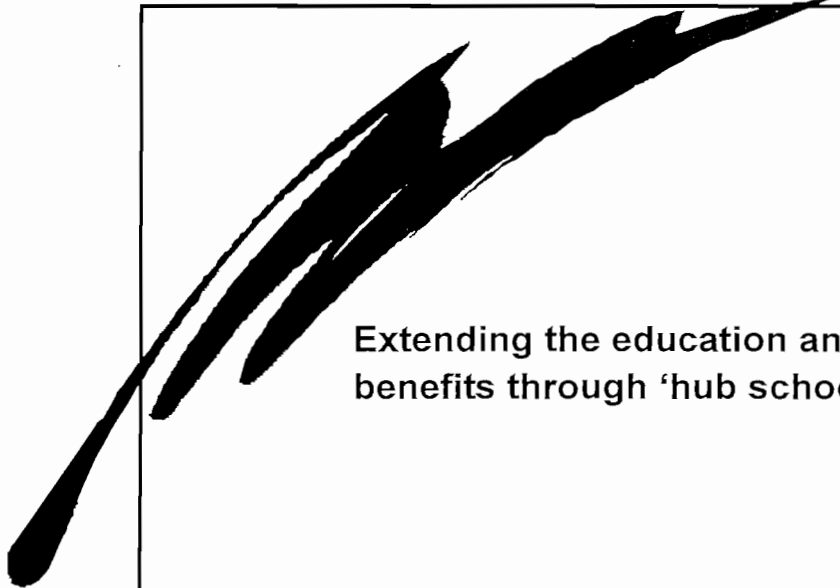
Responding to the needs of the Net Generation is an ever increasing challenge especially where ICTs and other technologies are being introduced into the classrooms. Teachers are having to adapt to these changes through a process of upgrading their own skills to empower them to become better facilitators. By doing so that are able to unleash the innate potential of the learners entrusted to them.

The proposed five dimensional educational model may be perceived as a tool for such teachers to comprehend the complexity of the situations they may find themselves in. The tool is aimed at raising the awareness of the possible similarities and differences that may exist between the teacher and the net generation in their class. Armed with this information the teacher will be better prepared to make the transition from the two dimensional world of the textbook to be able to operate in the multi-dimensional world of that the youth operate in to be able to capitalize on what these learning environments have to offer.

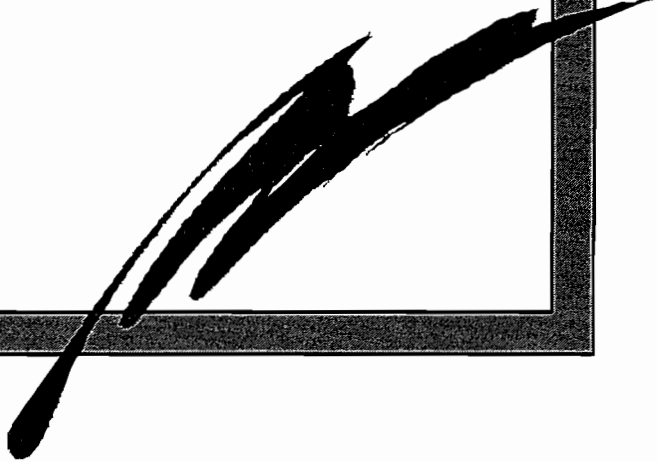
References

- 4x4 Challenge Project (2009). *4x4 in Schools Technology Challenge*, Retrieved May 01, 2009, from <http://www.4x4inschools.co.uk>.
- Barnes, K., Marateo, R., & Ferris, S. (2007). Teaching and Learning with the Net Generation. *Innovate Journal of Online Education*, 3 (4), retrieved May 1, 2009, from <http://innovateonline.info/?view=article&id=382>.
- Bell, A. (1982). Diagnosing students' misconceptions. *The Australian Mathematics Teacher*, 1, 6-10.
- Bell, A., O'Brien, D., & Shiu, C. (1980). Designing teaching in the light of research on understanding. In R. Karplus (Ed.), *Fourth International Conference for the Psychology of Mathematics Education*, August 16-17, Berkeley, CA.
- Beyers, R. (2007). The Ulwazi Concept – Virtual interactive and collaborative classrooms of the future. *South African Journal of Higher Education*, 21 (6), 746-758.
- Bhattacharya, K., & Han, S. (2001). Piaget and cognitive development. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology*, retrieved May 1, 2009, from <http://projects.coe.uga.edu/epltt/>.
- Bransford, J., Brown, A., & Cocking, R. (1999). *How people learn, Brain, Mind, Experience, and School*, retrieved May 20, 2009, from <http://books.nap.edu/html/howpeople1/ch6.html>.
- Burkhalter, B., McLean, J., & Jones, M. (2004). Recipients' Views of the Role of Christa McAuliffe Fellowships in Science Education. *Science Educator*, 13 (1), 50.

- Carlson, S. (2005). *The Net Generation Goes to College*, retrieved May 20, 2009, from <http://chronicle.com/free/v52/i07/07a03401.htm>.
- Carr, W. (1998). The curriculum in and for a democratic society. *Pedagogy, Culture & Society*, 6 (3), 323-340.
- Cogburn, D. (1998). *Globalization and the state in the information age: Thoughts on requirements for education and learning*, retrieved May 26, 2009, from http://www.unesco.org/webworld/infoethics_2/eng/papers/paper_23.htm.
- Department of Education (2004). *White Paper on e-Education: Transforming learning and teaching through information and communication technologies*, Cape Town: Government Press.
- Dorin, H., Demmin, P. E., & Gabel, D. (1990). *Chemistry: The study of matter* (3rd Ed.), Englewood Cliffs, NJ: Prentice Hall.
- enGauge (2003). *21st Century Skills for 21st Century Learners*, retrieved May 20, 2009, from <http://www.ncrel.org/engage/skills/skillsbrochure.pdf>.
- F1 in Schools (2008). *F1 in Schools Technology Challenge South Africa*, retrieved February 28, 2009, from <http://www.f1inschools.co.za>.
- Hanley, S. (1994). *On Constructivism*, retrieved May 26, 2009, <http://www.towson.edu/csme/mctp/Essays/Constructivism.txt>.
- Hooper, D. (2002). *Improving instruction as a team - President's Corner - Brief Article, Look Smart, Find Articles*, retrieved May 26, 2009, from http://findarticles.com/p/articles/mi_m0JSD/is_59_4/ai_84306242.
- James, M., Applefield, R., & Mahnaz, M. (2001). *Constructivism in Theory and Practice: Toward a Better Understanding*, North Carolina: The University of North Carolina Press.
- Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, 32, 465-491.
- Lemke, C. (2003). *enGauge 21st Century Skills. Literacy in the Digital Age*, retrieved May 26, 2009, from <http://www.metiri.com/21/21%20Century%20Skills%20Final.doc>.
- Mechlova, E., Konicek, L., & Balnar, A. (2003). *Distance Learning in teacher's training*, retrieved August 20, 2008, from <http://www.uniud.it/cird/girepseminar2003/abstracts/pdf/mechlova.pdf>.
- Mergel, B. (1998). *Instructional Design & Learning Theory*, retrieved February 26, 2009, from <http://www.usask.ca/education/coursework/802papers/mergel/brenda.htm>.
- Miller, A. (2000a). *Differences between the 'Traditional' and 'Outcomes Based' Education*, retrieved August 20, 2008, from http://www.metagroup.co.za/difference_sys3.htm.
- Miller, A. (2000). *Differences between the 'Traditional' and 'Outcomes Based' Education, Meta Group on Communications*, retrieved August 20, 2008, from http://www.metagroup.co.za/difference_sys.htm.
- Miller, A. (2000b). *Differences between the 'Traditional' and 'Outcomes Based' Education, Meta Group on Communications*, retrieved August 20, 2008, from http://www.metagroup.co.za/difference_sys.htm.
- Miller, A. (2000c). *Differences between the 'Traditional' and 'Outcomes Based' Education, Meta Group on Communications*, retrieved August 2008, 2008, from http://www.metagroup.co.za/difference_sys2.htm.
- Miller, R. (2000). *From Schools to Learning Communities: A Historic Shift*, retrieved February 26, 2009, from <http://www.creatinglearningcommunities.org/book/overview/miller1.htm>.
- Oblinger, D. G., & Oblinger, J. L. (2005). *Educating the Net Generation*, Educause, retrieved May 10, 2009, from <http://www.educause.edu/ir/library/pdf/pub7101.pdf>.
- O'Reilly, T. (2005). *What is web 2.0?* retrieved May 20, 2008, from <http://www.educause.edu/ir/library/pdf/pub7101.pdf>.
- Partnership for 21st Century Skills (2007). *The Intellectual and Policy Foundations of the 21st Century Skills Framework*, retrieved February 26, 2009, from http://www.21stcenturyskills.org/route21/images/stories/epapers/skills_foundations_final.pdf.
- Prensky, M. (2001). Digital Natives, Digital Immigrants, Part II: Do They Really Think Differently? *The Horizon*, 9 (6), 15-24.
- Schank, R., & Cleary, C. (2008). *Development of Current Educational Models; Engines for Educators*, retrieved May 26, 2009, from <http://www.engines4ed.org/hyperbook/nodes/NODE-84-pg.html>.
- Tapscott, D. (1988). *Growing up Digital: The rise of the Net Generation*, New York: McGraw-Hill.
- Yager, R. (1991). The constructivist learning model, towards real reform in science education. *The Science Teacher*, 58 (6), 52-57.



Extending the education and social
benefits through 'hub schools'



Extending education and social benefits through 'hub schools'

R. N. Beyers

Young Engineers and Scientists of Africa
In association with African Advanced Institute for
Information Communication Technologies
(The Meraka Institute)
Pretoria, South Africa
email: ron.yesa@gmail.com

Abstract

The Meraka Institute is involved in researching and developing a number of affordable and sustainable solutions designed to meet the social and economic needs of communities. The realisation of the 'hub school' concept relies heavily on the use of many of these innovative solutions to layer additional value-added educational and social services on top of an information communication infrastructure, to deliver a broader service to rural communities.

The educational value of interconnecting schools can enable virtual interactive classrooms with access to shared resources, such as teachers and other digital content, other schools, and teachers and learners' homes, to create connected learning communities. The presence of digital doorways, using a minimally invasive approach and other technologies, can provide a platform for applying the concept of a living laboratory for research to unravel the inherent potential of communities.

INTRODUCTION

As the trend to do more on-line increases, the need for bandwidth also increases. The need for Internet availability is also increasing in all spheres of life, including education, where wireless access is removing many barriers, to create opportunities for a more ubiquitous service. The challenge – especially in education, and more specifically distance education – is to bridge the digital divide that is excluding the vast majority of learners in developing countries such as South Africa.

© Unisa Press ISSN 0256-8853

Progressio 32 (1) 2010 pp 74–93

A major challenge for the South African government is to ensure the development of a more effective ICT sector strategy and policy framework for the country in order to harness the potential of ICTs, ensure better governance, deepen democracy and accelerate growth and development, especially job creation and poverty alleviation for the country, the region and the continent and in so doing, create an information society that improves the quality of life for all citizens. (Mbeki 2001)

South Africa is emerging from a heritage where resources were unevenly distributed to the few, at the expense of the many. We are now entering a period where knowledge has become a critical input into the creation of wealth and economic progress.

The digital revolution and the power of knowledge it disseminates, does not have the constraints of tangible factors of production, such as land and capital. South Africa has an opportunity to not only allow all the people of South Africa to benefit from ICTs, but to establish an internationally competitive infrastructure in the new economy. This will result in bridging the digital divide locally and globally. (Mbeki 2002)

In order for individuals to benefit from this, they have to be exposed to a modern education system where they are given the tools to access information, generate new knowledge and use the skills to compete in the global economy. Technology can offer individuals and communities the opportunity to circumvent the limitations of a poor education system or poor teaching, in order to benefit from this digital revolution.

The euphoria of an emerging democratic South Africa has passed, and the time has come to address the harsh realities of meeting the needs of the people across all sectors of the economy. With the shift to a knowledge society, where ICTs are becoming more pervasive in the lives of all citizens, people should be better prepared to take full advantage of this by receiving opportunities to leapfrog the digital divide. The national education system has seen a significant change – from a teacher-centred behaviouristic mode of information transfer, to an Outcomes Based Education (OBE) approach which emphasises the acquisition of skills. The expected outcomes of the OBE approach are future employees with the right knowledge, skills, attitudes and values needed to cope with life in a technological world, i.e. people who can make a meaningful contribution to the local and national economy of the country.

The post-apartheid government's response to improving the plight of learners entering a future knowledge economy, saw a number of key initiatives being tabled. The *White paper on e-education* in a new ICT environment was meant to create new learning opportunities and provide access to educational resources well beyond those traditionally available. Telecommunications infrastructure was designed to 'gradually increase and enhance the quality of teaching and learning

as well as school management and administration' (Pandor 2003). A nation-wide education network, EduNet, designed to serve the goals of universal access for every e-school in South Africa (Department of Education 2004), has been made realisable through the Telecommunications Act 103 of 1996 and amended in 2001 (Republic of South Africa 2001). Two significant educational projects in South Africa that are piloting the mass roll-out of province-wide networks include the Khanya Project (2009) in the Western Cape and the Gauteng Online Project (Gauteng Online 2009). A further significant development has also been the Thutong Education Portal (Thutong Portal 2009), which makes provision for educational content to be disseminated to South African schools.

Of relevance to this article is the African Advanced Institute for Information and Communications Technology, commonly referred to as the Meraka Institute. It derives its mandate as a national strategic initiative from the 2002 State of the Nation Address. The main objective of the Meraka Institute is to facilitate national economic and social development, through human capital development and needs-based research and innovation, leading to products and services based on Information and Communication Technology (Meraka Institute 2009). Meraka is based at the Council for Scientific and Industrial Research (CSIR).

While this article is not exclusively based on *open and distance education* per se, it is necessary to indicate the relevance of the 'hub school' concept, and how it can be used to supplement distance education. An essential characteristic of open learning is the removal of barriers to learning, implying no need for prior qualifications in order to study; and for students with disabilities, a determined effort is made to provide education in a suitable form that overcomes such disability. Distance education, on the other hand, is less a philosophy and more a method of education. Students can study in their own time, at the place of their choice and without face-to-face contact with a teacher, meaning that technology is a critical element (Bates 1995).

The hub school concept can go a long way towards enabling learners from isolated communities to benefit from the concepts inherent in open and distance learning. This includes having access to digital resources ... but therein lies the dilemma. Access is one thing, but computer literacy is another. It is imperative that learners are able to make use of the technologies, in order to benefit from the courses that are made available in a digital format. The world is operating in an information age where many individuals and companies make full use of the knowledge economy. In South Africa, like many other developing countries, a significant proportion of the population is excluded from the benefits of the digital age, as a result of the digital divide.

Merely teleporting individuals to the other side of the digital divide through the provision of access and computer literacy is no longer sufficient, as they will not be able to make full use of the benefits of the digital age. An alternative philosophical approach to the concept of the digital divide is to rather view the situation as a *technological ladder*, as represented diagrammatically in Figure 1.

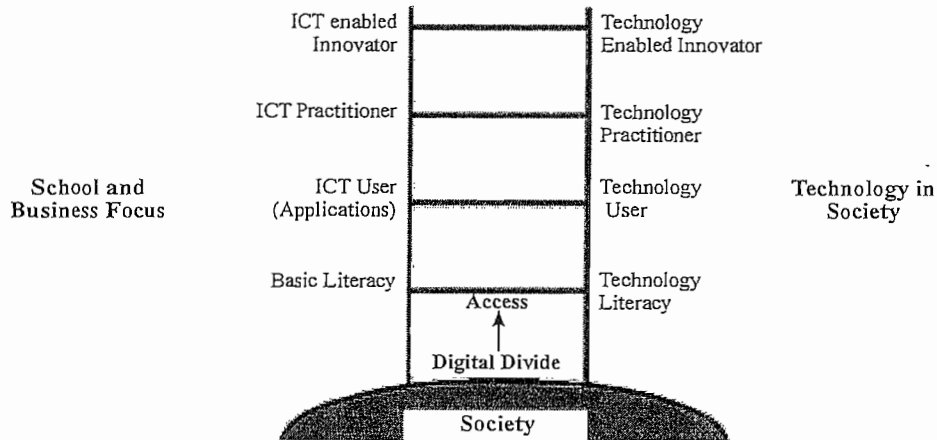


Figure 1: A schematic representation of the concept of a technological ladder (Beyers 2008)

The importance of the Digital Divide is not diminished in this model, as it is seen as the initial step to be overcome through the provision of access to technology. The concept of a Technological Ladder implies the need to continue to provide ICT developmental targets further up the ladder for the learners to aspire to. Unfortunately many learners will either remain on the first rung or even slip off as they are often not provided with additional support or access time to develop their newly acquired skills.

Once basic literacy has been achieved, users need to be encouraged and supported in mastering a variety of packages in order to become competent users. Beyond that is the mastery of the tools where ICT constitutes the main part of their future professions. The ultimate goal is utilizing the power of ICTs to conceptualize and realize their creative talents in the form of innovations (and ultimately patents). By providing challenges for ICT and other technology users they need to be afforded the necessary support and vision of what can be achieved rather than be left as casual users of products. (Beyers 2008)

Developing digital literacy in learners can no longer be a 'nice to have' for the more advantaged schools. This will ensure that those individuals who emerge from the education system are better prepared to participate as effective citizens

R. N. Beyers

of a digital world, and to make a productive contribution to the economy. Simply put, students who create 'documents' to be saved in 'folders' and placed on a 'desktop' are learning how to speak a corporate language (Burniske 2008). If this is the case, then learners on the wrong side of the digital divide will find it increasingly difficult to compete for jobs in the corporate environment.

BUILDING BLOCKS OF THE HUB SCHOOL CONCEPT

In order to conceptualise the hub school it is necessary to highlight a number of essential components, and it must be noted that each of the proposed components has been piloted within the Meraka Institute at the CSIR and reported on in various research papers. The concept entails the layering of these additional value-added services on top of an existing information communications infrastructure, to focus on meeting the educational, health and social needs – specifically of rural communities – through the provision of access as the first step in bridging the digital divide in these areas. Open and distance education can be seen as an additional value layer on top of the hub school service.

The components of the hub school concept originated with the Meraka Institute. These include Digital Doorways, Wireless Africa with the First Mile First Inch Project, The Ulwazi Project, and the Young Engineers and Scientists of Africa.

Each of the above components will be discussed briefly, to highlight their role.

Digital Doorway

Digital Doorway, which is a joint project involving the South African Department of Science and Technology (DST) and the Meraka Institute, is aimed at the promotion of computer literacy and associated skills in Africa. The assumption is that people have the inherent cognitive ability to learn computer skills with minimal external intervention. However, computers must be easily accessible to potential learners in an environment conducive to experimentation. Apart from the ability to read text, literacy involves image and screen literacy and, particularly, information navigation. The information provided by the Digital Doorway enables learning by 'discovery' rather than by 'lecture' (Cambridge, Smith and Gush 2008).

Digital doorways make use of the concept of the hole-in-the-wall (Mitra 2009), where it was demonstrated that groups of children could learn on their own without any direct intervention, given access using minimally invasive education (MIE). MIE uses children's natural curiosity and focuses on providing an enabling environment where they can learn on their own. Children, in the process of freely experimenting with the learning station, pick up critical problem-solving skills.

In a collaborative setting, children can share their knowledge, and in the process develop better group dynamics – all in a highly natural environment. The aim is to provide people in rural and disadvantaged areas with freely accessible computer equipment and open-source software, enabling them to experiment and learn without formal training and with minimal external input.

The Digital Doorway project offers access to a multi-terminal multimedia computer system, which provides access to information as well as various applications – something which could introduce alternative mechanisms for computer literacy in South Africa (Digital Doorway 2009). At the same time, this concept has the potential to enhance the goals of open and distance education through the provision of access to course content for rural communities. Figure 2 represents a more recent version of a digital doorway.

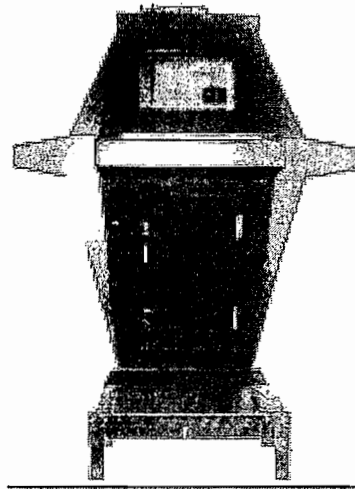


Figure 2: A photograph of a three-terminal system

The latest three-terminal configuration is based on a server running the Xubuntu Linux distribution, and two 'fat clients' without hard drives, which rely on the server for file access. The server also acts as one of the terminals, making a total of three terminals. The hardware is housed within a rugged steel enclosure with vandal-proof metal keyboards, LCD screens (protected by reinforced glass), webcams, speakers and uninterruptible power supply (UPS).

Digital doorways can potentially operate in a content delivery mode, with information stored locally and being downloaded from time to time. Connection to a network can enhance their flexibility, providing greater access and the freedom to do so beyond the restrictions of being locked up after hours in a classroom or store.

First Mile, First Inch (FMFI)

Access to information and communication technologies (ICTs) remains one of the biggest challenges to Africa in leapfrogging the development chasm (Morris 2007). First Mile, First Inch (FMFI) is a multi-disciplinary network of projects exploring the technological and social consequences of low-cost telecommunications implemented in remote schools, clinics and telecentres. As well as developing applications, research teams are exploring how people interact with the new technologies, and how their daily lives may be changed through such interaction using open-source, easy-to-use applications in local languages (Morris 1999). Their aim is to develop solutions that are affordable and applicable to rural communities.

Large communications infrastructure service providers, such as Telcos, often refer to the end point of their distribution networks as the 'last mile'. This is usually the most challenging and least desirable part of their network as it is often the most expensive and most difficult part to manage. This is particularly challenging in rural environments as this concerns the interface with rural communities. Finding the proper solutions to reduce these connection costs could increase access opportunities in rural areas. (FMFI 2008)

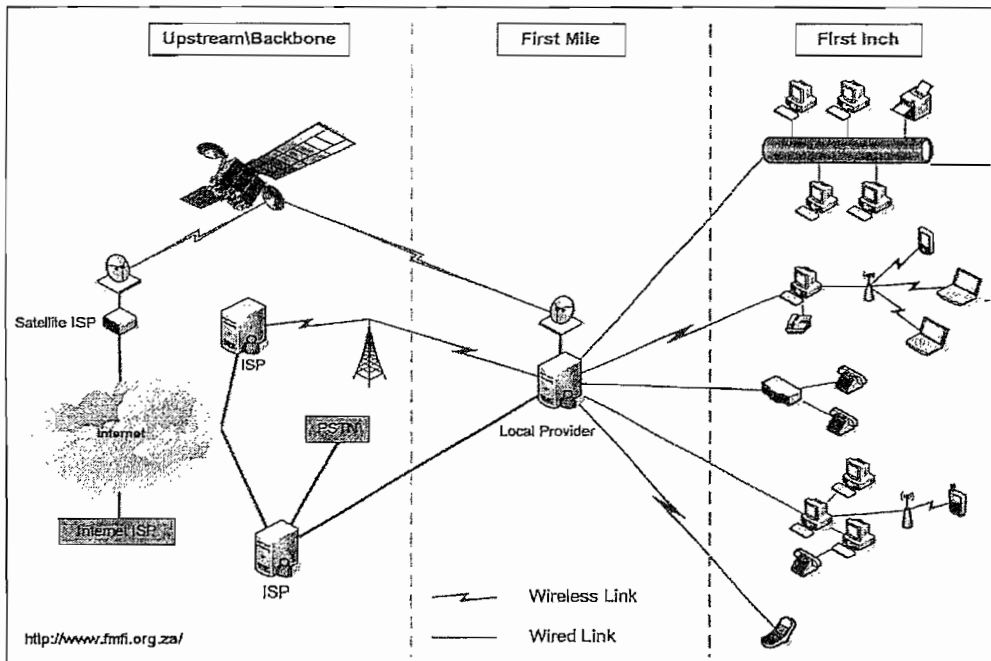


Figure 3: A schematic diagram of the *First Mile, First Inch* concept

Subsequent to the FMFI project, Wireless Africa was constituted as a research group of the Meraka Institute to research ways and means to develop sustainable information and communications technology in developing countries (CSIR 2005).

Providing connectivity to under-serviced rural areas comes with a unique set of challenges such as the high cost of installing equipment, lack of reliable power, skill shortages and high cost of providing Internet connectivity which is mostly satellite based. The recent emergence of low-cost commodity wireless 802.11 devices and the use of mesh networking as a key enabling technology for rural areas could see a new wave of connectivity in these areas. (Johnson and Roux 2008)

The Meraka Institute's first 'Cantenna' (an antenna made from a metal can, such as a coffee tin, and a section of bicycle spoke soldered into a special connector) was installed in a rural setting. It was mounted on the house of Agnes Mdluli, a health worker in Peebles Valley, near White River in Mpumalanga (as shown in Figure 4). These small, self-constructed antennas, which are made from locally available material, are connected to a low-cost WiFi card plugged into a computer. A small wireless router is placed in a weatherproof casing on a pole to which several community members can connect and form a community mesh network. This mesh networking technology allows the wireless installations to configure themselves automatically to find the optimal routes through the network, and very little configuration is needed to set them up. (CSIR 2005)

meraka
INSTITUTE
FOR
INFORMATION
AND COMMUNICATIONS
TECHNOLOGY



Figure 4: A photograph of the installation of a cantenna as part of a mesh network

R. N. Beyers

The Peebles Valley mesh network is deployed over an area of about 15 square kilometres, in a rural district near the Kruger National Park in South Africa. The network was built to explore cost-effective internet connectivity (802.11 network) to an AIDS clinic. This connects to surrounding schools, homes, farms and other clinic infrastructure through the mesh network. The AIDS clinic, which is a non-governmental organisation (NGO) funded by a pharmaceutical company social grant, has brought hope to over 700 patients in the area over the four years it has been running. The VSAT Internet connectivity was provided free of charge by a sponsor. The spare capacity is shared with users on the mesh network, free of charge, but has to be carefully managed by a firewall to ensure that its usage does not affect the clinic's Internet availability.

The lessons learnt from the deployment of mesh technologies, are that it is an affordable solution to address connectivity in rural communities. The added bonus is that it is possible to train a local entrepreneur to set up and maintain the network for the benefit of the whole community. The implication of this is that additional access points can be established, ranging from community centres, police stations, learners' and teachers' homes, libraries, district offices, etc providing more community members with access to information that may be deployed on such a network (adapted from Wireless Africa 2009).

The Ulwazi Project

In a separate initiative the *Ulwazi project* emerged in 2001 out of a need to address a digital divide that was further exaggerated by a transport divide. Learners from Mamelodi and Atteridgeville attending outreach classes at St Alban's College in the eastern suburbs of Pretoria from the early 1990's made huge personal sacrifices to receive essential supplementary tuition having to rely on inefficient bus services. (Beyers 2007)

In 2001, a partnership formed between the Department of Communications (which supplied seed funding), Motorola (which supplied the broadband Canopy radio network) and Edge Interactive (which supplied SMART Interactive Whiteboards) to wirelessly connect Gatang Comprehensive School in Mamelodi and St Alban's College some 15 km away. Each classroom was equipped with a PC, speakers, a microphone, data projector and a webcam. This facilitated two geographically separated classes being taught simultaneously, with a common digital curriculum interface in the form of a SMART interactive whiteboard, as shown in Figure 5.

Extending education and social benefits through 'hub schools'

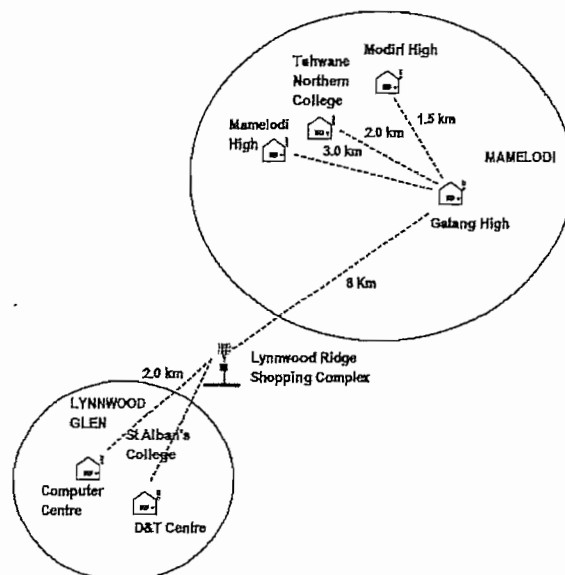


Figure 5: A schematic representation of the original Ulwazi network (Beyers 2007)

The lessons learnt from the establishment of the Ulwazi concept (Beyers 2007) demonstrated that

- cost effective inter-school connectivity could be achieved;
- virtual interactive classrooms could be established which did not rely on expensive satellite or other communication technologies;
- schools could be given access to shared digital resources to promote digital and social inclusion;
- educators could also be regarded as a sharable resource;
- interactive science lessons and experiments could be delivered across such a network;
- the success of such a project is reliant on the presence of a champion in the community.

The project was extended to include a further three schools in Mamelodi township outside Pretoria, thanks to a small grant from the Motorola Foundation.

The same concepts are inherent in the Ligbron e-Learning Project, a school community project that shares mathematics and science lessons with rural,

R. N. Beyers

disadvantaged and underperforming schools by using video conferencing and desktop sharing (Ligbron Academy of Technology 2009).

Young Engineers and Scientists of Africa (YESA)

Moving away from connectivity issues, the Young Engineers and Scientists of Africa (YESA) was conceived out of a need to stimulate the Science, Engineering and Technology (SET) pipeline from as early an age as possible, and to supplement the shortage of skills in the areas of SET. During the launch of the Joint Initiative on Priority Skills Acquisition (JIPSA) in 2006 (Mlambo-Ngcuka 2006), it was announced that ‘professional skills in engineering, science, finance and management, as well as technical and artisan skills, were critically needed as the South African economy moves into higher gear.’ The belief was that ‘nothing short of a skills revolution by a nation united will extricate us from the crisis we face’.

The Accelerated and Shared Growth Initiative for South Africa (Asgi-SA) ‘identified the shortage of skilled labour as one of the six constraints to its goal of boosting economic growth to 6%’ (SouthAfrica.info 2006) and the government has acknowledged that ‘the single greatest impediment to its public infrastructure programmes – as well as private investment programmes – is the country’s shortage of skills’. As South Africa moves more towards a knowledge economy, there is an increased need for innovation and associated production, infrastructure development and maintenance. The time is now right to make a long-term investment in future generations, by introducing interventions that will contribute positively to the nurturing of graduates with the right knowledge, skills, attitudes and values.

YESA was incubated within the Meraka Institute, where a range of interventions (as portrayed in Figure 6) was piloted in preparation for the formation of a national delivery vehicle aimed at reaching all schools in the country. The assumption is that more learners need to be exposed to the wonders of a world of SET, in the hope of convincing an increasing number of individuals to pursue careers in related fields, ultimately producing more PhD graduates. This will potentially also have a knock-on effect with the National System of Innovation.

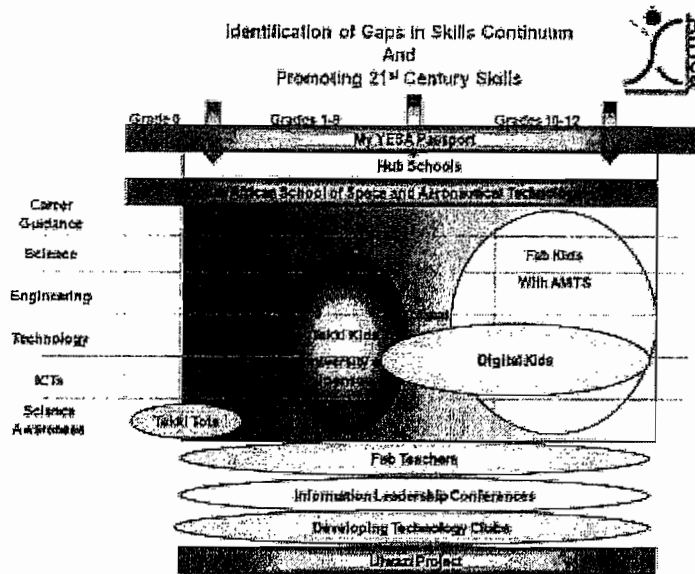


Figure 6: A schematic representation of various YESA interventions highlighting the focus areas across the different grades

The assumption is that the range of interventions should be catering for a broad continuum of SET skills, while providing meaningful career guidance opportunities. Figure 6 illustrates a number of key gaps in this continuum of skills, where further interventions will be sought to address these identified gaps.

YESA's primary focus is on stimulating creativity and innovation, rather than on training and information transfer. Through a process of hands-on interventions it is also possible to identify talent amongst learners as they participate in a variety of activities. YESA strives to achieve the ideal of having each learner participate in at least one SET intervention per year, throughout their school career, and to track this involvement via a national portal. In order to achieve this, YESA has aligned itself with the Youth into Science Strategy (YISS) (Mangena 2007) of the DST. YESA is also a member of the Federation of Engineering, Science, Technology Olympiads and Competitions (FESTOC 2009).

During the pilot phase of these interventions, the need to extend the reach to all schools became apparent, as did (more importantly) the need to extend these opportunities to rural communities. The ideal situation would be to have all approximately 28 000 schools in South Africa sufficiently resourced and interconnected to achieve this goal, but this is unlikely to happen in the near future, as the current government has higher priorities to attend to. The next logical step is to explore opportunities of capitalising on the lessons learnt from

the Ulwazi Project, to digitally include remote schools in YESA-type activities. This will add an additional layer on top of providing surrounding schools with access to shared resources for teaching and learning, including the digital sharing of educators.

e-Education plays a key role as the foundation stone of most YESA interventions, though the focus is much higher up the technological ladder, spawning high-level skills critically needed for the economy. Computer literacy is assumed, where the emphasis is on utilising technology as an enabling environment, and learners are encouraged to operate outside the box of traditional education.

PRINCIPLES OF THE HUB SCHOOL CONCEPT

The hub school concept is reliant on the availability of an information communication backbone such as a mesh network, where there is a point of presence in a community (as shown in Figure 7).

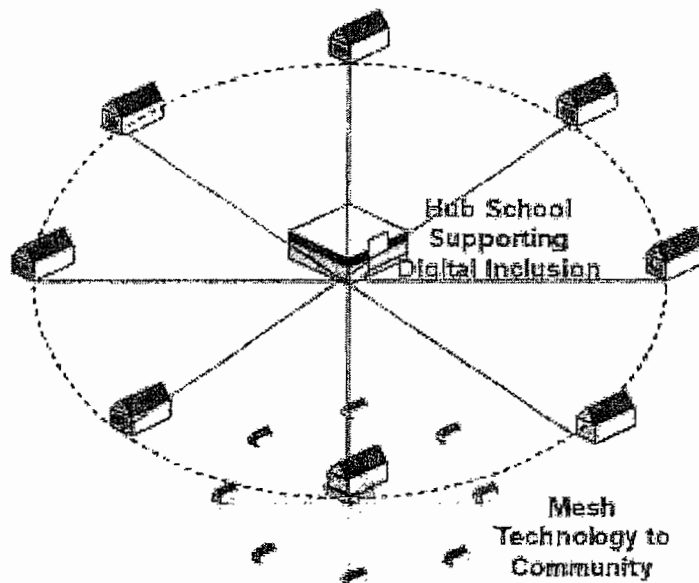


Figure 7: A schematic representation of the hub school concept, using mesh technologies to remote schools and distributing further to local communities

These points of presence can provide schools with access to shared resources on the network, thus reducing the geographic and information isolation currently experienced by many schools across South Africa, but more so in deep rural

areas. The concept of the hub school is the realisation of the principle of the e-school, as embodied in the *White paper on e-education*. The term 'e-school' has the tendency to retain the focus on activities within the school, and does not necessarily imply that the community can play a significant role in the lives of these organisations in their midst. On the other hand, the concept of a hub school implies that it is the focal point radiating outwards to the broader community. In the case being presented here, it involves digitally interconnecting the whole community to the school, so as to share both the physical and digital resources available, with as many local inhabitants as possible.

In order to physically realise this, it is proposed that mesh technologies currently being researched and deployed by Wireless Africa be used to disperse the points of presence of the radio networks, from a school to the broader community. While drawing on the digital resources provided by access to the provincial wireless backbone, mesh technologies can provide the infrastructure needed to connect the likes of

- other schools in the immediate area;
- the homes of teachers and learners;
- educational district offices;
- local community centres;
- police and fire stations;
- local libraries;
- local on-line entrepreneurial businesses, etc.

From an educational perspective, the concept of a hub school implies that there is an investment in a central point, rather than dispersing scarce resources across a wider area. A good example of this would be the proposed investment in the concept of a Fab School located at the hub school. It is not financially viable to invest in technology to equip a FabLab in every school in the country to provide hands-on training of FabKids. The hub school would assist in managing these resources, with the responsibility of sharing them with other schools as well as the local community through organised training sessions at the central venue.

To ensure that learners continue to develop their creative and innovative talents, they will be encouraged to take the Open Office (open source) software home with them to install on their personal computers, where available. In the absence of home computing and/or computers in outlying schools, it is proposed that digital doorways be installed in schools and community centres. Access to the hub school through the use of mesh technologies will ensure that learners

can continue ‘innovating’ and accessing information beyond the confines of the hub school. The option of participating in digital manufacturing exists, where learners could email their designs to the hub schools to be manufactured, for future collection.

Negropte wrote in an e-mail interview that ‘one of the saddest but most common conditions in elementary school computer labs (when they exist in the developing world), is that children are being trained to use Word, Excel and PowerPoint. I consider that criminal, because children should be making things, communicating, exploring, sharing, not running office automation tools’ (Vota 2007). There is a need to overcome the ‘ignorance-is-bliss’ factor by clearly demonstrating the power of ICTs as a tool, and encouraging learners to think and operate outside the box of traditional education.

EDUCATIONAL BENEFITS OF A HUB SCHOOL

Figure 8 represents a schematic diagramme of how the different elements of the hub school concept are interlinked.

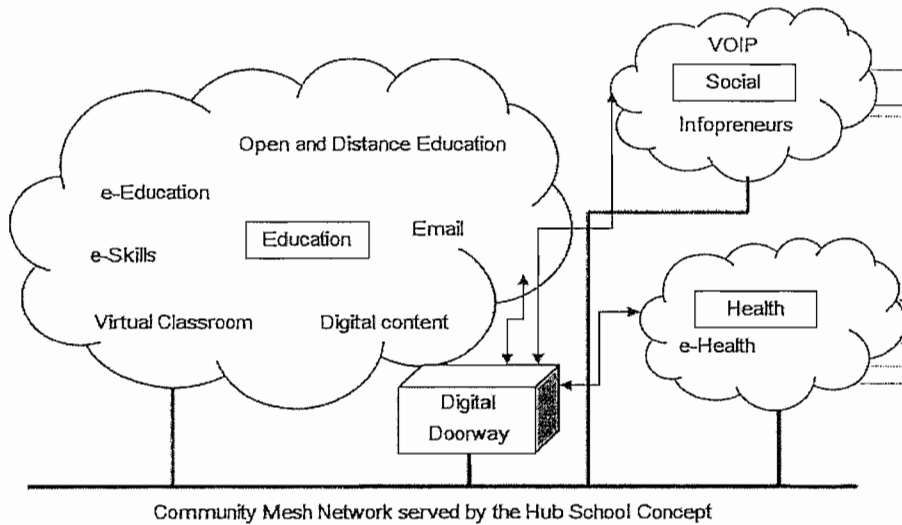


Figure 8: A schematic representation of the interrelationship of education, health and social benefits within a connected hub school community

The point of the presence of a radio network backbone located at a school, is a strategic decision to empower schools to become the centres of their communities. Possible benefits of such an infrastructure could be listed as follows:

- Schools and classrooms have cost-effective access to shared digital resources. The network could either have open access to the Internet or be closed, depending on the funding model. The positioning of a server anywhere on the network implies that digital content would be accessible virtually on demand. The type of digital resources could range from static Web pages to content management systems, wikis and blogs, and even digital videos on demand. Collaboration with learners and teachers at other schools can provide an essential catalyst for learners to utilise ICTs in a different mode from that of basic literacy, while making provision for collaborative projects;
- The content management systems could be used to supplement normal education and to make provision for accredited courses, where available. This will go a long way towards promoting the concepts inherent in distant education, by making provision for more learners to access information to further their education;
- Video conference and application sharing tools, coupled to shared timetables between schools in the community, can provide the opportunity to share educators within a region – especially in scarce key subjects like Mathematics and Science. At the same time, schools with additional resources would be well positioned to share them virtually with other schools as centres of excellence, especially in the sciences (as demonstrated in the original Ulwazi Project);
- Teachers and learners may be provided with free access to shared resources from home, through the use of cantennas attached to a mesh network which is either purchased or developed by a local entrepreneur. This will go a long way towards breaking down the phenomenon of 'strong-room technologies', where computer equipment is often locked away in the school's strong-room for fear of it being stolen. 24-hour connectivity to this content means that it becomes a resource outside of the confines of the school building and normal school hours;
- The presence of an IP-based network implies that teachers and learners will also have access to a minimum of email connectivity. This can be operated internally within the network, or, if circumstances allow, full email connectivity to the Internet. This is an important tool that learners need to interact with, in order to develop essential communication skills as part of a process of globalisation and accessing information. Yes, many learners are already communicating via cell phone text messages, but they also need to acquire the netiquette of utilising additional business tools for the real world;

R. N. Beyers

- When planning for the establishment of such a network, it is important to include the option of publishing information in the form of web pages, blogs and wikis. Web 2.0 tools can play an important part in collaboratively generating new knowledge, and learners need to be exposed to the process of authenticating information as well as addressing the realities of plagiarism;
- The presence of computers in schools can be used to automate the capturing and processing of school administrative data, as well as test and examination results. By centralising the software for the school's administration systems at a strategic point on the network, district officials can data mine the collective records of all schools, in order to make real-time decisions for the benefit of the whole community. School attendance, trends in subject results, numbers of students per grade or subject, etc., can be made available to senior management;
- The distribution of circulars can be enhanced and monitored more effectively by email. This could be coupled to a free IP-based telephony system over the network, empowering principals and officials alike to communicate with all network-linked institutions in the district;
- The concept of a hub school could also be deployed at other institutions, such as FET colleges. Learners in these environments could be provided with the academic background to electronics, networking, computers, etc., and then tasked to set up and maintain mesh networks linking schools and other centres in their immediate vicinity. This would enhance the notion of a true OBE approach, where learners potentially enter the job market with skills that could be applied immediately. The presence of a FabLab within FET colleges could further stimulate creativity and innovation, thus promoting the concepts of manufacturing within these institutions;
- The presence of a hub school in a community can provide the framework for Living Labs.

The lack of a proper understanding of what triggers innovations and which innovations prove to be successful in different environmental, social and cultural contexts poses a big threat to the design of real-world innovation. This is in particular true for South Africa. Being a 'society in transition' facing the challenge of social change and social innovation South Africa needs to understand how to do advanced African innovation research. Designing real-world innovation in an African way might therefore differ from the indigenous tradition and might not be similar to the western world as well; however, what's similar is that its start is community-driven and co-creation of innovation where all stakeholders are involved. (LLISA 2009)

This article is confined largely to the educational benefits of a hub school, where the presence of such infrastructure can go a long way towards community empowerment. Local entrepreneurs could be invited to set up and maintain the infrastructure, to the point of purchasing the equipment within the community as well. Interconnecting a number of businesses within such communities has the potential to spawn additional new industries, thus providing further employment opportunities.

As part of the way forward, it is proposed that an appropriate instrument be developed to evaluate and validate the effectiveness of the hub school system in communities. This will provide invaluable research to determine the multi-layered impact of such an intervention.

CONCLUSION

There is a great deal of untapped potential amongst the South African Net Generation, and the challenge is therefore to unleash it by providing more individuals with tools in their 'tool-bags for life'. The deployment of hub schools, as part of community networking opportunities, can benefit from large-scale connectivity projects. At the same time, the concept cannot be seen as just an educational solution, but rather the layering of additional services on top of a communications infrastructure that can be scaled up, should bandwidth consumption demand it.

The presence of a hub school in a community, together with more and more technologies emerging in rural communities, provides opportunities for the e-skills debate to be expanded further, for the benefit of more individuals. The focus shifts more towards how to utilise the technologies for social gain, rather than just skills training. In terms of the technological ladder, it creates opportunities for more individuals to move up towards the ICT practitioner and innovator level.

This multi-disciplined approach to deploying a range of solutions can provide a test-bed for some real African research, in order to come up with an African solution. This approach in no way attempts to circumvent the important role of teachers in the education process. On the other hand, it can provide the mechanism to supplement this process by providing greater access to information.

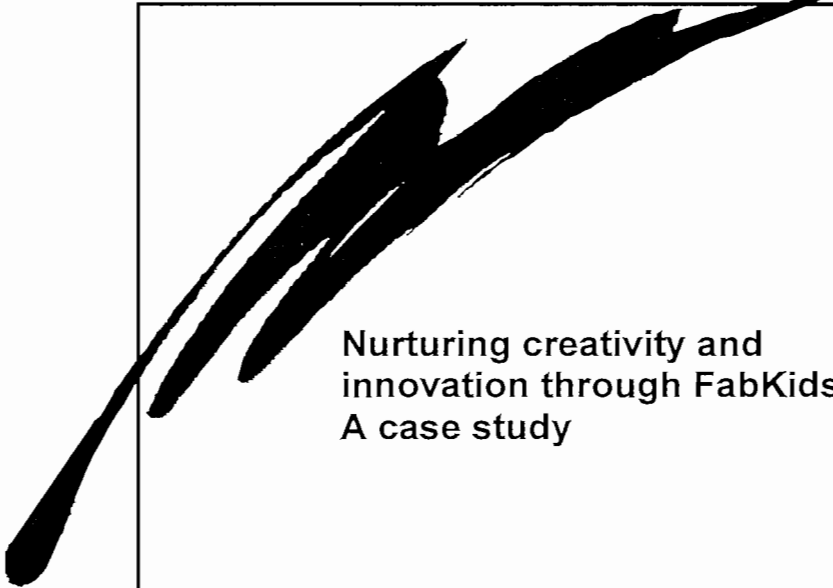
ICT provides hope for overcoming barriers of social and geographical isolation, increases access to information and education, and enables the poor to participate in the making of decisions that have an impact on their lives. (Department of Education 2003)

R. N. Beyers

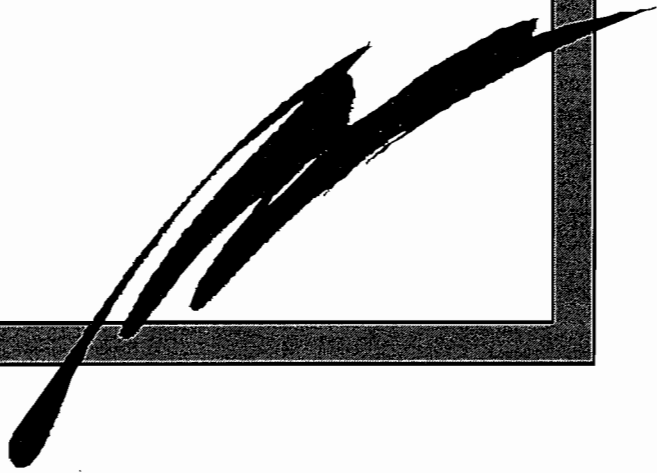
REFERENCES

- Bates, A. W. 1995. *Technology, e-learning and distance education*. Oxford: Routledge.
- Beyers, R. N. 2007. The Ulwazi Concept – virtual interactive and collaborative classrooms of the future. *South African Journal of Higher Education* 21: 748–760.
- _____. 2008. Creating a Sputnik moment for learners in Africa. Second South African International Aerospace Symposium, Cape Town.
- Burniske, R. W. 2008. *Literacy in the digital age*. Thousand Oaks: Corwin Press.
- Cambridge, G. L., R. Smith and K. L. Gush. 2008. Kiosks are breaking through the digital divide in Africa: First among equals. *Kiosk Europe Summer*. Kiosk Europe.
- CSIR. 2005. *CSIR annual report*. Pretoria: CSIR.
- Department Of Education. 2003. Draft White Paper on e-Education: Transforming learning and teaching through ICT. Cape Town: Government Press.
- _____. 2004. White Paper on e-Education: Transforming learning and teaching through information and communication technologies. Cape Town: Government Press.
- Digital Doorway. 2009. The Digital Doorway. Available at: http://www.digitaldoorway.org.za/index_main.php. Accessed on 29 October 2009.
- FESTOC. 2009. Federation of Engineering, Science, Technology Olympiads and Competitions. Available at: <http://www.nstf.org.za/festoc>. Accessed on 27 October 2009.
- FMFI. 2008. First Mile, First Inch. Available at: http://www.fmfi.org.za/wiki/index.php/First_Mile_First_Inch_Home_Page. Accessed 27 October 2009.
- Gauteng Online. 2009. *Gauteng Online* [Online]. Available: <http://www.gautengonline.gov.za/web/guest/home>. Accessed on 27 October 2009.
- Johnson, D. and K. Roux. 2008. Building rural wireless networks: Lessons learnt and future directions. 2008 ACM Workshop on Wireless Networks and Systems for Developing Regions, San Fransisco, California, USA.
- Khanya Project. 2009. Khanya Project. www.khanya.co.za. Accessed on 27 October 2009.
- Ligbron Academy Of Technology. 2009. Ligbron Distance Learning Project. Available at: <http://www.ligbronelearning.page.tl/Home.htm>. Accessed on 4 March 2010.
- LLISA. 2009. Living Labs in Southern Africa – LLISA. Available at: http://llisa.meraka.org.za/index.php/Living_Labs_in_Southern_Africa. Accessed on 29 October 2009.
- Mangena, M. 2007. Keynote address by Minister Mosibudi Mangena at the launch of the Youth into Science Strategy. 28 October, Sci-Bono Discovery Centre, Johannesburg. Available at: <http://www.dst.gov.za/media-room/speeches/keynote-address-by-minister-mosibudi-mangena-at-the-launch-of-the-youth-into-science-strategy>. Accessed 27 October 2009.
- Mbeki, T. 2001. State of the Nation Address of the President of South Africa, at the National Assembly Chamber, Cape Town, 9 February. Available at: <http://www.info.gov.za/speeches/2001/0102131223p1001.htm>. Accessed on 28 October 2009.

- _____. 2002. State of the Nation Address by the President of South Africa, Thabo Mbeki, to the Joint Sitting of the Houses of Parliament, Cape Town, 8 February. Available at: <http://www.info.gov.za/speeches/2002/0202281146a1001.htm>. Accessed 28 October 2009.
- Meraka Institute. 2009. African Advanced Institute for Informaiton and Communication Technologies. Available at: <http://www.meraka.org.za>. Accessed 27 October 2009.
- Mitra, S. 2009. Hole in the wall: Lighting the spark of learning. Available at: <http://www.hole-in-the-wall.com/MIE.html>. Accessed 4 March 2010.
- Mlambo-Ngcuka, P. 2006. Address delivered by the Deputy President, Phumzile Mlambo-Ngcuka, at the launch of the Joint Initiative for Priority Skills Acquisition (JIPSA), Presidential Guest House, 27 March. Available at: <http://www.info.gov.za/speeches/2006/06032810451001.htm>. Accessed 27 October 2009.
- Morris, C. 1999. First Mile, First Inch (FMFI). Available at: http://www.idrc.ca/en/ev-86357-201-1-DO_TOPIC.html. Accessed on 27 October 2009.
- _____. 2007. First mile, first inch. IST-Africa 2007 Conference, Maputo, Mozambique.
- Pandor, G. 2003. Draft White Paper on e-Education: Transforming learning and teaching through ICT. Available at: <http://www.info.gov.za/view/DownloadFileAction?id=68766>. Accessed 28 October 28.
- Republic of South Africa. 2001. Telecommunications Act, 2001. Telecommunications Amendment, No. 64 of 2001. Government Gazette. Pretoria: Government Printers.
- SouthAfrica.info. 2006. Skills initiative to boost growth. Available at: <http://www.southafrica.info/business/economy/development/jipsa-270306.htm>. Accessed on 27 October 2009.
- Thutong Portal. 2009. Thutong: National Educational Portal. Available at: <http://www.thutong.org.za>. Accessed on 27 October 2009.
- Vota, W. 2007. Microsoft Office is practical, not criminal education. Available at: http://www.olpcnews.com/use_cases/business/microsoft_office_education.html. Accessed on 27 October 2009.
- Wireless Africa. 2009. Wireless Africa. Available at: http://wirelessafrica.meraka.org.za/wiki/index.php/Wireless_Africa_Home_Page. Accessed on 29 October 2009.



**Nurturing creativity and
innovation through FabKids:
A case study**



Nurturing Creativity and Innovation Through FabKids: A Case Study

Ronald Noel Beyers

© Springer Science+Business Media, LLC 2010

Abstract This paper will report on a case study that was conducted involving Grade 10 learners who were exposed to a high-tech rapid-prototyping environment of a Fabrication Laboratory as part of a FabKids experience. This project must be viewed in the context of a global shortage of key skills placing a higher priority on the initiation and development of a pipeline to attract youth into science, engineering and technology careers. Creativity and innovation feature high on the skills agenda but more importantly preliminary results indicate that learners from a broad range of schools were able to operate effectively in this post constructivist environment. Participants had to apply their knowledge, skill, attitudes and values in order to produce a solution to the challenges provided. The fundamentals of the design process of investigate, design, make, evaluate and communicate were emphasized where the FabKids had to draw on their own collective knowledge using a range of technologies available to them.

Keywords Creativity · Innovation · Design process · FabLab · Net Generation · Knowledge workers

Abbreviations

AMTS	Advanced Manufacturing Technology Strategies
DST	Department of Science and Technology
FabLab	Fabrication Laboratory
FESTOC	Federation of Science, Technology and Engineering Olympiads and Competitions

FET	Further Education and Training (Grades 10-12)
GET	General Education and Training (Grades 0-9)
LED	Light Emitting Diode
MIT	Massachusetts Institute of Technology
N-Gen	Net Generation
NCS	National Curriculum Statements
NSI	National system of innovation
RNCS	Revised National Curriculum Statements
OBE	Outcomes Based Education
RFID	Radio-frequency identification
YESA	Young Engineers and Scientists of Africa
YiSS	Youth into Science Strategy
ZPD	Zone of Proximal Development

Introduction

What can be made in a Fabrication Laboratory or FabLab? While there are limits, especially for technical novices, the imagination drives the process. Currently the labs include computer controlled machines with spatial resolution down to microns, and electronics that have time resolution in microseconds. The ability to design and innovate in microns and microseconds puts powerful capabilities into the hands of FabLab users. Communication devices, sensing technologies, building structures, arts and crafts—all are within reach using the tools and materials in a FabLab. High profile projects made in FabLabs include: solar and wind turbines, wireless data networks, thin client computer interfaces, a press fit house (no nails, no cement), long-range antennas, and sheep sensing and tracking devices (Lassiter 2009, p. 3).

R. N. Beyers (✉)
Young Engineers and Scientists of Africa Programme, CSIR
Meraka Institute, PO Box 395, Pretoria 0001, South Africa
e-mail: ron@yesa.org.za

Lassiter also shares a vision of the twenty-first century and strategizes around this “emerging economy where there are new skills, new kinds of knowledge, and new ways of knowing that will be required to compete in an economy based on digital media, communication, and information.”

These labs are showing that “giving people the ability to make things for themselves can be the fastest way to solve their problems, particularly in communities with little access to education or technology” (Fab Central 2008). Some labs are on the verge of spinning off small businesses. “Fabs are now moving from experiments to becoming serious tools in addressing developing nations’ problems,” says Sushil Borde, executive director of the non-profit Fab Foundation, who has helped launch FabLabs in both India and South Africa. The deepest form of aid you can give a country is to allow them to design and make things (Mandavilli 2006).

The introduction of FabLabs into South Africa in recent years saw the focus on sharing these resources with the general public to empower both individuals and rural communities where the vast majority of users were university students and enthusiasts. The problem that was identified by the researcher was that even though access was open there was little or no emphasis on promoting the use of these resources at school level. The need to expose learners to the high-tech rapid-prototyping environment from as early as possible was also identified as a means of promoting creativity and innovation. This was perceived as being of benefit to learners entering tertiary education and potentially promoting Science, Engineering and Technology (SET) based careers.

Reynolds in his statement of research and teaching interests recalls a turning point in his life when he knew from a very early age that he was a scientist and engineer at heart. His career effectively began as a 10 year old ham radio fanatic, on the day his father brought him his first oscilloscope. Twenty years later he was a qualified electrical engineer and computer scientist, designing, building, and characterizing complex systems of sensors, actuators, computation, and communication to solve real world problems (Reynolds 2006).

A critical component of Reynolds’ statement is that his focus was on real-world problems which were not limited to laboratory curiosities. Extrapolating this further, the knowledge that he generated was not restricted to the confines of textbook knowledge but resulted in a wide variety of innovative real-world applications.

Reflecting back on this scenario it could be argued that had he not had access to the opportunities that his education and upbringing afforded him he may not have found himself on the same career path. In contrast to this the vast majority of learners, especially in a multicultural and economically diverse country such as South Africa, have to rely on an education system to provide career guidance information. This is compounded by the fact that the social and economic fabric of many homes has been disrupted by the AIDS pandemic, resulting in an increasing number of teenagers as heads of households. Daily life for many youth is focused on survival with limited access to meaningful career changing opportunities. It may be argued that there are many learners with Einstein’s capabilities that are being lost by a society that is failing to address their basic socio-economic needs, let alone affording every child a meaningful education.

The main difference between the original intention embodied in Gershenfeld’s FabLab and the FabKids is that the latter approach exposes learners to a marginally structured process rather than relying on a more open-ended one. Details of the process will be elaborated on later in this paper.

This paper will report on the pilot project as a case study conducted with a range of learners from difference schools in the greater Tshwane metropolitan area. The research problem under investigation was to investigate whether learners would be able to operate effectively in such an environment given their different school backgrounds.

The FabKids intervention forms one of the corner stones of the Young Engineers and Scientists of Africa (YESA) project which was initiated by the Meraka Institute in 2006. Other programs which are associated with YESA include TekkiTots (pre-school), TekkiKids (Grades 4–7), Fab Teachers (for selected subject and all grades) and Digital Kids programs (all grades). There are also plans to investigate Digital Teachers and even Digital Parents. The aim of YESA is to initiate a SET pipeline by creating hands-on opportunities for learners to experience more key moments of exposure to SET in their school careers and to assist them in making more informed career choices.

The FabKids intervention supports the DST’s Youth into Science Strategy (YiSS), which relates, “firstly, to the promotion of science and technology literacy among the public, generally, and the youth, in particular; and secondly, to increasing the enrolment of a cohort of demographically representative youth with talent and potential into science, engineering and technology (SET)-based careers” (Mangena 2007). YESA is also an active member of Federation of Science, Technology and Engineering Olympiads and Competitions (FESTOC) which “aims provide a structured support to the affiliated Olympiads and

competitions, and will be better able to get the thousands of youth with talent and potential to participate in such competitions” (Mangena 2008).

Science, Engineering, Technology and Outcomes Based Education

Technology has been a determining factor in human history since time immemorial and in the twenty-first Century this will be so to an even greater extent. It is imperative that South Africa makes the right choices, sometimes difficult, to enhance our adoption and mastery of the technologies which will assist us in becoming a competitive nation. Basic science also has a crucial role to play in our country, not just because it is the platform on which applied science and technology are based, but because it has cultural and intellectual foundations as profound as those underpinning music, literature and other products of the human mind (Mabandla 1996).

‘Creativity’ and a ‘national system of innovation’ (NSI) are two critical elements of the South African government’s White Paper on Science and Technology. It refers to

Innovation as becoming a crucial survival issue. A society that pursues wellbeing and prosperity for its members can no longer treat it as an option. In practice innovation is the application in practice of creative new ideas, which in many cases involves the introduction of inventions into the marketplace. In contrast, creativity is the generating and articulating of new ideas (Department of Arts Culture Science and Technology 1996).

Naiman (2007) on the other hand defines “creativity as the act of turning new and imaginative ideas into reality. Creativity involves two processes: thinking, then producing. Innovation is the production or implementation of an idea. If you have ideas, but don’t act on them, you are imaginative but not creative.”

A more elaborate definition of the term Innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services. There are generally two types of Innovation: incremental and radical. Incremental innovation is generally understood to exploit existing forms or technologies. It either improves upon something that already exists or reconfigures an existing form of technology to serve some other purpose. In this sense it is innovation at the margins. A radical innovation, in contrast, is something new to the world and a departure from existing technology or

methods. The terms breakthrough innovation and discontinuous innovation are often used as synonyms for radical innovation. More recently, Christensen has used the term disruptive innovation to describe a technical innovation that has the potential to upset the organization’s or the industry’s existing business model. In almost all cases, these innovations are radical. Disruptive technologies displace the established technology and precipitate the decline of companies whose business models are based on them. In many instances, disruptive technologies create new markets (Harvard Business School Press 2003, p. 3).

The establishment of YESA has provided an opportunity to encourage learners to allow their creativity to come to the fore especially through the FabKids and Digital Kids programmes. The intention is to demonstrate that over a period of time it is possible to nurture this creative spirit to the point where individuals are able to see opportunities for incremental innovation and ultimately move onto stimulate radical innovation in the different sectors that they may find themselves in.

In a teacher-centred education system there is very little scope for development of these types of skills where the main mode of “teaching is usually based on pure information transfer and where the teachers is regarded as a gatekeeper who authorizes knowledge” (Buckler 2004). This is in stark contrast to a knowledge society where people of similar interests try to make effective use of their combined knowledge and experience in their areas of interest, and in the process contribute to the body of knowledge.

In order for South Africa to draw benefits from participating in a knowledge economy the education system has to produce knowledge workers who are equipped with the necessary knowledge, skills, attitudes and values to do so. Creativity and innovation should be viewed as primary skills and attitudes in the toolkits of such workers who are able to turn creative ideas into innovative ones through the manufacture and delivery of physical artefacts or systems.

While individual creativity is important, exciting, and even crucial to business, the creativity of groups is equally important.

The creation of today’s complex systems of products and services requires the merging of knowledge from diverse national, disciplinary, and personal skill-based perspectives. Innovation—whether it be revealed in new products and services, new processes, or new organizational forms—is rarely an individual undertaking. Creative cooperation is critical (Leonard and Sensiper 2000).

The content-heavy education system of the apartheid era in South Africa has been superseded by a more skills-based

learner-centred Outcomes Based Education (OBE) which attempts to embrace constructivism as a learning theory. Legislation is in place for the deployment of the National Curriculum Statements (Department of Education 2002) as entrenched in the Curriculum 2005 approach to education. The first cohort of learners who have been exposed to this new pedagogy exited the system in 2008. The new approach does not require teachers to define in advance what they are going to teach as behavioural objectives but rather to assess the effectiveness of this process by looking for the evidence that teaching had taken place. In the former approach learners were assessed according to a predefined memorandum whereas OBE looks for hard evidence that learners are able to apply the knowledge acquired through the demonstration of key skills

Theoretical Perspectives

In conceptualizing the FabKids project it is relevant to ground the work in a pedagogical perspective. This project relies heavily on the theory of Piaget's constructivism.

From his observation of children, Piaget understood that children were creating ideas. They were not limited to receiving knowledge from parents or teachers; they actively constructed their own knowledge. Piaget's work provides the foundation on which constructionist theories are based. Constructionists believe that knowledge is constructed and learning occurs when children create products or artifacts. They assert that learners are more likely to be engaged in learning when these artifacts are personally relevant and meaningful (Wood et al. 2008).

This theory forms an integral part of interpreting active learning and in the school of constructivism which has its origins in work of education reformer John Dewey and Russian psychologist Lev Vygotsky. In the case of the FabKids the technologies that are employed are not the focal point of the exercise but are used as tools to create artifacts through the design, manufacture and assembly of a solution to a given challenge.

The FabKids are able to combine personal experience and their existing knowledge in order to construct new meaning in solving the challenges that they are confronted with. This was evident in the diverse range of solutions that were produced as the physical manifestation of the individual's and group's collective creativity.

The Net Generation (N-Gen) is defined as "the population of about 90 million young people who have grown up or are growing up in constant contact with digital media" (Tapscott 1998).

Born between roughly 1980 and 1994, the Millennials have already been pegged and defined by academics, trend spotters, and futurists: They are smart but impatient, expect results immediately and carry an arsenal of electronic devices—the more portable the better. Raised amid a barrage of information, they are able to juggle a conversation via Instant Messaging, surf the Web, and listen to an iTunes playlist while reading *Twelfth Night* for homework. Whether or not they are absorbing the finer points of the play is a matter of debate (Carlson 2005).

Most teachers in the classroom today, by contrast, grew up without computers in their homes, schools, or even at teacher training colleges and universities. As a result, some are trying to catch up with the technological innovations that are making their way into the classroom. In addition to acquiring new technical skills, teachers also must decide how to best implement these new teaching tools into the curriculum and their personal style of teaching.

Real learning gets to the heart of what it is to be human. We become able to re-create ourselves. This applies to both individuals and organizations. Thus, for a 'learning organization it is not enough to survive. "Survival learning" or what is more often termed "adaptive learning" is important—indeed it is necessary. But for a learning organization, "adaptive learning" must be joined by "generative learning", learning that enhances our capacity to create' (Senge 1990, p. 14).

Translating this into the school environment one would assume that the stakeholders are the learners themselves and not necessarily the parents. As learners in a constructivist environment they are not passive recipients of information but should be actively engaged in the learning process. More importantly, barriers to enabling all learners to maximise their potential need to be removed. It is imperative that interventions involving learning should take cognizance of the changing needs of the Net Generation within enabling learning environments especially where ICTs are employed in the classroom. This implies that educational institutions should be transformed into dynamic learning organizations that are preparing the youth for life in a technological world and not for the outdated society that their teachers grew up in.

The introduction of projects such as the Formula One in Schools Project (<http://www.flinschools.co.za>) is a good example of "authentic learning where the learners become 'cognitive apprentices' to the experts while focusing on what happens in the real world" (Marra n.d.).

This is in stark contrast to the information transfer that has very little reference to the real world and which is

prevalent in many schools in South Africa today. This approach stifles knowledge generation and ultimately limits creativity and innovation as necessary ingredients to nurture higher order thinking skills. “For many students, education has become nothing more than drill and response where there is no relevance for the materials the students are expected to learn” (Gardner 1991).

Authentic learning for FabKids is vested in the notion that there is very little information transfer via formal ‘teaching’ processes during FabLab sessions. Learners bring their own knowledge tool kits with them and are encouraged to apply this information to solve the problems using their collective wisdom.

It is relevant to consider an educational theory on psychology relating to the Zone of Proximal Development (ZPD) which was conceived by Vygotsky.

ZPD is defined as ‘the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers’ (Vygotsky 1978, p. 86). In simple terms this can be viewed as ‘what the child is able to do in collaboration today he will be able to do independently tomorrow’ (Vygotsky 1987, p. 211). What is implied in this theory is that learning and development are interrelated. Learning is not the same as development but may lead to it.

Adult involvement in the process can provide the scaffolding of information in order to add greater meaning to the learning process. The term ‘scaffolding’ was developed as a metaphor to describe the type of assistance offered by a teacher or peer to support learning. In the process of scaffolding, the teacher helps the student master a task or concept that the student is initially unable to grasp independently. The teacher offers assistance with only those skills that are beyond the student’s capability (Lipscomb et al. 2004).

Group Demographics

The focus of the original pilot project conducted in 2007 and 2008 at the Innovation Hub in Pretoria, was to demonstrate proof of concept for the FabKids intervention. The information that was gathered was based on a course assessment questionnaire. Permission was granted from the Gauteng Education Department to interact with Grade 10 learners the following schools:

- St Mary’s DSG (12 Female—mixed races)
- St Alban’s College (12 Male—mixed races)
- Mamelodi High (5 Male and 5 Female)
- Gatang Comprehensive (5 Male and 5 Female)
- The Glen High (6 Male and 6 Female—mixed races)

A total of 56 learners participated in the pilot project with each school being involved for approximately 7 hours.

Summary of the Activities for the Day

After a brief welcome learners were introduced to the FabLab. This was followed by an introduction to such concepts as Gershenfeld’s “printing of a bicycle” (Gershenfeld 2005), to stimulate the thought processes and to encourage them to think outside the box.

A critical element of FabKids methodology is the application of the Design Process inherent in the Learning Area of Technology Education at the General Education and Training Phase (GET) for grades 1–9 (Department of Education 2002). The five steps include: Investigate, Design, Make, Evaluate and Communicate. These steps were contextualised in the challenge presented to the learners. For the purposes of the pilot project all schools were given the same problem of: ‘Designing a business card holder that would attract the attention of people walking past a desk’. The FabKids experience is based on the concept of teamwork which is essential for competing in today’s global arena, where “individual perfection is not as desirable as a high level of collective performance” (Stevens 2002, p. 24).

It may be possible to differentiate between collaboration and cooperation with reference to a division of labour. In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work ‘together’. However, some spontaneous division of labour may occur even when two people really do work together (Dillenbourg 1999).

The net result of this approach is a “more efficient use of manpower leads to opportunities for informal and incidental learning” (Marsick and Volpe 1999).

The specific tasks assigned to each team included:

- Team Managers had to oversee all phases of the task.
- Design Engineers were responsible for the capturing of the ideas onto computer using Open Office Draw which were then printed to a laser cutter.
- Electronics Engineers had to assemble the electronic components using a 555 timer circuit and two Light Emitting Diodes (LEDs).
- Media specialists were responsible for the development of the group logos using Open Office Draw or the

completion of a report for the day which is published live on the internet via Google Groups.

The selection of the groups and the allocation of the responsibilities were left entirely up to members of each team in order to cater for individual interests. Once the groups were formed, they were tasked to pool their ideas by collectively producing a number of possible solutions as simple sketches on paper which included the dimensions of the different components. At a stage when the designs were nearing completion all the Design Engineers were extracted from the groups and given a rudimentary introduction to Open Office Draw for approximately 10 min. Their instructions included:

- launching the program in Windows or Linux (Ubuntu)
- defining the page layout size to accommodate the laser printer
- saving their designs regularly
- creating objects such as lines and shapes
- resetting sizes of object to absolute sizes
- rotation of objects and
- merging of shapes

On completion of this the Electronics Engineers were extracted from their groups where they spent approximately 3 hours with individual attention for the assembly and completion of the circuits. The training was conducted by an intern based at the FabLab.

The first phase of the activity lasted approximately 1–2 hours after which the Design Engineer transferred their designs to the computer in collaboration with the Team Manager. Their task was to accurately capture their sketches as two dimensional components which, when cut on the laser cutter, could easily be assembled as three dimensional objects. The first prototype was produced on a sheet of cardboard. This ‘cheap mistake’ is perceived as a critical step in the process as most teams discovered small inconsistencies which had been overlooked during the design phase. Teams were encouraged to ‘make mistakes’ and to learn from the process rather than be worried by a fear of failure. This is encapsulated in the English Proverb “He who never makes mistakes, never makes anything”.

After making the necessary adjustments to the designs the final models were cut out of Perspex using the laser cutter as shown in Fig. 1. By this time the circuits were either complete or nearing completion, depending on how efficiently the Electronics Engineers were at identifying problems such as dry soldering joints and the correct placement of components. The circuits and LEDs were integrated into the final models by the whole team.

Figure 2 shows a team assembling the final product including the electronic circuit into the base of the model. The Media Specialist was also responsible for a journal

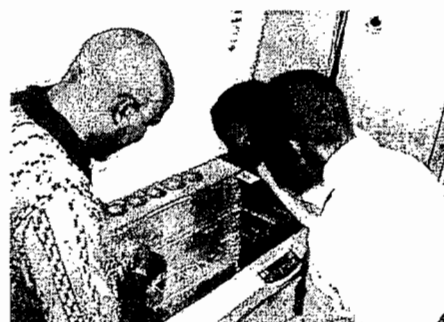


Fig. 1 Two students and a teacher observing the laser cutter in action



Fig. 2 Shows team members assembling the final product including the electronic components

report for the day which generally included digital photographs to be posted onto a Google Groups web page.

The management of the day was largely done through a process of “dynamic facilitation which worked with each person’s natural inclinations and genius, enabling the group to produce a better solution in faster time, while building trust and new levels of capability” (Rough 2008). The learners were free to ask for assistance when they encountered problems rather than the adoption of a teacher-led step-by-step process. In essence the Team Managers took full responsibility for the completion of the tasks and all teams did so successfully although two of the 16 sub groups were pressed for time.

Summary of the Findings

It must be emphasized that the pilot project was not aimed at doing an in-depth quantitative study but rather to establish proof of concept. The data presented thus provides an insight into how the participants experienced the FabKids sessions. The administration of the course evaluation questionnaires served to identify some important

aspects that will need further investigation in order to draw more conclusive results.

The following points serve as relevant highlights:

- 78% of learners regarded themselves as computer literate
- 62% had not participated in any science or technology related competitions
- 84% would consider a career in Science, Engineering and Technology as a result of the FabKids experience

Responses to the question of what they did enjoy included:

- 94% enjoyed the design process
- 34% highlighted team work as being important
- 49% electronic enjoyed the electronics even though only one in four participants had hands-on experience of this section

Responses to the question of “What they did not enjoy” included:

- Approximately 94% were happy with everything
- 22% of learners reported that the laser cutter took too long to print especially with the more complex designs.
- Overall the ‘negative comments’ were of a minor and more personal nature and did not detract from the overall success of the day.

Responses to what the participants learnt from the FabKids experience included:

- The results were positive with a broad spectrum of learning taking place across a range of skills.
- In general approximately 30% highlighted the importance of team work in the completion of the task.

During a videotaped ‘informal press conference with learners from the Glen High School, a student reported that it was the first time that they were able to experience and apply the design process rather than learning about it theoretically. Added to this the group agreed that there was very little information transfer that took place during the workshop as they were responsible for their own outputs. The opportunity that they were afforded allowed them to apply a range of skills such as lateral thinking, problem solving, creativity and innovation while working in groups in an environment where there were no right or wrong answers.

All groups produced a final product which represented a broad range of solutions. This concept is inherent in the learning area of Technology for Grades 1–9 which is contrary to the more traditional woodworking model where all learners produce the same final product according to the teacher’s specifications. The fact that all the learners were actively engaged in the process meant that many of the groups did not break for tea or lunch time as they were

totally absorbed in their work. The final solutions from the groups were all functional and of a similar high standard.

A final observation is that all learners who participated in the pilot project were able to operate at a similar level no matter what school they came from. This indicates that potentially all learners may benefit equally from such an intervention if the project were to be massified to all schools in the country.

Conclusions and Recommendations

In reflecting back on the learner-centred FabKids experience it is relevant to take stock of the outcomes achieved. OBE in a South African context emphasizes a learner-centred and activity-based approach to education. The Critical Outcomes of the National Curriculum Statements require learners to be able to:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively with others as members of a team, group, organization and community;
- organize and manage themselves and their activities responsibly and effectively;
- collect, analyze, organize and critically evaluate information;
- communicate effectively using visual, symbolic and/or language skills in various modes;
- use science and technology effectively and critically showing responsibility towards the environment and the health of others; and
- demonstrate an understanding of the world as a set of related systems by recognizing that problem solving contexts do not exist in isolation

(Department of Education 2002)

In reviewing the FabKids experience it is evident that all of these National Critical Outcomes are met within a single project although initial FabKids encounters were of a limited nature due to time constraints of a single session. The intention is to expose more learners to these types of experiences in order to develop a more positive attitude towards SET from a hands-on perspective which warrants further investigation. The process has been equated to ‘lifting the lid of education’ and allowing the learners to operate outside the confines of traditional classrooms and pedagogies.

The implicit assumption in selecting the types of learners drawn from a broad range of schools was that they would all cope with the challenges of a FabKids experience. This assumption was confirmed by the fact that all groups managed to complete the tasks by effectively using the tools available to produce realistic solutions, irrespective of their backgrounds. Another important issue is that

all groups were working to their own design specifications and not according to ones supplied by the teacher as is the case in a more traditional woodwork or metalwork methodology.

There is a significant emphasis on computer literacy in most schools as they attempt to address issues such as access and bridging the digital divide. The dilemma is that the potential impact of this approach is severely hampered by limited access time to computer laboratories. Where computers have been deployed in schools, the access time for the vast majority of learners is severely restricted. In addition, the teachers may not be competent and confident enough to deal with large classes, let alone be able to deliver meaningful e-learning experiences.

The FabKids experience focuses on the use of computers as a tool to promote such concepts as teamwork, authentic and experiential learning by adopting a constructivist approach. This approach emphasizes the need "to create opportunities to use ICTs beyond just computer literacy which will empower the learners to operate much higher up the technological ladder" (Beyers 2008). Embedded in this approach is the notion of providing each learner with a meaningful experience which potentially could become a key SET moment in making a career choice. Long term impact studies are needed to clarify the effectiveness of this methodology.

The FabKids experience has the potential to provide an avenue for these Net Generation learners to express themselves in a more meaningful manner. Many were comfortable with using ICTs as the tools of their choice in solving the real world problems, irrespective of their backgrounds.

A significant outcome of the original pilot project is the need to support the learners when they returned to their respective schools. Many of the participants left on a creative and innovative 'high' and there is little support for them thereafter. As a result of the pilot FabKids intervention a Fab Teacher project is proposed where educators and even subject advisors for various learning areas and subjects would be exposed to the same processes as the FabKids. The only difference being the discussion of the pedagogy needed to assist the Fab Teachers to replicate the processes in their respective schools. It must be emphasized that the focus is on how technology can be used as a tool in education implying that teachers do not need to have access to a technology rich environment to implement the design process. The presence of a well-equipped technology-rich environment such as a FabLab can, however, greatly enhance the outcomes of such an experience.

To add further support to the Fab Teachers project, a process of curriculum mapping has been undertaken to link the design briefs to the NCS. This has been done effectively with the subject of Design at the Further Education and Training (FET) level. Distinct possibilities exist for

synergy with Engineering, Graphics and Design, Science as well as Technology as a learning area at the GET level. The possibilities exist of linking up with languages, computer studies and Life Orientation, intimating the cross curricular nature of a FabKids intervention.

As part of the massification process a model of deploying a number of Fab Schools is envisaged for each of the provinces.

The intention is to invest in a Hub School which could provide support to a number of satellite schools in the immediate community. Learners and teachers would be exposed to a Fab School experience and may be able to continue innovating in their own schools which are connected to the Hub School via a mesh network along the lines of the Ulwazi Concept (Beyers 2007).

This may also provide support to teachers and learners in their own communities while enabling a process of social transformation to take place through access to more community based information and other schools. Access to the shared resources could be increased where it is conceivable that learners will be empowered to translate their ideas into designs that are then emailed to the Hub School for digital manufacturing and collection, thereby increasing the returns on investments at such a Hub School.

Other aspects of the project that need further investigation include integrating the FabKids experience into science and technology Olympiads as well as SET competitions in association with FESTOC. This can be done by providing learners with the insight into how the FabLab resources could be used to translate ideas into physical artifacts. Adding an entrepreneurial aspect to this process could spawn a number of interesting small industries adding greater value to the economy as a whole.

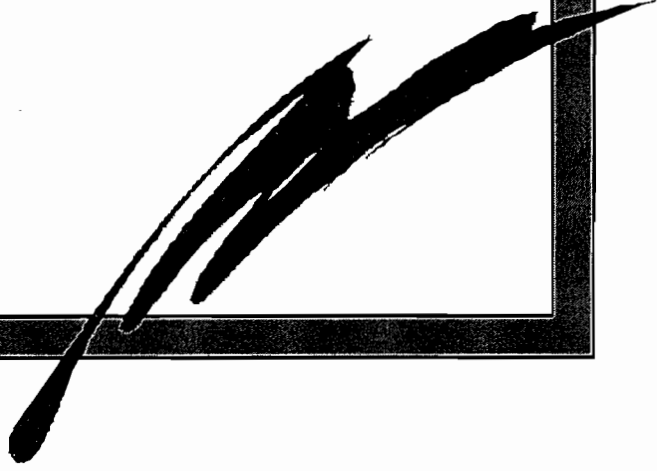
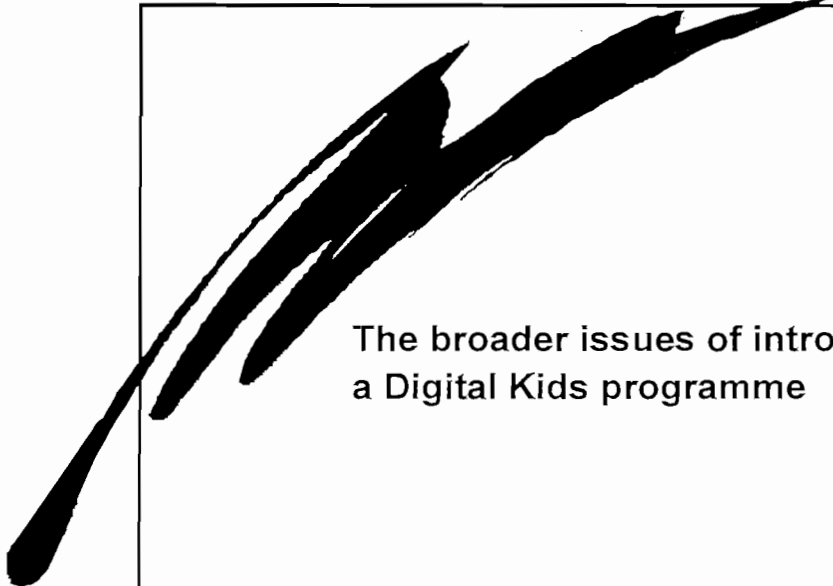
With time and experience further design challenges will be developed and tested across a range of different grades matching the levels of interest and capabilities with the individual learners while developing additional 21st century skills. The option of integrating the FabKids into a number of other projects is certainly not out of the question. These may include longer term interventions where learners participate in collaborative projects with other schools integrating mechanisms to produce more complex solutions to challenges.

To increase the number of PhD graduates contributing to the goals of the National System of Innovation, requires a long-term investment. Given the necessary support and encouragement at the lower levels the SET pipeline can be initiated and developed from an early age with positive long term outcomes. The FabKids intervention has demonstrated that there is potential amongst our youth which needs to be channelled in the right direction for the benefit of the country as a whole.

The FabKids experience has given new meaning to the dictum of Confucius around 450 BC: "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand."

References

- Beyers RN (2007) The Ulwazi concept—virtual interactive and collaborative classrooms of the future. *S Afr J High Educ* 21(6):748–760
- Beyers RN (2008) Creating a Sputnik moment for learners in Africa. Paper presented at the in South African international aerospace symposium
- Buckler A (2004) Towards a new model of general education at Harvard College. Retrieved 27 Aug 2008, from <http://www.lancs.ac.uk/fias/events/general07/docs/interdisc/Interdisc-Buckler-Harvard.pdf>
- Carlson S (2005) The net generation goes to college. the chronicles of high education; information technology. Retrieved 20 Aug 2008 from <http://chronicle.com/free/v52/i07/07a03401.htm>
- Department of Arts Culture Science and Technology (1996) White paper on science & technology: preparing for the 21st century. Retrieved 24 Aug 2009, from http://www.dst.gov.za/publications-policies/legislation/white_papers/Science_Technology_White_Paper.pdf
- Department of Education (2002) National curriculum statements grades R-9, from <http://www.education.gov.za/Curriculum/GET/doc/overview.pdf>
- Dillenbourg P (1999) What do you mean by collaborative learning? In: Dillenbourg P (ed) *Collaborative-learning: cognitive and computational approaches*. Elsevier, Oxford, pp 1–19
- Fab Central (2008) Fab Central. Retrieved 25 Aug 2008, from <http://fab.cba.mit.edu/about/>
- Gardner H (1991) *The unschooled mind: how children think and how schools should teach*. Basic Books, New York
- Gershenfeld G (2005) FAB: the coming revolution on your desktop—from personal computers to personal fabrication. Basic Books, New York
- Harvard Business School Press (2003) *Managing creativity and innovation* (Harvard Business Essentials). Available from http://www.amazon.com/Managing-Creativity-Innovation-Business-Essentials/dp/1591391121/ref=sr_1_1?ie=UTF8&s=books&qid=1256631556&sr=1-1
- Stevens M (2002) *Extreme management: what they teach at Harvard Business School's Advanced Management Program*. Warner Books, New York
- Lassiter S (2009) Vision on the road to the future. Retrieved 27 Oct 2009 from <http://isites.harvard.edu/fs/docs/icb.topic558015.files/Lassiter-Vision-On%20the%20road%20to%20the%20future.pdf>
- Leonard D, Sensiper S (2000) The role of tacit knowledge in group innovation. In: Smith DE (ed) *Knowledge, groupware and the Internet*. Elsevier, Amsterdam, p 281
- Lipscomb L, Swanson J, West A (2004) Scaffolding. *Emerging perspectives on learning, teaching, and technology*. Retrieved 5 Feb 2010, from <http://projects.coe.uga.edu/epltt/index.php?title=Scaffolding>
- Mabandla B (1996) White paper on science & technology. Preparing for the 21st Century. Retrieved 31 Aug 2008, from http://www.naci.org.za/pdfs/whitepaper_st.pdf
- Mandavilli A (2006) Appropriate technology: make anything, anywhere. *Nature* 442:862–864
- Mangena M (2007) Keynote address by Minister Mosibudi Mangena at the launch of the youth into science strategy. Department of Science and Technology, South Africa
- Mangena M (2008) Speech by Minister Mosibudi Mangena, at the launch of National Youth Service and FESTOC. Department of Science and Technology, South Africa
- Marra T (n.d.) Authentic learning. The history of "Authenticity". Retrieved 28 Aug 2008 from <http://www-personal.umich.edu/~tmarra/authenticity/authen.html>
- Marsick V, Volpe M (1999) The nature and need for informal learning: advances in developing human resources. *Sage J Online* 1(3):1–9
- Naiman L (2007) Creativity at work: articles & tips. What is creativity? Retrieved 26 Oct 2009 from <http://www.creativityatwork.com/articlesContent/whatis.htm>
- Reynolds M (2006) Statement of research and teaching experience and interests. Retrieved 12 Sep 2007 from <http://alumni.media.mit.edu/~matt/cv/reynolds-research-teaching.pdf>
- Rough J (2008) Dynamic facilitation skills. *Dynamic facilitation*. Retrieved 12 Aug 2008 from <http://www.tobe.net/>
- Senge PM (1990) *The fifth discipline: the art & practice of the learning organization*. Currency and Doubleday Publishing, New York
- Tapscott D (1998) *Growing up digital: the rise of the net generation*. McGraw-Hill, New York
- Vygotsky LS (1978) Interaction between learning and development (trans Lopez-Morillas M). In: Cole M, John-Steiner V, Scribner S, Soubberman E (eds) *Mind in society: the development of higher psychological processes*, pp 79–91
- Vygotsky LS (1987) *Thinking and speech* (trans Minick N). In: Rieber RW, Carton AS (eds) *The collected works of L. S. Vygotsky: vol 1. Problems of general psychology*. Plenum Press, New York, pp 39–285
- Wood KC, Smith H, Grossniklaus D (2008) Piaget's stages of cognitive development. Retrieved 2 Feb 2010 from http://projects.coe.uga.edu/epltt/index.php?title=Piaget%27s_Stages



The broader issues of introducing
a Digital Kids programme

Article 5

THE BROADER ISSUES OF INTRODUCING A DIGITAL KIDS PROGRAMME

ABSTRACT

The Digital Kids project is set in the context of establishing a pipeline for science, engineering and technology - as part of the Young Engineers and Scientists of Africa initiative. This was incubated within the Meraka Institute. Digital Kids aims to nurture key 21st century skills, especially digital literacy, in the youth of South Africa, thereby contributing to a larger human capital development process.

Digital Kids starts where computer literacy ends, promoting digital literacy by exposing learners to two- and three-dimensional graphics and animations, video editing, blogs, wikis and an introduction to programming - by using predominantly open-source, freeware and shareware software. Options for future sessions with these Net Generation learners include Live CDs, bootable USBs and portable applications. This paper will also look at some of the lessons learnt from the introduction of Digital Kids into a school environment, since these lessons may have an influence on the development of this initiative.

The concept of a digital divide has been devised to portray a life for learners beyond their level of basic access. This alternative approach integrates the digital divide into a technological ladder, encouraging and equipping learners to find their niche beyond computer literacy - all the way up to an ICT-facilitated practitioner. The country is in need of Prensky's Digital Natives to become thinking technologists - able to take full advantage of a wide range of software to master digital age skills. The skills learnt are to be viewed as tools to enable individuals to take full advantage of the knowledge society.

Key Words

21st Century Skills, Creativity, Digital Divide, Digital Literacy, Innovation, SET Pipeline

1. Introduction

In keeping with the South African Government's intense drive to harness and improve the skills of South Africans needed to sustain an accelerated economic growth, the Young Engineers and Scientists of Africa (YESA) programme was established in 2009 by the Meraka Institute (2007). It was sponsored by the South African Department of Science and Technology (DST). The aim of this intervention was to initiate and nurture the pipeline of science, engineering and technology (SET) graduates and postgraduates by addressing the problems - starting from pre-school to Grade 12.

This was undertaken in direct response to an ever-increasing shortage of skills in these areas. At the launch of the Joint Initiative on Priority Skills Acquisition (JipSA), it was announced that "professional skills in engineering, science, finance and management, as well as technical and artisan skills, were critically needed as the South African economy moved into higher gear" (Mlambo-Ngcuka, 2006).

The Accelerated and Shared Growth Initiative for South Africa (ASGISA) has "identified the shortage of skilled labour as one of the six constraints to its goal of boosting economic growth to 6%" (ASGISA, 2006). As South Africa moves more towards a knowledge-economy, there is an increased need for innovation and associated products, infrastructural development and improved maintenance programmes. The time is now right to make a long-term investment in the future generations by introducing interventions that will contribute positively to the nurturing of future graduates with the right knowledge, skills, attitudes and values needed to feed the South African National System of Innovation (NSI) and to meet the Millennium Development Goals.

This article will focus on one of the YESA programmes that is referred to as "Digital Kids". The intention of the research was not to conduct a detailed quantitative or qualitative investigation, but rather to focus on establishing a proof-of-concept and identifying some of the issues involved in introducing such a programme in a developing world scenario. Open-source, freeware and shareware software were all used to promote creativity and innovation - while developing 21st century skills. The research also sets out to investigate the feasibility of introducing such an intervention into the South African schooling system in extramural technology clubs.

Learners from five primary schools and two high schools in the Tshwane, or greater Pretoria metropolitan area, were exposed to the programme - with one school being adopted as a 'YESA school' - where a technology club was established.

Eighteen teachers attending the Advanced Certificate of Education (ACE) at Rhodes University were also exposed to certain aspects of the programme.

Though the penetration rates are low, there is a growing number of schools in recent years in South Africa that are placing a higher priority on exposing learners to the world of computer literacy through the acquisition of computer labs. This is happening with varying degrees of success. These scarce resources have generally provided limited access to a select number of learners to teach basic computer literacy - with little focus on skills higher up the technological ladder.

The Digital Kids programme should be viewed, not as an isolated entity, but rather as an integral component of a much larger process of equipping youth to operate more effectively in a technology-enriched knowledge economy. Digital Kids starts where computer literacy stops. It can also contribute to developing digital resources for educational purposes across all subjects and grades.

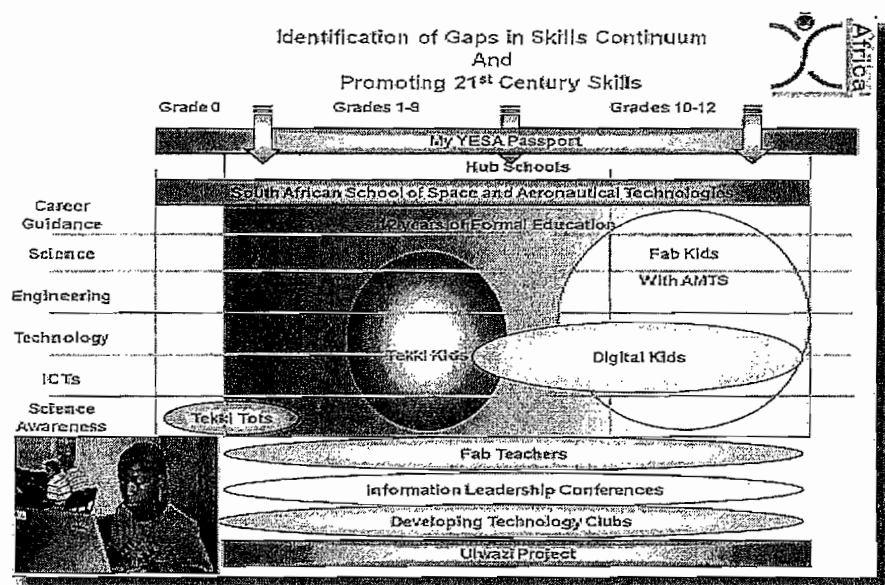


Figure 1: The YESA Skills Grid

Figure 1 represents the YESA skills grid; this was used to conceive the different interventions and to develop a skills continuum across all the grades. Each of the interventions was mapped according to the focus area of the skills involved. This same approach will be used to formulate future programmes to address identified gaps in the current system. The Digital Kids programme is set in the context of the recently introduced Outcomes Based Education (OBE) in South Africa. This emphasises skills development.

2. Concept Analysis

2.1. Action Research

The methodology that was adopted for this case study was based on the principles of action research.

Although there is a plethora of terms coined to describe this, research reflects wide disagreement on many key issues. Most agree on the following: action research is inquiry that is done by or with insiders to an organisation or community, but never to or on them. It is a reflective process, but it is different from isolated, spontaneous reflection - in that it is deliberately and systematically undertaken and generally requires that some form of evidence be presented to support any assertions. What constitutes evidence or, in more traditional terms, data is, however, still being debated (Herr, 2005: 3).

Action research is oriented to some action or cycle of actions that organisational or community members have taken, are taking, or wish to take, to address a particular problematic situation. The idea is that changes occur, either within the setting and/or within the researchers themselves (Herr, 2005: 3).

Typically, action research is undertaken in a school setting. It is a reflective process that allows for inquiry and discussion as components of the "research." Rather than dealing with the theoretical issues, action research allows practitioners to address those concerns that are closest to them, ones over which they can exhibit some influence and make any necessary changes (Ferrance, 2000: 6).

2.2. Digital Literacy

What exactly does it mean to be *literate* in the "post-modern" world? And what are educators talking about when they use the term "computer literacy" these days? On the one hand, "literacy" conjures up images of the technical skills required to "read and write," the denotation that the United States Army reinforced when it coined the term *functional literacy* during World War II. This line of thinking, as a number of literacy experts have noted, bred the ideas of "survival literacy" and "basic literacy."

However, the second strain of literacy, *critical literacy*, vexes the conversation far more today because of its many connotations, most of which stem from the idea of what it means to be "educated."

Though they may not be able to articulate it, many people intuitively understand that "functional literacy", though the prerequisite to other types of literacy seldom demands higher- order thinking skills. The teacher who incorporates new technology into her classroom may help students to learn how to "read and write", but she also needs to teach them how to interpret and "contextualise" the words and information they encounter in chatrooms, discussion forums, websites and more (Burniske, 2000).

Prior to the 21st century, literature defined a person's ability to read and write, separating the educated from the uneducated. With the advent of a new millennium and the rapidity with which technology has changed society, the concept of literacy has assumed new meanings. Experts in the field suggest that the current generation of teenagers possesses digital competencies to effectively navigate the multidimensional and fast-paced digital environment. For generations of adults who grew up in a world of books, travelling through cyberspace seems as treacherous and intimidating as attempting to speak a new language (Jones-Kavalier, 2006).

The public is often reminded that computers are powerful tools. The implication is, that with their use, personal power can accrue to the user. In the broadest sense, history does show a fluctuating connection between new literacy tools and power - in that success comes to those who can understand and manipulate at least one of two main domains of the information technologies: (a) the technical information infrastructure; that is, the physical properties and raw materials of literacy, including the tools, the technical personnel, the systems design, and the distribution mechanisms; and (b) the information itself, or more precisely, the discursive style that is peculiar to each medium and that shapes its content (Tyner, 1998: 3).

Tyner goes on to suggest a third way to use "literacy as a source of social power, and that is the ability to decode information into a variety of forms, analogous to the reading of print, but also applicable to audio, graphics and the moving image" (Tyner, 1998: 4).

The primary role of education is to equip a future generation to become effective citizens within a defined community. In an ideal world this would include a global village which is a goal for which educators should strive. With the introduction of modern information communication technologies (ICTs), the concept of globalisation has come to the fore - with more and more individuals finding themselves exposed to other societies. "The dynamic forces behind this era of globalisation were breakthroughs in hardware - from steamships and railroads in the beginning - to telephones and mainframe computers towards the end" (Friedman, 2007: 10).

Given the recent advances made in computers, improved networking capabilities, and more recently the processing power of mobile phones, connectivity to the rest of the world can be achieved from virtually anywhere, at any time – and it is not necessarily confined to an office, school or home environment.

The skills of the digitally literate are becoming as necessary as a driver's licence. The Internet is the fastest-growing medium in history. Whether we like it or not, this will affect you, and those around you at home and on the job, from the merging of your television portraying images with network data, to the emergence

of communities of users whose activities will change the shape of commerce and education. The Net's growing universality will create priceless resources for learning and self-advancement. If these won't overwhelm your life overnight, they will surely change it, subtly, continually, and with irresistible force (Glister, 1997: 2).

Digital literacy involves more than the mere ability to use software or operate a digital device; it includes a large variety of complex cognitive, motor, sociological, and emotional skills, which users will need in order to function effectively in digital environments. The tasks required in this context include, for example, "reading" instructions from graphical displays in user interfaces; using digital reproduction to create new, meaningful materials from existing ones; constructing knowledge from a non-linear, hypertextual navigation; evaluating the quality and validity of information; and have a mature and realistic understanding of the "rules" that prevail in the cyberspace (Eshet-Alkalai, 2004: 93-106).

2.3. The Technological Ladder vs the Digital divide

The origins of the term 'digital divide' emerged in the late 1990s in America. It was set in the context of the ancient problem of information inequality, the knowledge gap, computer literacy, and participation in the information society. Commonly, the digital divide was defined as the gap between those who do and those who do not have access to computers and the Internet. Access first of all meant physical access: having a personal computer and Internet connection (van Dijk, 2005: 1).

The term 'digital divide' caters for the clear demarcation of those who have access to technology and those who do not, but it does not envisage a future for learners and users beyond mere access. An alternative philosophical approach to the concept of the Digital Divide is to rather view the situation as a Technological Ladder - as represented diagrammatically in Figure 2. This is done in order to convey further development beyond mere access, as proposed by Beyers (2008).

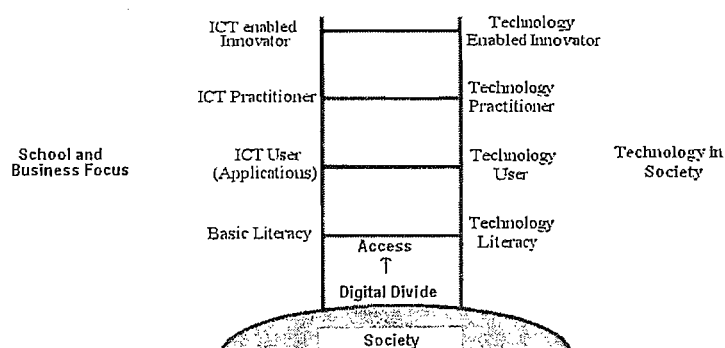


Figure 2. A Schematic Representation of the Concept of a Technological Ladder

The importance of the Digital Divide is not diminished in this model, but it is seen as the initial step to be overcome through the provision of access. The concept of a Technological Ladder implies the need to continue to provide ICT developmental targets higher up the ladder to which learners may aspire. Unfortunately, many learners will either remain on the first rung or even slip off it - as they are frequently left unprovided with any additional support or the necessary access time to further develop their newly acquired skills (Beyers, 2008).

Once basic literacy has been achieved, users need to be exposed to a variety of packages in order to become competent users. Beyond that, it is the mastery of the tools where ICT constitutes the main part of their future professions. The ultimate goal is the utilisation of the power of ICTs to conceptualise and realise their creative talents in the form of innovations (and ultimately patents). By providing challenges for ICT and other technology users, they need to be afforded the necessary support and vision of what can be achieved - rather than to be left as casual users of the products (Beyers, 2008).

Developing digital literacy in learners can no longer be merely a "nice route to go" for the more-advantaged schools. The education system needs to nurture more individuals who are better prepared to participate as effectual citizens in a digital world, and who can make a productive contribution to the economy. Simply put, "students who create "documents" to be saved in "folders" and placed on a "desktop" are learning how to speak a corporate language" (Burniske, 2008: 9). If this is the case then learners on the wrong side of the digital divide will find it increasingly difficult to compete for jobs in the corporate environment.

2.4. A National System of Innovation (NSI)

It is important to consider the impact of the formative years on the number of doctoral students a country can produce. The yardstick for innovation is generally the number of PhDs that a country produces. To increase capacity in the pipeline it is necessary to return to the source and make a long-term investment from as early an age as possible - in the hope of increasing the human capital feeder stock. YESA is the start of such an initiative and will feed into the South African government's awareness of the need to stimulate entrepreneurship, innovation and growth in knowledge-intensive businesses.

Science and technology education, innovation and commercialisation are integral components of our National System of Innovation (NSI). The key challenges are adequate funding, skilled human resources, improved private sector R&D, protecting and exploiting intellectual property, and integrating a fragmented government science and technology system (Comins, 2009).

3. The Digital Kids Programme

The seeds for the Digital Kids approach were sown in the late 1990s. While teaching Science to Grade 10 learners, the researcher had the opportunity to also teach Computer Science to the same group of learners. Given the fact that the curriculum was not very prescriptive in the middle grades in a private school environment, it was possible to introduce additional software packages to encourage learners to draw on a range of solutions – in order to enhance the presentation of projects submitted in other subjects. It was during one of these sessions that learners were asked to apply their newly acquired skills by using two software packages, namely Microsoft Paint and Ulead GIF Animator 1.5.

Assuming a more traditional approach to the teaching of the concept of the Electrolysis of Copper II Chloride, one may assume that the learners would be expected to draw and/or annotate a diagram of the process for which marks would be allocated accordingly. Figure 3 represents a memorandum for the marking of such an annotation.

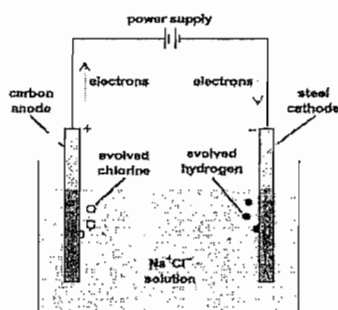


Figure 3: representing the annotation of the Electrolysis of Copper II Chloride (Electrolysis, 2009)

After completing a section on Chemistry the learners were then tasked to produce an animated Gif as part of a cross-curricular project using the newly acquired skills. Though there were varying degrees of success and some poor efforts, there was one in particular which is highlighted in Figure 4 as a successful effort.

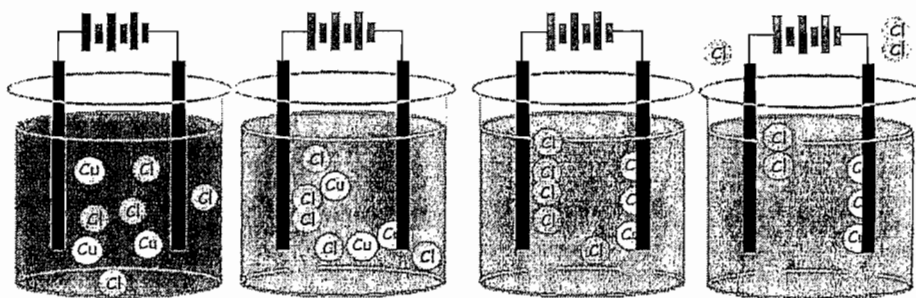


Figure 4 represents a select number of graphics in the animation series.

The following is a summary of three key lessons learnt from the exercise:

- The learners were able to translate their academic content into a digital format.
- This methodology provided for the identification of the more creative individual through the quality of the work produced.
- The materials developed could be used as a teaching resource.

The ability of the teacher to identify misconceptions in Science is often difficult. In this case it was possible to ascertain that the learners who produced the animations had a basic understanding of the process of electrolysis, but had failed to address the following problems:

- The 'ions' depicted in the animations were not clearly indicated as being charged.
- Chlorine was not depicted as being diatomic, (only in the last diagram).
- There was no indication of the flow of electrons.

Assuming that the learners were assessed in the traditional manner, they would probably have been awarded full marks for annotating and drawing a scientific sketch of the process, but this assessment would not have included an assessment of their ability to 'apply their knowledge'. Given the fact that the animations had inherent faults, one could potentially assume that it was of no use for teaching purposes. On the contrary, this same animation was used on a regular basis to highlight the importance of understanding the scientific processes, rather than absorbing mere rote learning of the content.

This opened up opportunities for further dialogues with the learners who were then encouraged to move on to more complex two- and three-dimensional graphics and integrated as animations. A key element for the researcher was that this provided an opportunity to 'see into the minds of the learners'.

4. Pilot Project Feedback

A key approach that was adopted during the pilot phase was based on utilising the available resources at the schools where, in this case, all training was conducted in a Microsoft Windows environment. Table 1 represents the number of schools that participated in the pilot project, together with the type of software used for training.

The schools were chosen on the basis of permission from the principal and the availability of a computer laboratory. Most of the schools were also involved in some way with the other initiatives of YESA, but not necessarily with the same group of learners. The decision as to which learners were selected was left entirely to the individual schools where the grades the learners were drawn from, was agreed upon between the school and the researcher at the outset of the meeting with the principals.

Once selected, the parents were sent a letter of introduction, together with a general indemnity form and a request for the necessary permission to proceed.

The software that was selected was based on the availability of open-source, freeware and shareware versions. Though there may well be more sophisticated software available for each of the software titles listed, they were generally selected for ease of use by learners. The emphasis was placed on providing the participants with a broad range of digital experiences during the initial training session. The intention was to then locate more advanced packages during the second and third years of repeating Digital Kids to the same set of learners.

The programme has not yet completed a full year of implementation, but this aspect will be borne in mind. It must also be noted that the list of software packages should not be seen as a definitive list, as further titles could yet be added to the list based on the interest levels of the learners.

	1. Meraka Staff Children	2. Hatfield Christian School	3. Gatang Comprehensive	4. Irene Primary School	5. Lynnwood Primary	6. Rhodes University (ACE)	7. Anton van Wouw Primary	8. Garsfontein Primary
Number of Learners	1 2	1 4	2 8	2 5	1 5	1 8	2 5	2 2
Microsoft Paint <i>Create a series of graphics</i>	X	X	X	X	X	X	X	X
Paint.Net <i>Editing and creating images</i>							X	
ULead Gif Animator <i>Merging a series of images</i>	X	X		X	X	X	X	X
Cinema 4D 6E <i>3D Graphics and animations</i>	X			X		X		
Microsoft Publisher <i>Business Cards and Letter Heads</i>			X					
Microsoft Front Page <i>Web Page designs</i>			X					
Microsoft Movie Maker <i>Capturing and editing video images</i>	X	X		X	X	X		
Microsoft Gif Animator <i>Merging a series of images</i>							X	X
Pivot Stick Animator <i>Stick animations</i>							X	X
CamStudio <i>Screen capturing for training videos</i>							X	X
PB Wiki <i>Storing work, blogs, collaboration</i>		X					X	
Gmail <i>Email communications</i>							X	
VLC Media Player <i>Viewing videos</i>							X	X

Table 1: Software packages used in the teaching of Digital Kids per group

School 3 presented an interesting case. The intention was to include as broad a range of schools as possible - especially where the institution in question was in a previously

disadvantaged community with a computer laboratory that was part of a provincial education departmental project. The PC securities had been so tightly configured that no additional software could be installed, even with six provincially appointed computer laboratory assistants in attendance. As a result of this, the session was restricted to the Microsoft software that was available on the system: with understandably limited outcomes.

The end product of each of the training sessions was a broad range of educational multimedia. Though the scope of this research was not to determine the efficacy of these end products, there can be little doubt that the learners were actively engaged in the process of acquiring new skills. All the lessons were conducted outside normal school hours.

In general learners were left with a positive attitude of "I can do IT". Apart from the school where the securities prevented the installation of software and the university environment where there were technical difficulties and security issues, the rest of the sessions were regarded as being generally successful. This was based on the fact that all the learners were able to complete the assigned tasks with varying degrees of creativity. However, further investigations are necessary to determine the effectiveness of this - by using the appropriate tools and methodologies.

5. Additional research opportunities

During the investigation into different operating systems: open-source, freeware and shareware, further opportunities emerged. The cost factor to the parents was an important consideration. All schools, except for school 7, did not pay for the training that was conducted, as the work was regarded as being part of a pilot phase of the investigation. In the case of school 7, four x five-hour sessions were conducted on Saturday mornings over a period of one school term. The software that was implemented was open-source software, thereby implying that no additional costs would accrue to the Technology Club.

Opportunities that need further investigation include the use of distributing Linux operating systems (OS) on bootable memory sticks, or as Live CD distributions as an alternative OS to Windows. The advantages of this are that users are able to boot up a fully functional OS without affecting the host machine's installation settings. Users are provided with a full Linux experience before deciding to take the bold step of installing the OS on their own PCs. The price to pay for such an experience is additional booting time, but this has to be weighed up against the portability of the OS to another PC.

Other alternatives are to set up virtual machines on the host machine with an additional OS, but this does require higher specifications on the host machine and additional skill sets.

Early versions of computer software did not require complex installation processes involving permanent storage devices - contrary to the modern resource-hungry versions of many office suites and other commercial packages. This model of distribution restricts the software to a single station and further licences are required for additional computers to

remain legal. A class of software which is emerging is referred to as Portable Applications which can be installed on to a flash drive.

Free Portable Software, Portable Freeware and Open-Source Portable Applications that can be run directly from a USB device are also required. It is possible to instal any of the portable appliances to a USB flash drive, thumb drive, pen drive, iPod or almost any other storage device. One can carry applications, tools, software, personal settings and files (in one's pocket) to use on any available Windows (or Mac in some cases) client's computer.

Many applications run entirely from the portable device, saving personal settings and changes back to the same device (Pendriveapps, 2006).

For learners, the ability to customise an application - and to transfer their own personal data between home and school - is certainly an advantage, provided the flash drives are not mislaid. Learners, after a Digital Kids session, often requested permission to remove the files that they had created to 'show their parents'. Portable applications of this nature could be sourced for future training sessions. Two applications that fall into this category would be Gimp (an open-source image manipulation programme (GIMP, 2009) and Blender (open- source, cross platform suite of tools for 3D creation (Blender.org, 2009).

In a teacher-centric mode of education, learners are expected to proceed at the pace defined by the teacher. Given the opportunity - especially in the absence of any supervision - learners who are interested in a topic are able to teach themselves: given the right resources. With the introduction of the Internet individuals have virtually instantaneous and potentially unlimited access to a wealth of information which is now at their fingertips. Numerous text-based and video-based tutorials are freely available for all the software packages used - ranging from entry level to advanced users - with a wide range of examples.

Over the past few years there has been a significant development of a broader range of software solutions which are no longer constrained by computing-processing power or memory and storage capacity. Earlier methods of delivering digital information were text-based. These have now become superseded by high-powered multimedia and virtual reality. These options can teleport learners into worlds previously not possible, giving thereby new meaning to Prensky's Digital Natives (Prensky, 2001).

6. Conclusions

This paper focuses on some of the issues and possible solutions to introducing supplementary programmes into schools through such initiatives as Digital Kids. This can now be done within the context of YESA, thereby promoting creativity and innovation. Although this paper serves to document the initial stages, further research is needed to measure the learning gains of such an initiative. This can be done by using the appropriate

tools and research methodologies. This will assist in unravelling the complexities of introducing ICTs into classrooms - especially in a developing world scenario.

The main outcome of the South African Government's White Paper on e-Learning is for: "Every learner in the Grades 1-9 to be ICT-capable by 2013": (Department of Education, 2004: 38). The document also makes reference to the need to go beyond computer literacy and to "developing the skills necessary to operate various types of information and communication technology" (Department of Education, 2004: 15).

Given the low penetration rates of computers into schools, high learner-to-computer ratios and inadequately prepared teachers, the chances of this becoming a reality for all Grade 1-9 learners is low.

The question is whether the South African society can afford to bear the costs of computer and digital ignorance - thereby adding weight to the old saying: "If you think education is expensive, try to cost ignorance" (Author unknown).

Educators should be encouraging the Net Generation to become knowledge producers, as learners have the adaptability to take full advantage of the convergence of modern technologies in an era of ubiquitous computing. Educators should be encouraging the use of mobile devices and fostering the ethics behind them to generate new forms of re-usable knowledge by using tools that unleash the creative and innovative spirit amongst more learners.

The Digital Kids experience has provided an opportunity for learners to develop digital and technology literacy within their educational context. "The shift from broadcast to interactive media is the cornerstone of the Net Generation, as they want to be users – not just viewers and listeners" (Tapscott, 1998: 3).

The introduction of Digital Kids into school environments has the potential to develop further e-skills to the point where learners can now generate very comprehensive e-portfolios which can be submitted for assessment. The question is whether teachers will be able to effectively assess such work when submitted in this format. This raises the potential to introduce a Digital Teachers programme to create a more sustained intervention for Digital Kids through the introduction of extra mural Technology Clubs in YESA-adopted schools. Digital Parents are also a distinct possibility for creating channels of communication between parents and their children. Parents need to be immersed in the 'language' of their children, while at the same time being exposed to the same or similar skills-development processes.

"Instead of being the targets of an educational system, learners should be offered an opportunity to be actively engaged in a constructivist manner" (James, 2001: 37) in the world with which they are familiar. They should further be encouraged to interact with it in ways that adults and teachers find difficult to comprehend - let alone to be able to teach in. Ideally, the modern curriculum should be equipping learners with the tools, skills, attitudes and values needed to take full advantage of what the digital world has to offer.

Digital Kids provides an opportunity for learners to climb the technological ladder. This opportunity is seldom being provided within the national curriculum in most schools in South Africa.

Adopting a more holistic approach to nurturing the SET pipeline, YESA is suitably positioned to make a meaningful contribution to the development of a range of e-skills, while simultaneously exposing learners to 21st century skills of Inventive Thinking, Digital Age Literacy, Effective Communication, High Productivity (Lemke, 2003: 5). Added to this is creativity and innovation as recipes for engaging learners within the stimulating environment of Technology Clubs.

Glossary of Terms

2D	Two-Dimensional
3D	Three-Dimensional
ACE	Advanced Certificate in Education
AsgiSA	Accelerated and Shared Growth-South Africa
DST	Department of Science and Technology
ICT	Information Communication Technology
JipSA	Joint Initiative on Priority Skills Acquisition
NSI	National System of Innovation
OBE	Outcomes Based Education
OS	Operating System
R&D	Research and Development
SET	Science, Engineering and Technology
YESA	Young Engineers and Scientists of Africa

- ASGISA. 2006. Accelerated and Shared Growth Initiative - South Africa (ASGISA) A Summary. <http://www.info.gov.za/asgisa> Date of access: 25 September 2009.
- BEYERS, R.N. 2008. *Creating a Sputnik Moment for Learners in Africa*. Paper presented at the 2nd South African International Aerospace Symposium.
- BLENDER.ORG. 2009. Blender.org. <http://www.blender.org/> Date of access: 02 October 2009.
- BURNISKE, R.W. 2000. Literacy in the Cyber Age http://www.acm.org/ubiquity/book/r_burniske_2.html Date of access: 22 September 2009.
- BURNISKE, R.W. 2008. *Literacy in the Digital Age* Second ed. Thousand Oaks: Corwin Press. p.
- COMINS, N.R. 2009. Innovation in South Africa - Are we doing enough? . <http://www.saine.co.za/?p=317> Date of access: 22 September 2009.
- DEPARTMENT OF EDUCATION. 2004. *White Paper on e-Education: Transforming learning and teaching through information and communication technologies*. <http://www.info.gov.za/view/DownloadFileAction?id=68777> Date of access: 24 August 2009.
- ELECTROLYSIS. 2009. Electrolysis: Definition from Answers.com. <http://www.answers.com/topic/electrolysis> Date of access: 03 August 2009.
- ESHET-ALKALAI, Y. 2004. Digital Literacy: A Conceptual Framework for Survival Skills in the Digital Era. . *Journal of Educational Multimedia and Hypermedia*, 13 (1): 93-106.
- FERRANCE, E. 2000. Action Research : Themes in Edfucation. (Northeast and Islands Regional Educational Laboratory At Brown University) http://www.alliance.brown.edu/pubs/themes_ed/act_research.pdf Date of access: 03 August 2009.
- FRIEDMAN, T.L. 2007. *The World is Flat. A Brief History of the Twenty-First Century*. New York: Picador. p.
- GIMP. 2009. GIMP - The GNU Image Manipulation Program. <http://www.gimp.org/> Date of access: 02 October 2009.
- GLISTER, P. 1997. *Digital Literacy*. John Wiley & Sons, In. p.
- HERR, K.G., & ANDERSON, G. L. 2005. *The Action Research Dissertation: A Guide for Student and Faculty* Thousand Oaks: Sage. p.
- JAMES, M., APPLEFIELD, R., & MAHNAZ, M. . 2001. *Constructivism in Theory and Practice: Toward a Better Understanding*. The University of North Carolina Press. p.
- JONES-KAVAILIER, B.R., & FLANNIGAN, S. L. . 2006. Connecting the Digital Dots: Literacy of the 21st Century

- <http://www.educause.edu/EDUCAUSE+Quarterly/EDUCAUSEQuarterlyMagazineVolume/ConnectingtheDigitalDotsLitera/157395> Date of access: 03 August 2009.
- LEMKE, C. 2003. enGauge 21st Century Skills. Literacy in the Digital Age. .
<http://www.metiri.com/21/21%20Century%20Skills%20Final.doc> Date of access: 26 February 2009.
- MERAKA INSTITUTE. 2007. Meraka Institute. <http://www.meraka.org.za> Date of access: 23 September 2009.
- MLAMBO-NGCUKA, P. 2006. *Address delivered by the Deputy President, Phumzile Mlambo-Ngcuka, at the launch of the Joint Initiative for Priority Skills Acquisition (JIPSA), Presidential Guest House: South African Government Information.*
- PENDRIVEAPPS. 2006. Free Portable Software USB Flash Drive Applications | Pendriveapps. <http://www.pendriveapps.com/> Date of access: 02 October 2009.
- PRENSKY, M. 2001. *Digital Natives, Digital Immigrants*. Vol. 9: MCB University Press. p.
- TAPSCOTT, D. 1998. *Growing up Digital: The rise of the Net Generation*. New York: McGraw-Hill. p.
- TYNER, K. 1998. *Literacy in a Digital World: Teaching and Learning in the Age of Information*. Lawrence Erlbaum Associates. p.
- VAN DIJK, J.A. 2005. *The Deepening Divide: Inequality in the Information Society*. Thousand Oaks: Sage. p.



Synopsis, reflection and contribution



SYNOPSIS, REFLECTION AND CONTRIBUTION

1. Introduction

The five articles submitted as part of this thesis were designed to reflect on the main research question. The unifying thread which runs through all the articles revolves around what role Human Capital Development and ICTs, creativity and innovation can play.

The first article, *The Ulwazi Concept – Virtual Interactive and Collaborative Classrooms of the Future*, was conceived as an experiment to resolve the question of a transport divide—accomplished by using a range of technologies. In this article the researcher laid the foundation for the rest of the investigations. The second article, *A Five-Dimensional Model for Educating the Net Generation*, the researcher took a philosophical stand in developing an alternative model to the use of ICTs in the classroom. The third article, *Extending the Education and Social Benefits through ‘Hub Schools’* relied on the presence of a stable information communications backbone, while it amalgamates a number of different projects of the Meraka Institute which the researcher formulated into a potentially larger project for the benefit of a wider community.

The lessons learnt from deploying the Ulwazi project played a significant role in the formulation of the Hub School Concept. With the *Nurturing Creativity and Innovation through Fab-Kids—A Case Study* article together with *The Broader Issues of Introducing a Digital Kids Programme*, the researcher shifted the focus to a more practical demonstration of the integration of technology, including ICTs, in the development of creativity and innovation and applying many of the lessons learnt in the previous three articles.

In the build up to 2006, the Meraka Institute at the CSIR, Pretoria, identified the need to establish a pipeline for youth involved in SET. The outcome of this was the establishment of the Young Engineers and Scientists of Africa (YESA) project—where the researcher piloted a number of interventions over a period of three years as part of an incubation phase of the organisation. This research was based largely on the results of two of these pilot projects, together with the accumulated experience of two decades of additional work that was conducted while the researcher was based at St Alban’s College in Pretoria.

The role of the newly established YESA project for which the researcher is solely responsible, has to be taken into consideration, as it is seen as a national delivery vehicle for all of the above-mentioned articles. YESA, in collaboration with a range of partner organisations can facilitate the process of introducing more learners to the SET pipeline by providing them

with access to the different interventions to which they may not necessarily have been exposed. Each intervention can have a significant impact on the number of learners pursuing SET-related careers in one way or another.

The underlying value-added service that YESA can provide is the tracking of an individual's involvement in SET activities. The aim is to identify learners with talent through the MY YESA passport system with a content-delivery mechanism through a MXit social networking environment. Opportunities were created to digitally include learners in remote locations through more cost-effective means by using mobile telephony.

Most of the investigations focused on developing a 'proof of concept' for the different interventions. As part of the investigations a design research methodology was used with the approach being predominantly of a qualitative nature with a limited amount of quantitative analysis. The researcher was able to explore, acquire and understand the nature of the problem being investigated. The research highlights the need for the more extensive use of ICTs to promote creativity and innovation through human capital development.

The Ulwazi project was the precursor to grappling with the issues of virtual classrooms at school level. The researcher—immersed in a digital world—grappled with the challenges of combining digital literacy with traditional teaching via a digital curriculum interface. These interactions heavily influenced the researcher's development of the five-dimensional educational model proposed, as the researcher saw a need to categorise and position teachers relative to learners in the emerging digital environment in order to assist teachers in better understanding their role where modern ICTs are involved in the learning process.

The main lesson learnt from this was the ability of the researcher to be more in tune with what it is that "switched the learners on." It meant that the researcher, in interacting with the learners, would strive to avoid merely trying to meet the behavioural objectives of a single lesson. A more learner-centric approach was adopted where the learners were placed in charge of the learning process, while assuming different roles within a group scenario. Not all learning can and should take place in a constructivist environment, but the researcher maintains that the educator should strive to achieve a balance in the different approaches to cater for the different types of learners.

After the development and validating of a model for the use of wireless broadband to teach learners via virtual classrooms, the researcher expanded the concept further to potentially maximize the returns on investment. The Hub School model sees additional value-added services being bundled with an existing communication backbone to deliver services to the

wider community. These are then incorporated into such potential projects as the Broadband4All project of Wireless Africa—as part of the Wireless Africa initiative of the Meraka Institute (Roux, 2009).

The transition to a research environment provided opportunities for the researcher to develop the additional interventions for YESA in collaboration with organizations, such as Wireless Africa, Digital Doorways and other Meraka and CSIR-based units. The researcher's success with the Fabrication Laboratories at the Innovation Hub and Soshaguve provided opportunities for learners from different schools in the Tshwane area to be invited to participate in the FabKids experience. Though the original FabLabs were designed for university students and the general public, the researcher identified a need to develop a more formal programme to introduce learners from as many grades as possible to these facilities.

Given the emphasis on the move to Free and Open Source Software (FOSS) the concept of Digital Kids emerged—whereby learners were exposed to digital literacy that goes well beyond the confines of basic computer literacy. The basic premise was to provide learners with the tools to express themselves through a different medium by exposure to open source, freeware and shareware software through the introduction of technology clubs.

2. Synopsis of the Findings

The five articles contained within this thesis were compiled over a period of almost four years. Though each one may be read as a separate entity, their value lies in the collective nature where each can contribute significantly to human capital development, primarily at school level.

The emphasis of all of the different articles is not so much on content development but rather on increasing the range of experiences to provide as many learners in state schools as well as the independent schools systems. The Western Cape Education Department recognizes the need for this and has formalized it through the A Human Capital Development Strategy for the Western Cape: A focus on Youth Document (Western Cape Education Department, 2006).

The value of the different policies and initiatives which are aimed at promoting SET HCD, lies in their ability to translate into actions which have a significant impact on the ground. There is no point in having a paper-based strategy with no measurable impact on the lives of as many individuals as possible.

3. Addressing the Main Research Question

For ease of reading, the researcher will repeat the main research question and review how the various articles have contributed towards addressing the different sub-questions. The main research question was:

How can technology in education promote creativity and innovation for human capital development at school level to teleport more learners up the technological ladder?

3.1. Possible Implications for the Deployment of Hub Schools

Sub-question #2

What are the implications for the development of a multi-layered solution to address the needs of rural communities?

This article is a concept based on the findings of a number of different projects, each of which is an independent entity with its own set of research findings. The researcher proposed that part of the underlying principle was to create opportunities to maximise the returns on investment once an information communications infrastructure had been established in a given community. By marginally increasing the bandwidth, if necessary, additional service layers can be added to increase the number of participants who can benefit from the wireless footprint in a community or region.

Many community-based projects in areas of education, communications and health tend to be isolated interventions with limited impact beyond the scope of the project. This paper highlights the amalgamation of a series of successful stand-alone interventions into a *super project* to significantly impact on the lives of a whole community, rather than just on isolated individuals. The deployment of a wireless information communications backbone includes additional value-added service layers at minimal additional costs to partnering organisations—thereby enabling social inclusion on a wider scale, while at the same time increasing the returns on the original investment for the benefit of the whole community.

The researcher is advocating a more inclusive approach, where a number of projects are amalgamated for the benefit of more members of the recipient community. Though not tested, the researcher believes that a multi-focal approach to community-based projects can potentially have a greater impact, while reducing the risks of failure as a common factor in single-focused projects.

These additional value-added services included a component of distance education where learners and teachers access information from the comfort of their homes, schools and communities. The researcher sees the benefits of being interconnected as including access to shared digital resources, connecting district educational office to schools to improve communications, accessing low-cost/free Voice-over IP (VOIP) within a community, etc. *Infopreneurs (van Rensburg et al., 2008)* can also benefit from such networks leading to further entrepreneurial opportunities.

Restricting access to information to office hours can become a thing of the past, especially in under-resourced communities. Those who are enveloped in a digital information wireless footprint can now enjoy the potential of accessing information on a network with increasing ease from the comfort of their homes or from key points in the community, such as Digital Doorways. This proposed model can go a long way to overcoming the restrictions imposed on *strongroom* technologies by making it possible to access information virtually on demand.

The Hub School concept emerged from the researcher interacting with various research units within the Meraka Institute over several years. Investors in the types of research with which the Meraka Institute is involved are always looking for impact on communities and the Hub School Concept was the researcher's attempt to address this problem by adding value through integrating a number of related research projects which were already successful in their own right.

An added bonus is the provision of a platform for the Living Labs concept. Living Labs is a new research area and a phenomenon that introduces new ways of managing innovation processes. The underlying idea is that people's ideas, experiences, and knowledge, as well as their daily need for support from products, services, or applications, should be the starting point in all such innovation (Bergvall-Kåreborn *et al.*, 2009). The deployment of research interventions adds value to the process of innovation, especially in the more rural areas.

3.1.1. Opportunities for Further Research Based on the Hub School Concept

Based on the Hub School Concept the following research questions have arisen:

- What is the impact of the Hub School on a community?
- What is the educational, human capital development and social impact of the deployment of the Hub School Concept?
- How can the deployment of the Hub School concept be used to promote human capital development and innovation in rural areas through the inclusion of Living Labs?

- What are the impact and success factors of a multi-focal project as opposed to a signal-focal project?

3.2. Development of a New Educational Model of an ICT Learning Environment

Sub-question #3

How can the development of a new educational model assist in identifying the complexity of the learning environment to inform teachers of the diverse nature of an ICT-enabled classroom?

The role of ICTs in the classroom is a complex issue especially to the digital immigrant teachers (Prensky, 2001). Coming to terms with the characteristics of the Net Generation: (Oblinger *et al.*, 2005: 2.5) visual-spatial skills, inductive discovery, attentional deployment, fast-response time, the digitally literate, etc., can assist both the computer-literate teacher, as well as the ICT innovative teacher. They require all the assistance they can get to leverage the innate ability of the youth to use modern technologies in all aspects of their lives, from education to socially communicating.

The researcher developed this model to assist teachers to comprehend the effects of introducing ICTs into learning environments based on the researcher's experience while interacting with colleagues from both affluent and poor schools. The researcher aims to develop the model into a classroom tool to enable teachers to identify and plot the dynamics of their learners in order to address learners' changing needs.

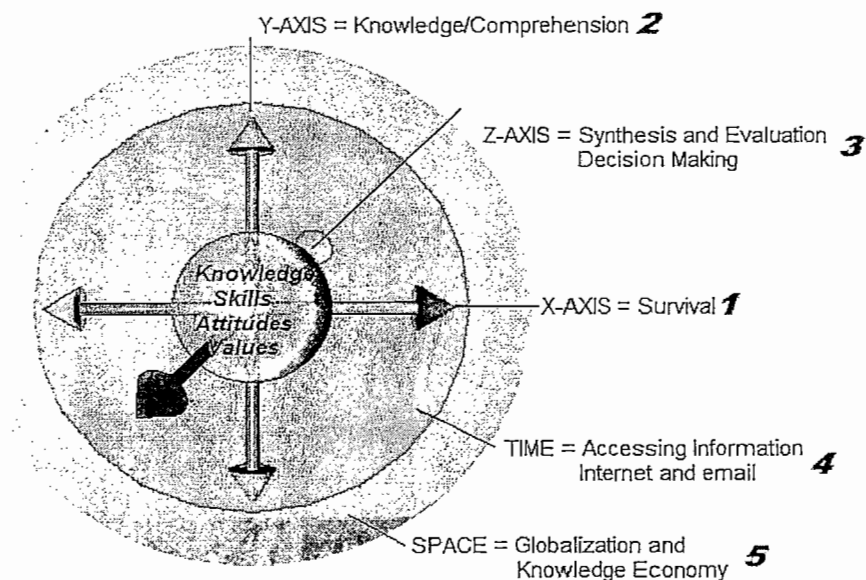


Figure 3 : Five-Dimensional Model of Education (Beyers, 2009: 221)

It may be advantageous to view the Five-Dimensional Model of education as displayed in Figure 3, in parallel with the five stages of technology adoption, as suggested by the CEO Forum's School Technology and Readiness Report (CEO Forum, 1999: 14) as these steps also apply to all those schools where ICTs have been introduced. These stages included Entry, Adoption, Adaptation, Appropriation and Invention—where the researcher views most teachers as operating at the entry level of the scale. However, these stages of technology adoption should not be confused with the five dimensions highlighted in the proposed five-dimensional model of education. The researcher believes that it could assist in increasing the pace at which teachers can move themselves beyond the entry and adoption phase for the benefit of more learners at the end of the day.

This implies moving learners beyond the survival strategy of reading, writing and comprehension, while not ignoring the importance of building on these stages as the foundations for the future. Given the nature of modern technologies and different projects like the Formula One in Schools projects, the researcher believes that learners should be exposed to the third, fourth and fifth dimensions on a regular basis through the integration of ICTs into the classrooms on a more regular basis.

It is not about individuals learning how to use the macros in an office environment, but rather about stimulating their creativity and innovation in order to develop a more holistic learner who is able to make a meaningful contribution to society at the end of the day through being able to utilize the individual's potential for the benefit of society in a meaningful way.

3.2.1. Opportunities for Further Research Based on the Five-Dimensional Model of Education

Based on the Five-Dimensional Model of Education, the following research opportunities arise:

- What is the impact of developing and deploying a tool to categorize learners and teachers based on the principles of the five-dimensional model of education?
- A comparison of educational models involving the use of ICTs in the classroom
- A comparison of different types of learners, based on the implementation of the five-dimensional model of education.

3.3. Utilizing Broadband Technologies to Digitally Include Learners in Remote Locations

Sub-question #1:

What are the implications for using broadband communication technologies to digitally link two geographically separated classrooms?

The culmination of this research is the formulation of the Ulwazi Concept of virtual interactive classrooms which capitalize on the use of broadband wireless networks. The deployment of the Ulwazi Project was in response to a transport problem that the researcher identified where learners from a neighbouring township were desperate for supplementary tuition. Though the original project took place a decade ago, it potentially contributed to the EduNet debate of interconnecting schools in South Africa by providing a cost-effective working solution to digitally sharing top educators and other digital resources with under-resourced and under-performing schools.

The investigations of the researcher have clearly demonstrated that learners from geographically separated classrooms—especially in a subject like science—could be digitally included by using the Ulwazi Principle.

This project also made a contribution to a number of national initiatives. Firstly, the researcher made a submission to the Parliamentary Portfolio Committee on Communications on 19 August 2005, at a time when the telecommunications bill was served before Parliament. The submission was part of a process of lobbying for the removal of legislative and regulatory obstacles to the roll-out of wireless broadband networks in the educational sphere. Problems at the time were: (a) a prohibition against the deployment of private networks—as any educational network would necessarily be classed by the Independent Communications Authority of South Africa (ICASA)—unless such a network was deployed on a contiguous piece of land belonging to one owner; (b) the general unavailability of the 5.8GHz frequency band for point-to-point and point-to-multipoint wireless networks, for which very cost-effective wireless equipment was available—also equipment for long-distance links in rural networks, and (c) the exorbitant price of the spectrum for the 5.8GHz spectrum where ICASA was allowed to be used for experimental educational purposes—*viz.* the Ulwazi network (Seeber, 2010).

In effect, the legislative and regulatory framework presented a major obstacle to the rollout of the educational networks beyond the Ulwazi network, the latter only being allowed by ICASA because of its experimental, temporary nature. The Ulwazi network was a powerful demonstrator of what the country was forfeiting as a result of poor telecommunications legislation and regulation. The fact that the Ulwazi concept could not be replicated helped the researcher to present a strong argument to the Portfolio Committee on Communications for removing the obstacles and creating an education-friendly dispensation (Seeber, 2010).

The outcome of the process was that ICASA over the following three years since the promulgation of the Electronic Communications Act of 2005 (South African Government Information, 2005), came up with a set of regulations that allowed private networks of unlimited geographic scope in the Government Gazette No 31289 of 29 July 2008 (Independent Communications Authority of South Africa, 2008). What is more, these networks are now exempted from service licences. The last major move on the part of ICASA was when it laid down the technical requirements for the use of the 5.8GHz band, which effectively opened up the band for broadband networks, including networks for education, as indicated in the Government Gazette No 32769 of 2 December 2009.

Although the issue of exemption from a spectrum licence for the 5.8GHz band still needs to be formalised by ICASA publication in a Government Gazette, ICASA is already allowing licence-exempt use. The regulatory scenario for the rollout of educational wireless broadband networks in South Africa is now as good as anywhere else in the world, for both urban and rural environments. The lessons learnt from dealing with higher level issues of legislation, was that individual projects are important, but their power lies in their collective ability to bring about change.

Secondly, the educational value of the Ulwazi project lies not only in a demonstration of its ability to create virtual classrooms that are geographically separated, but to the fact that it also contributed to changing the policy for the licence exemption of the use of this 5.8GHz radio frequency. This could have far-reaching consequences for the delivery on the White Paper on e-Education (Department of Education, 2004) in terms of the development of a network for education (EduNet) that would connect all schools to each other and to the Internet through multi-media laboratories. The Ulwazi project was considered as a possible solution for such a deployment.

Thirdly, the Broadband4All project is the outcome of a collaborative effort spearheaded by the Meraka Institute to bridge the digital divide and bring the social and economic benefits offered by broadband connectivity to rural communities in South Africa and other developing countries. The objective of the project is to offer broadband access to rural communities in an affordable and sustainable fashion (Roux, 2009). This is a connectivity project currently under development. The Ulwazi project, together with the Digital Kids and FabKids projects can be seen as contributing to such initiatives for the benefit of learners in the communities that are served by the information communications infrastructure of the Broadband4All project.

The researcher maintains that the deployment of the YESA initiatives mentioned in this thesis across a Broadband4All network will demonstrate that an interschool network can bring about significant educational value especially to rural communities. The implications of this are that schools which were previously geographically isolated can now also share in the benefits of modern technologies. To take the issue a step further, it is now possible to link learners' and teachers' home PCs to the network by making use of low-cost devices called *cantenna* or an antenna made from a tin, a piece of bicycle spoke and an inexpensive router.

The researcher maintains that it may also be possible to circumvent the limitations of schools by imposing what the researcher has termed the *strongroom technology approach*. In some cases learners and teachers are not given access to the computer equipment which is permanently stored in the school's strong room for fear of the equipment being stolen. This will go a long way to reducing the digital divide for members of those communities which lie within the digital footprint of such wireless coverage.

The Ulwazi Principle is based on the ability to digitally share educators as a digital resource through the use of a broadband wireless information communication backbone—together with additional off-the-shelf hardware components. The research has demonstrated that this can be used to circumvent the limitations of teachers in remote schools through the establishment of virtual classrooms. The idea of a virtual class is that everybody can talk and be heard and be identified and everybody can see the same words, diagrams and pictures, at the same time. This calls for the use of telecommunications and computers (Tiffin *et al.*, 1995: 6).

As chairman of the Ulwazi project committee, the researcher gave priority to using off-the-shelf technologies, such as simple webcams which allowed both the learners physically present in the laboratory, as well as more remote learners to be drawn closer to the action. Making use of the built-in features of the SMART Notebook software, the researcher was able to record science experiments during the lessons and to then store them, as part of the lesson summary.

The researcher was able to replay recorded videos of the experiments virtually on demand. By making use of the example of the refraction of water waves in a Ripple Tank, it was possible to freeze-frame the video clip at any stage. Rather than instructing the learners *looked for* a key feature, the researcher was able to instruct them to actually *look at* them which were enhanced through the ability to annotate over the video footage created a stronger interrelationship between theoretical knowledge and experimental application.

Though comparative research into the cost-effectiveness of the solution was not conducted, it is expected that Ulwazi types of network operating costs will be substantially lower than VSAT or other connectivity models. The main reason for this is that the researcher envisaged a closed Internet Protocol (IP) based network which would exclude the high monthly Internet Service Provider (ISP) fees. This would allow for virtually unlimited access to information on the closed network. Costs that were incurred were restricted to the hosting of communications equipment on towers at strategic high sites.

The Ulwazi Concept was institutionalised early in 2001—at a time when a number of key elements came together. St Alban’s College played an active role in addressing the hardships in the black community’s deficiencies in the early 1980s with the likes of Don Mac-Robert encouraging this private Anglican school in Pretoria to become involved in learner and teacher upliftment programmes. The College was the first school to embark on such an initiative (Boje, 1997: 125-126).

It is against this legacy that the researcher conceived the Ulwazi Project to contribute to the outreach initiatives of the College. The internet had only been introduced into St Alban’s in 1996 and was still a foreign element in most classrooms at the College. The uptake of the internet into other schools was confined largely to private schools and a select few government schools which were supported by such initiatives as SchoolNet South Africa (SNSA). This institution was established as a national organisation—thanks to the efforts of volunteer educators and innovative thinkers in school networking during the 1990s. The Western Cape Schools Network was established in 1993 as the first regional schools network in Africa. It served as the model on which several other grassroots non-profit regional school networks were established by volunteering educators. These included the Eastern Cape Schools Network, KwaZulu-Natal Schools Network (later Schoolnet KZN), Gauteng Schools Network and PretNet (SNSA, 2003).

The researcher served as chairperson for the PretNet programme, followed by Gauteng Schools, and served as a member of the SNSA Board for a number of years.

3.3.1. Additional Research Questions Emerging from the Ulwazi Concept

Based on the Ulwazi Project, the following research question emerged:

- What is the impact on learning through the deployment of an Ulwazi-type of network between two schools?
- How can a community-based network be used to digitally include learners and teachers in a connected learning community?

- What are the similarities and differences between different connectivity models to promote virtual interactive classrooms for developing countries?

3.4. A Rapid-prototyping Environment to Stimulate Creativity and Innovation

Sub-question #4

How can a rapid-prototyping environment be used to stimulate creativity and innovation?

The introduction of FabLabs into South Africa can be viewed as a necessary response to transforming creative ideas into innovative solutions by providing access to the technology and the means of production to under-resourced and under-served communities. In conceiving the FabKids intervention, the researcher identified the gap in the market to expose learners to a high-tech rapid-prototyping environment. The researcher was able to draw on a broad range of experiences in order to master the pedagogies which were conducive to encouraging the learners to perform in a post-constructivist environment.

Through being involved in the delivery of the FabKids sessions, the researcher was able to create an opportunity to accelerate the application of the *design process* by introducing learners to the technology-rich FabLab environment. This improved the efficiency with which the learners worked, substantially reducing the time taken to complete a similar project had they been given it as part of a Technology assignment in a school environment. Added to this, the researcher discovered a range of additional benefits, such as working in teams, utilising the power of computers, lateral thinking, problem-solving and creativity. The project also demonstrated that learners from both advantaged and disadvantaged schools were well able to operate at similar levels when exposed to the same challenges set before them.

The researcher views the FabKids project as bridging the gap between the traditional classroom and the real world through the provision of a stimulating learning experience that the vast majority of learners would otherwise not have had in a normal school environment. FabKids can potentially make a significant contribution to HCD in the area of SET by highlighting the design process within the context of solving real-world challenges. Through the FabKids project the researcher demonstrated that these sessions can be used to supplement the national curriculum in a number of areas—both within the General Education and Training (GET) and Further Education and Training (FET) bands.

The heart of the pedagogical approach is the application of the design process with an emphasis on the acquisition of essential 21st century skills. Though it has not been demon-

strated as yet, the potential is to improve the quality of submissions to FESTOC events, such as the Eskom Expo for Young Scientists and the SAIMEchE Technology Olympiad.

Creativity and a NSI are two critical elements of the South African government's White Paper on Science and Technology. The White Paper refers to Innovation as becoming a crucial survival issue. A society that pursues wellbeing and prosperity for its members can no longer treat it as an option. In practice innovation is the application of creating new ideas, which in many cases involve the introduction of inventions into the marketplace. In contrast, creativity is the generating and articulating of new ideas (Department of Arts Culture Science and Technology, 1996). Naiman (2007), on the other hand, defines Creativity as the act of turning new and imaginative ideas into a reality. Creativity involves two processes: thinking, then producing. Innovation is the production or implementation of an idea. If you have ideas, but don't act on them, you are imaginative but not creative.

A more elaborate definition of the term innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services (Harvard Business School Press, 2003: 11). There are generally two types of Innovation: incremental innovation and radical innovation. Incremental innovation is generally understood to exploit existing forms or technologies. It either improves upon something that already exists or reconfigures an existing form of technology to serve some other purpose. In this sense it is innovation at the margins. A radical innovation, in contrast, is something new to the world, and a departure from any of the existing technologies or methods.

The terms breakthrough innovation and discontinuous innovation are often used as synonyms for radical innovation. More recently, Christensen has used the term disruptive innovation to describe a technical innovation that has the potential to upset the organisation's or the industry's existing business model. In almost all cases, these innovations are radical. Disruptive technologies displace the established technology and precipitate the decline of companies whose business models are based on them. In many instances, disruptive technologies create new markets, however (Harvard Business School Press, 2003: 3).

The lesson learnt from the FabKids intervention for the researcher was that all learners should be exposed to what innovation entails, as well as to the role of human capacity in the development of new technological solutions. There are many devices, such as mobile phones, cars, microwaves, etc, that are simply taken for granted without the users being aware of the research and innovation that have gone into the development of such products. The researcher maintains that more learners should be provided with key moments which could potentially switch them on to careers in SET-related fields.

FabLabs are about giving people the ability to make things for themselves. They can be the fastest way to solve their problems, particularly in communities with little access to education or technology (Fab Central, 2008). Overcoming the question of access can be addressed through the Engineering Star Programme (Department of Science and Technology, 2009). This will potentially see an increase in the number of FabLabs distributed around the country. The researcher was co-opted as part of a DST national task team to draft the ESP document. Mobile FabLabs associated with the fixed FabLabs will be used to take the technology into deeper rural communities on a regular rotational basis.

It is envisaged that the Living Labs approach can play a critical role in leveraging the potential of rural innovations. Like many of the FESTOC programmes, one of the current limitations of FabKids is that it is restricted to a single intervention. The researcher believes that learners should be exposed to a sustained intervention over a period of a single school year in order to maximise the benefits that FabKids have to offer. Creating a key moment for an individual may increase their chances of changing their career choices to one in SET. It is through such increased exposure that more learners will be encouraged to do so—nurturing thereby a more enlightened feeder stock for the SET pipeline.

3.4.1. Opportunities for Further Research Based on the FabKids Concept

Based on the Fab Kids concept, the following research questions have emerged:

- What is the impact on education and human capital development of deploying a digital manufacturing centre at a Hub School?
- What is the impact of fixed and mobile FabLabs on learners pursuing careers in Science, Engineering and Technology?
- How can the integration of Living Labs and Hub Schools be used to promote rural creativity and innovation?

3.5. Digital Literacy Taught as Part of Technology Clubs at Schools

Sub-question #5

How can digital literacy be taught as part of technology clubs at schools?

What exactly does it mean to be *literate* in the "post-modern" world? And what are educators talking about when they use the term "computer literacy" these days? On the one hand, "literacy" conjures images of the technical skills required to "read and write," the denotation that the United States Army reinforced when it coined the term *functional literacy* during World

War II. This line of thinking, as a number of literacy experts have noted, bred the ideas of "survival literacy" and "basic literacy." However, the second strain of literacy, *critical literacy*, aggravates the problem far more today because of its many connotations, most of which stem from the idea of what it means to be "educated" (Burniske, 2000).

Though they may not be able to articulate it, many people intuitively understand that "functional literacy," though a prerequisite to other types of literacy, seldom demands higher-order thinking skills. The teacher who incorporates new technology into her classroom may help students to learn how to "read and write," but she also needs to teach them how to interpret and "contextualize" the words and information they encounter in chat rooms, discussion forums, websites and more (Burniske, 2000).

Prior to the 21st century, literate defined a person's ability to read and write, separating the educated from the uneducated. With the advent of a new millennium and the rapidity with which technology has changed society, the concept of literacy has assumed new meanings. Experts in the field suggest that the current generation of teenagers possesses digital competencies to effectively navigate the multidimensional and fast-paced digital environment. For generations of adults who grew up in a world of books, travelling through cyberspace seems as treacherous and intimidating as speaking a new language (Jones-Kavalier *et al.*, 2006).

Many schools place a high priority on curriculum issues and meeting the minimum requirements for learners to be graded according to the official standards. In order to encourage a different approach to facilitate digital literacy in place of traditional *computer literacy* the researcher is advocating the establishment of a Technology Club at school level. This will be in the form of extramural sessions run on a regular basis at a participating school where ultimately the institution will be adopted as a YESA school through the establishment of long-term relationships. From experiences gained at Anton van Wouw Primary School in Pretoria, the model has worked well with a very flexible approach designed to meet the varying requirements of each learner. The researcher advocates the use of Open Source Software to reduce the costs of funding such sessions, while retaining the benefits of industry standard software. It also allows the learners to install the software legally on their home computers as well.

The focus of all training sessions was on the development of educational resources which the learners could apply to their own school-based projects. A perceived added benefit is the sharing of animations and other multimedia developed with their teachers. These can assist in breaking down the technological excuses that teachers put up in resisting the introduction

of computers into their lessons. Extending this concept further, the researcher believes that the Digital Kids could form the nucleus of a club which acts as an *outsourced production unit* for a variety of multimedia for the school environment—thereby introducing an interesting element of entrepreneurial skills, while simultaneously providing leadership opportunities.

Summing up, the researcher believes that Digital Kids challenges the existing mindset of computer literacy which promotes the teaching of office automation skills through macros such as spell checks, document formatting, changing fonts, etc. Digital Kids can empower learners to acquire digital age literacy skills which are portable in the real world—by using a broad range of open-source software packages. The promotion of Digital Kids through Technology Clubs at schools can bring a new dimension to the everyday experiences of many learners who would otherwise not have had the opportunity to develop such skills in a normal school environment. Digital Kids takes cognisance of the differences of the Net Generation (Oblinger *et al.*, 2005) catering for their desires to be involved in planning the journey towards their own future. They understand the digital world in which they live and should be empowered to express themselves digitally by means of a medium with which they are comfortable.

3.5.1. Opportunities for Further Research Based on the Digital Kids Concept

Based on the Digital Kids concept, the following research questions have emerged:

- What is the long-term impact of introducing Digital Kids in promoting 21st century skills in learners in comparison with their mainstream counterparts?
- What are the similarities and differences of learners in technology clubs in South Africa in comparison to learners in other international countries?
- What is the impact of Digital Kids on learners pursuing careers in Science, Engineering and Technology?

3.6. Addressing the Main Research Question

Main Research Question:

How can technology in education promote creativity and innovation for human capital development at school level to teleport more learners up the technological ladder?

The journey through the different articles has raised many issues and possibilities where the emphasis has shifted from information transfer to creating opportunities for skills development while simultaneously encouraging learners to become ICT innovators higher up the technology ladder (Beyers, 2008).

This research has produced a collection of stand-alone solutions which collectively constitute the key elements of a HCD strategy for SET. The researcher calls for more emphasis on the formative years—in order to produce, not only PhD graduates, but also individuals who have the appropriate knowledge, skills, attitudes and values to contribute meaningfully to, and who can also operate effectively in a knowledge society. With a greater emphasis on ICTs, creativity and innovation through such interventions as YESA, it should be possible to successfully nurture a growing feeder stock to supplement the NSI, while at the same time to make a significant contribution to a range of other national initiatives.

All learners should be afforded such opportunities and encouraged to go beyond the initial rungs of computer literacy. Learners should be empowered to find their niche as ICT practitioners and even ICT innovators who can make a significant contribution to the globalised knowledge society in which they are destined to seek employment.

All of the researcher's interactions with the various interventions have paved the way to the formation of the My YESA Passport. The researcher has had the privilege of working alongside some bright minds of the future where the researcher found that given the opportunity the learners were able to flourish under such circumstances and produce some very creative solutions. The evidence of this was in the manner in which they worked and the end products that were produced. It was as a result of these types of interactions that the researcher was able to identify a gap in the market to formulate the My YESA Passport as a means of tracking learners from Grade 1 to PhD level.

FESTOC can provide limited statistics on individual learners participating in respective events, but there is no system of tracking learner involvement across multiple events and years. The researcher believes that the advantages of such a system can provide a range of benefits to both the individual—as well as to an industry that is desperate to identify scarce skills as the country grapples with the new knowledge economy (Beyers *et al.*, 2010), while simultaneously encouraging economic growth.

As a result of the researcher's contract with the Meraka Institute to establish a pipeline for SET, YESA is positioned as a national delivery vehicle in the form of the FabKids, the Digital Kids and My YESA Passport. These are all able to operate in both urban and rural schools. YESA has also been identified as playing a key role in the development of essential e-skills on a national level. The challenges will be in the formulation of the right organisational model to deliver on its mandate as it moves forward into the future.

A meta-analysis of key concepts was conducted over the five articles, the results of which may be found in Table 5 which is graphically represented in Figure 4.

Table 5: A Meta-Analysis of Key Words across the Five Articles

	Article 1	Article 2	Article 3	Article 4	Article 5
Digital inclusion	3				
Virtual classrooms	1				
Social transformation	5				
Interactive Whiteboards	2		2		
Net Generation		10		2	
Computer Literacy			3	2	6
Digital literacy		1	1		
National System of Innovation			11	23	16
Authentic learning				2	
Educational Models		18			
Rapid Prototyping				1	
Team work.				2	
The Design Process				8	
Learning theories		7		6	

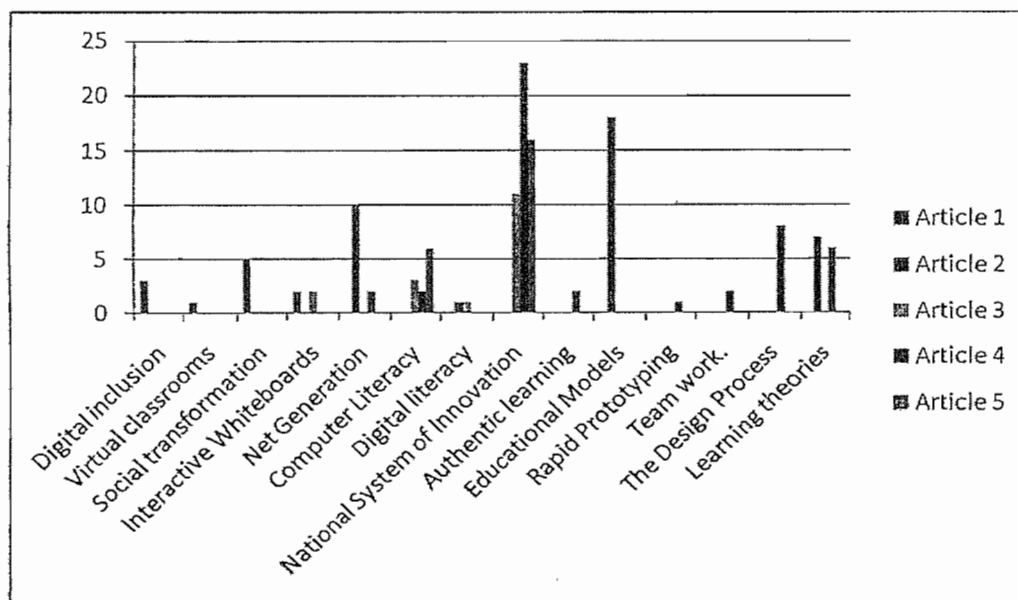


Figure 4: A Graphic Representation of the Meta-Analysis of Key Concepts used in the Articles

The results of a meta-analysis of the key concepts used in the five articles are displayed in Figure 4. These reveal a strong leaning of the whole research towards NSI, Computer literacy and the Net Generation. This outcome is in support of the main research question.

These are essential components in the promotion of HCD in the context of this research—where creativity and innovation will continue to play a key role. Figure 5 represents the researcher’s attempt to make meaning of the interrelationship between the five different articles presented in this thesis.

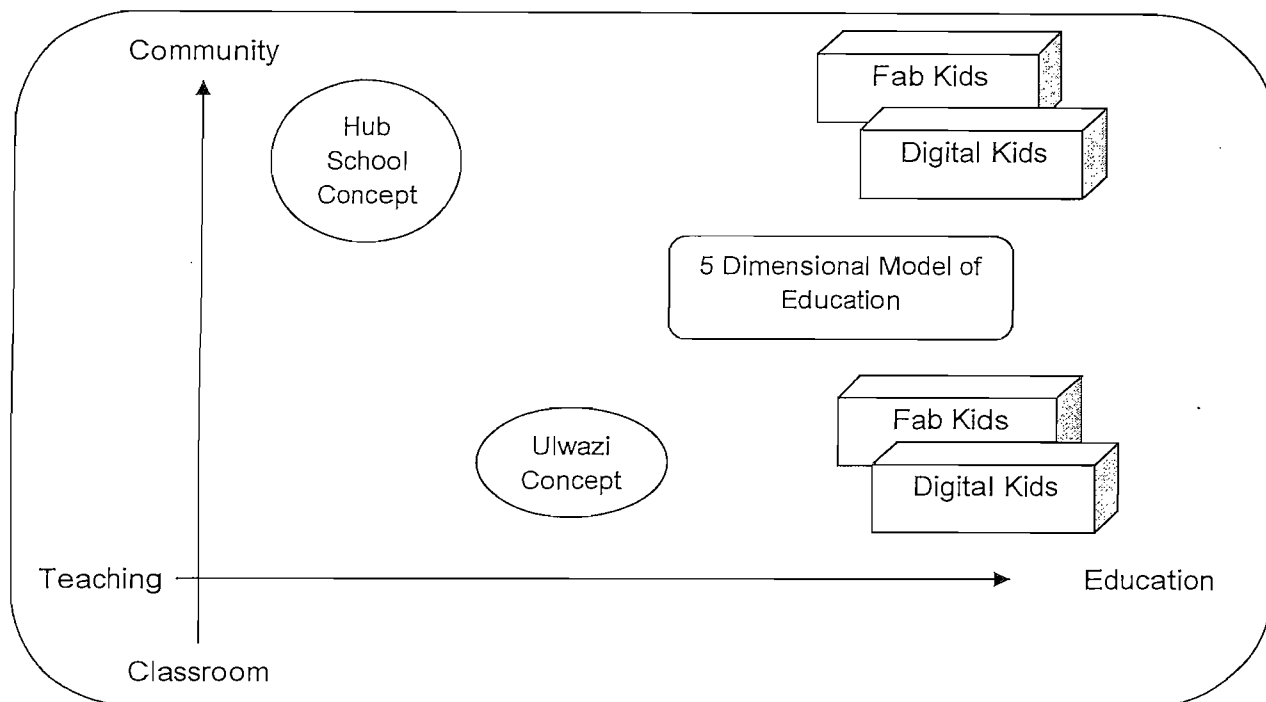


Figure 5: A graphic Representation of how the Main Arguments from the Different Articles Interrelate

The horizontal axis represents a continuum between teaching as a process of information transfer on the one extreme—to education as a process skills development and self-discovery on the other hand. The vertical axis represents a classroom as a single venue with a limited number of learners in a managed learning environment. At the opposite extremes of the vertical continuum is a community which involves a larger number of individuals who have the capacity to learn from a range of different experiences.

The Ulwazi concept is viewed as a small scale intervention leaning more towards the educational side, while the Hub School Concept would tend to favour the more traditional teaching mode, especially where educators are used as a shared resource in a point-to-multipoint lesson delivery mode. It is important to note that the Hub School concept is designed to meet the needs of the whole community and not just those of single classes.

With the Five-Dimensional model, the emphasis is heavily on the educational side to interface between the teacher-centric computer literacy, as opposed to learner-centric digital literacy mode. This would also explain the location of the FabKids and Digital Kids projects

being placed on the right where they are designed to operate in both small classroom modes, but also to have the capacity to impact on the broader communities.

3.6.1. Opportunities for Further Research

Based on the overall outcome of this thesis the following research questions appear possible:

- *What is the long term impact of YESA on human capital development?*
- *What is the role of technology in human capital development for a knowledge society?*
- *What is the national impact of deploying the Engineering Star Programme in promoting the SET pipeline?*
- *How can Design Research be used as a methodology to identify human capital as part of YESA initiatives in nurturing a pipeline for SET?*

4. Limitations of the Study

The philosophical journey of the academic process involved in compiling this thesis has served to highlight many strengths and weaknesses. As has been intimated, the project spans more than two decades of work at state and private schools, as well as the time spent at the Meraka Institute. In many respects this has served to allow the projects to develop independently of the rigours of academic research. On the one hand, this has provided an opportunity for the work to progress in different directions; while on the other hand, a more rigorous approach could well have produced more concrete verifiable results. There are merits and demerits in either approach, while this thesis serves to record the researcher's collective progress made to date.

The researcher's original intent with all the interventions was to demonstrate a proof of concept and hence there is less emphasis on quantitative research throughout the articles. It also needs to be highlighted that all the research was conducted on either a shoe-string budget or no budget at all—although the researcher believes the availability of substantial research funding may not have significantly influenced the findings presented. The availability of funds may have increased the range of interventions and possibly the sample size.

A counter-argument to this could be the need for the different interventions to become more focused in nature. Only time will tell, since the different interventions still require further deployment, in order to determine the efficacy in different schooling environments across the

country. This will form part of YESA's strategy which is viewed as the national delivery vehicle for all the interventions, as well as others not contained within this research.

The researcher maintains that a significant dilemma facing all educational authorities today is developing the paradigms of teaching and learning to prepare students for a high-tech society, while using low educational methodologies and technologies. With the rapid advancements in technology there is very little that cannot be achieved today. The bottom line still remains the availability of funds in many cases—but the old saying that it cannot be achieved because of the hardware constraints no longer applies. The biggest stumbling block in the implementation of any technological solution is not based on the hardware or software issues but rather on the *warmware* issues. This refers specifically to the warm bodies that are associated with any project (Beyers, 1998).

Further limitations for this research include the limited sample size together with the fact that there were no comparisons drawn up between different geographical regions, although this was not the purpose of this research. Greater emphasis could have been placed on the quantitative analysis to increase the integrity of the findings. However, these limitations could be viewed as opportunities for further investigations in the future. There is scope for the research to be expanded to more grades, different schools and across different provinces.

At the same time many of the concepts need to be formalized as working documents which can act as resources for other institutions and teachers to adopt as part of the massification process. There is also scope to test the concept within the framework of different government departments. The Department of Education is a natural choice, but there is a perceived benefit in the Department of Labour in terms of human capital development. Coupled to this is the Department of Communication's interest in adding greater value to the information communication networks. All of these will need—through research—to unravel the true potential yet untapped in making a meaningful contribution to the economy of the country through human capital development.

5. Recommendations

The ideal outcome for this thesis would be the transformation of the proof of concept of the different interventions into fully operational projects having an impact on education across the country. The perceived vehicle to achieve this is YESA which is set to become the national delivery vehicle for all the interventions researched. Through the process of constitut-

ing a not-for-profit company, opportunities for deployment will be identified in the different schools and provinces across South Africa. In deploying the different initiatives, further research opportunities will emerge where a range of research institutes will be invited to avail themselves of these opportunities.

As part of the process of Human Capital Development it is important to establish a longitudinal study to track learners with talent. Currently, the My YESA Passport Portal is being developed to provide the means to track these learners, while there is still scope for other research organisations to become involved in the process at this stage in the development of the product. The members of FESTOC are perceived as playing a significant role in this process through the provision of access to already established SET networks operating at school level in collaboration with the various YESA interventions.

The My YESA Passport is perceived to be the next logical step in the process of the tracking and identification of talent across the country. The different components outlined in this thesis operate at the grassroots level, but there is a perceived need for a tool to manage the process of gathering data from the community of practice to create a longitudinal data collection strategy. These concepts are in the development phase, where the alpha version of the portal was developed by MetaLab and has been sponsored by a small grant from South Africa—Finland Knowledge Partnership on Information Communication Technologies Programme (SAFIPA), as well as FESTOC.

There is scope to develop the Five-Dimensional model as a *software tool* to be used by teachers in the classroom to assist them in identifying their position relative to where their learners are when it comes to introducing ICTs into the classroom. The tools need to be easy to use and should be able to provide immediate feedback with suggestions for improvements and additional professional growth. This could add value to the already established Dutch ICT—Tools through the 'ICT op School' programme (Kennisnet, 2009).

6. Contribution of the Study

In concluding this research it is necessary to reflect back on the key objectives of this investigation which included:

- To investigate a small-scale intervention into digitally-including remote learners in geographically separated virtual classrooms
- To conceptualise a multi-layered approach for the provision of a *range of community-focused solutions* on top of a communications network infrastructure

- To conceptualise an alternative educational model which highlights the similarities and the differences between teachers and learners, where ICTs are used in the classroom
- To pilot a *FabKids* intervention, which utilises a rapid-prototyping environment to promote creativity and innovation
- To pilot a Digital Kids intervention, within the context of Technology Clubs which focuses on the development of digital literacy amongst learners using open-source software.

The objectives for this investigation were met where the outcomes were recorded in accredited academic journals. This research demonstrated a meaningful impact on learners in the classroom. Each intervention produced a conclusive proof of concept where there is now a greater need to integrate the outcomes into the work of the Departments of Education and of Science and Technology at a provincial and national level. YESA is perceived to be the national delivery vehicle for this important HCD programme.

When dealing with HCD and innovation on a national scale discussions tend to revolve around increasing the production of PhD graduate students as a measure of success. The researcher believes that in order to increase the returns on investment, it is imperative to initiate the SET pipeline from grass roots level—with a broad range of opportunities—in order to increase the outputs from the SET pipeline needed to nurture a NSI.

In summary up, the researcher advocates that the process should be distilled into the following simple analysis of the situation, as represented in Figure 6.

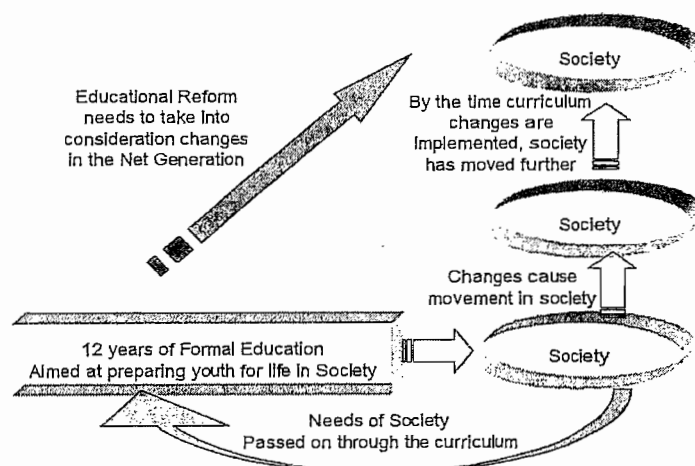


Figure 6: The Education System, Society and the Curriculum (Beyers, 2009: 219)

The researcher maintains that the current education system is preparing learners for a society that no longer exists—since the society has in the meantime moved on. In order to rectify the situation, the call is for a greater emphasis on issues of digital inclusion, the integration of whole communities, an understanding of the dynamics of integrating ICTs into the classroom, exploring opportunities for the expansion of rapid-prototyping at school level and the promotion of digital literacy. There are certainly additional factors that could be included in this list of encouraging creativity and innovation at grassroots level.

YESA is poised to take on this responsibility to establish a national delivery vehicle serving the aspirations of our youth in nurturing creativity and innovation through the use of effective ICTs and other technologies. The researcher is intimately involved in this process to promote human capital development through the initiation of a vibrant SET pipeline for the long-term benefit of the South African economy as a whole. Our human resources in science and technology are not being adequately developed and renewed; and we have an ageing and shrinking scientific population. The key indicators show that black and women scientists, technologists and engineers are not entering the academic ranks, and that the key research infrastructure is composed of people who will soon retire (Department of Science and Technology, 2002: 22).

In 1990, the percentage of scientific publications produced by researchers 50 years of age and older was 18% (one in five), but by 1998 this figure had increased, alarmingly, to 45% (one in two). Over the same period the percentage of publications by black scientists rose only very slightly, from 3,5% to 8% (less than one in ten). The participation of women has not changed since the 1990s, with their publication output being about 10% of the total. Currently, there is less than one researcher for every thousand members of the workforce, as compared with five in Australia and ten in Japan. Given that “technology walks on two legs,” the “frozen demographics” prevalent in our NSI represents an extremely critical state of affairs (Department of Science and Technology, 2002: 54).

The outcome of this research in conjunction with YESA as a national delivery vehicle can to make a significant difference to this situation which is aimed not just at the low-level training, but at having an impact on addressing the demographics of NSI as a long-term intervention



Bibliography



BIBLIOGRAPHY

- ADAMS, D.M. & HAMM, M. 2008. *Bringing science and mathematics to life for all learners*. Singapore: World Scientific Publishing. 276 p.
- AHMED, J. 2009. *Teaching Of Biological Sciences*. Delhi: PHI Learning Private Limited. p.
- ALEXANDER, S. 2004. Learners creating the learning environment. (In Selinger, M., ed. *Connected Schools - Thought leaders: Essays from innovators*. London: Premium Publishing. p. 26-33)
- ANDERSON, G.J. & ARSENAULT, N. 1998. *Fundamentals of educational research*. 2nd ed. London: RoutledgeFalmer. 200 p.
- BABBIE, E. & MOUTON, J. 2007. *The practice of social research*. 11th ed. Chapman University: Casebound. 608 p.
- BANNAN-RITLAND, B. 2003. The role of design in research: The integrative learning design framework. *Educational Researcher*, 32(1): 21-24.
- BARAB, S. & SQUIRE, K. 2004. Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, 13(1): 1-14.
- BASKARAN, A. & MUCHIE, M. 2006. *Bridging the digital divide: Innovation systems for ICT in Brazil, China, India, Thailand and Southern Africa*. London: Adonis & Abbey Publishers. 256 p.
- BEN, W. 2007. *Social inclusion in schools: Improving outcomes, raising standards*. New York: Routledge. 112 p.
- BENNETT, S., MATON, K., 2 KERVIN, L. . 2008. The 'digital natives' debate: A critical review of the evidence. *British Journal of Educational Technology*, 39 (5): 775 - 786.
- BERGVALL-KÅREBORN, B., HOLST, M. & STÅHLBRÖST, A. 2009. *Concept design with a living lab approach*. Paper presented at the 42nd Hawaii International Conference on System Sciences.
- BEYERS, R.N. 1998. *Warmware issues in education*. Paper presented at the United Nations Regional Preparatory Conference on UNISPACE III For Africa and the Middle East.

- BEYERS, R.N. 1999. *The connected learning community in South Africa: A classic case for open learning*. Paper presented at the Forum on Open Learning: Empowerment through Knowledge and Technology.
- BEYERS, R.N. 2007. The Ulwazi Concept – Virtual interactive and collaborative classrooms of the future. *South African Journal of Higher Education*, 21(6): 748-760.
- BEYERS, R.N. 2008. *Creating a Sputnik moment for learners in Africa*. Paper presented at the The 2nd South African International Aerospace Symposium.
- BEYERS, R.N. 2009. A five dimensional model for educating the Net Generation. *Journal of Educational Technology & Society*, 12(4): 218–227.
- BEYERS, R.N. 2010a. Extending the Education and Social Benefits through 'Hub Schools'. *Progressio: South African Journal for Open and Distance Learning* 31(1): 74-94.
- BEYERS, R.N. 2010b. Nurturing Creativity and Innovation Through FabKids: A Case Study. *Journal of Science Education and Technology*.
- BEYERS, R.N., BLIGNAUT, A.S. & HERSELMAN, M. 2010. *The young engineers and scientists of Africa: Initiating the SET pipeline from Grade 1*. Paper presented at the INORMS 2010.
- BLESSING, L. & CHAKRABARTI, A. 2009. *DRM: A design research methodology*. London: Springer. 397 p.
- BOJE, J. 1997. *Something to be told: A first history of St Alban's College, Pretoria*. Cape Town: National Book Printers. 241 p.
- BROOKS-YOUNG, S. 2010. *Teaching With the Tools Kids Really Use: Learning With Web and Mobile ...* Thousand Oaks, California: Corwin.
- BROWN, M. 2005. Learning spaces. (In Oblinger, D.G. & Oblinger J.L., eds. *Educating the Net Generation*. Washington: Educause. p. 12.11-12.22)
- BULLEN, M. 2009. Grown Up Digital Research Methods, *Net Gen Skeptic* (Vol. 2010).
- BURNISKE, R.W. 2000. Literacy in the cyberage.
http://www.acm.org/ubiquity/book/r_burniske_2.html Date of access: 22 September 2009.
- BURRELL, G. & MORGAN, G. 1979. *Sociological paradigms and organisational analysis*. London: Heinemann. 432 p.

- CASPARI, A., KUHLETHAU, C. & MANIOTES, L. 2007. *Guided inquiry: Learning in the 21st century*. Westport: Libraries Unlimited. 170 p.
- CEO FORUM. 1999. CEO Forum on Education and Technology.
<http://www.ceoforum.org/downloads/99report.pdf> Date of access: 14 April 2010.
- CHRISTENSEN, C.M. 1997. *The innovator's dilemma: When new technologies cause great firms to fail*. Boston: Harvard Business School Press. 277 p.
- COHEN, L. & MANION, L. 1985. *Research methods in education*. 2nd ed. London: Croom Helm. 638 p.
- COMINS, N.R. 2009. Innovation in South Africa - are we doing enough?
<http://www.saine.co.za/?p=317> Date of access: 22 September 2009.
- DE JONG, T. 2010. *Linking Social Capital to Knowledge Productivity*. Springer Uitgeverij. p.
- DE VOS, A.S. 1998. *Research at grass roots: A primer for the caring profession*. Pretoria: J.L. van Schaik. 471 p.
- DEPARTMENT OF ARTS CULTURE SCIENCE AND TECHNOLOGY. 1996. *White Paper on Science & Technology: Preparing for the 21st Century*
http://www.dst.gov.za/publications-policies/legislation/white_papers/Science_Technology_White_Paper.pdf Date of access: 24 August 2009.
- DEPARTMENT OF EDUCATION. 2002. *National Curriculum Statements Grades R-9*.
<http://www.education.gov.za/Curriculum/GET/doc/overview.pdf> Date of access: 22 February 2010.
- DEPARTMENT OF EDUCATION. 2003. *National Curriculum Statements Grades 10-12: Information Technology*.
<http://www.education.gov.za/Curriculum/SUBSTATEMENTS/Information%20Technology.pdf> Date of access: 22 February 2010.
- DEPARTMENT OF EDUCATION. 2004. *White Paper on e-Education: Transforming learning and teaching through information and communication technologies*.
<http://www.info.gov.za/view/DownloadFileAction?id=68777> Date of access: 24 August 2009.

- DEPARTMENT OF SCIENCE AND TECHNOLOGY. 2002. *South Africa's National Research and Development Strategy*.
http://www.info.gov.za/otherdocs/2002/rd_strat.pdf Date of access: 10 March 2010.
- DEPARTMENT OF SCIENCE AND TECHNOLOGY. 2004. *South African National Survey of Research and Experimental Development (R&D)*.
<http://www.hsrc.ac.za/Document-186.phtml> Date of access: 26 August 2009.
- DEPARTMENT OF SCIENCE AND TECHNOLOGY. 2006. *Youth into Science Strategy, Nurturing Youth Talent for a Stronger National System of Innovation*.
<http://www.lib.uct.ac.za/govpubs/index.php?html=/govpubs/youth1.htm&libid=19>
 Date of access: 26 August 2009.
- DEPARTMENT OF SCIENCE AND TECHNOLOGY. 2008. Tackling unemployment among youth. <http://www.dst.gov.za/media-room/press-releases/tackling-unemployment-among-youth/> Date of access: 24 August 2009.
- DEPARTMENT OF SCIENCE AND TECHNOLOGY. 2009. Engineering Stars Project: Scope Document. Department of Science and Technology, Unpublished report.
- DISMUKES, J. 2005. Information accelerated radical innovation: From principles to an operational methodology. *The Industrial Geographer*, 3(1): 19-42.
- DVIR, R. 2008. Creating the climate – Disruptive innovation ecology.
<http://innovationecology.com/papers/disruptive%20innovation%20ecology.pdf> Date of access: 25 October 2009.
- DVIR, R., GARCIA, T., OZORES, F. & SHWARTZBERG, Y. 2007. *The future center as a catalyzer for innovation ecology in science and technology parks*. Paper presented at the IASP Conference.
- E-MZANZI INFORMATION SOCIETY. 2009. South Africa's efforts to address the e-skills challenge.
http://www.pnc.gov.za/emzanzi_issue3_07/index.php?option=com_content&task=blogcategory&id=54&Itemid=79 Date of access: 17 February 2009.
- ENGUAGE. 2003. 21st Century skills for 21st century learners.
<http://www.ncrel.org/engage/skills/skillsbrochure.pdf> Date of access: 20 August 2009.
- FAB CENTRAL. 2008. Fab Central. <http://fab.cba.mit.edu/about/> Date of access: August 25 2008.

- FRIEDMAN, T.L. 2006. *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus and Giroux. 649 p.
- GERSHENFELD, N. 2005. *FAB: The coming revolution on your desktop - from personal computers to personal fabrication*. New York: Basic Books. 278 p.
- GRAVETT, S. 2001. *Adult learning: Designing and implementing learning events - a dialogic approach*. Pretoria: Van Schaik. 78 p.
- HARVARD BUSINESS SCHOOL PRESS. 2003. *Managing creativity and innovation*.
http://www.amazon.com/Managing-Creativity-Innovation-Business-Essentials/dp/1591391121/ref=sr_1_1?ie=UTF8&s=books&qid=1256631556&sr=1-1
 Date of access: 27 October 2009.
- HEALEY, M. & HEALEY, R. 2010. How to conduct a Literature Search. (In Valentine, G. & Clifford N., eds. *Key Methods in Geography*. p. 16-17)
- HELSPER, E.J. 2008. Digital Inclusion: An Analysis of Social; Disadvantage and the Information Society [Electronic Version]. Retrieved 05 August 2010 from
<http://www.communities.gov.uk/documents/communities/pdf/digitalinclusionanalysis>.
- HOWE, K.R. & MOSES, M.S. 1999. Ethics in educational research. *Review of Research in Education*, 24(1): 21-59.
- INDEPENDENT COMMUNICATIONS AUTHORITY OF SOUTH AFRICA. 2008.
Regulations Regarding Licence Exempt Electronic Communications Networks, Electronic Communications Network Services And Electronic Communications Services In Terms Of Section 6 Of The Electronic Communications Act, 2005 (Act No. 36 Of 2005). http://www.ellipsis.co.za/wp-content/uploads/2008/07/licence_exemption_regulations_2008.pdf Date of access:
- JACKSON, J. 2010. Veterans, Baby Boomers, Gen X, Gen Y and Gen Z ; Understanding the Different Generations and Their Characteristics.
http://geography.suite101.com/article.cfm/veterans_baby_boomers_gen_x_gen_y_and_gen_z Date of access: 04 August 2010.
- JOHN, P.D. 2004. Teaching and learning with ICT: New technology, new pedagogy? *Education, Communication & Information*, 4(1): 101-107.
- JONASSEN, D. 1991. Evaluating Constructivist Learning. *Educational Technology*, 31(9): 28-33.

- JONES-KAVALIER, B.R. & FLANNIGAN, S.L. 2006. Connecting the digital dots: Literacy of the 21st century. *Educause Quarterly*, 29(2): 8-10.
- KELLEY, B. 2010. Book Review and Innovation Summary - "The Design of Business" *Bloggin Innovation* (Vol. 2010).
- KELLY, A.E. 2003. Research as design. *Educational Researcher*, 32(1): 3-4.
- KENNISNET. 2009. Dutch ICT-tools: for a balanced use of ICT in the Netherlands. <http://web.kennisnet2.nl/attachments/1667403/dutchicttools.pdf> Date of access: 6 January 2010.
- LARKIN, J. 2007. The "Digital Natives" Debate Continues... *Watershed: Thoughts on teaching, technology, learning and life in an era of change*. (Vol. 2010).
- LITTLEDYKE, M. 1998. Constructivist ideas about learning. (In Littledyke, M. & Huxford L., eds. *Teaching the primary curriculum for constructive learning*. London: David Fulton Publishers. p. 1-16)
- LUNDY, K.G. 2007. *Leap Into Literacy: Teaching the Tough Stuff So It Sticks!* Markham: Pembroke.
- LUNENFELD, P. 2003. The design cluster. (In Laurel, B., ed. *Design research: Methods and perspectives*. Los Angeles: Massachusetts Institute of Technology. p. 10-15)
- MANGENA, M. 2006. Keynote address by the Minister of Science and Technology, Mosibudi Mangena, at the launch of the 2006/7 DST-NRF Internship Programme. <http://www.dst.gov.za/media-room/speeches/speech.2007-02-16.6389371287/> Date of access: 24 August 2009.
- MANGENA, M. 2007. Address by Minister Mosibudi Mangena at the press launch of the South African Research Chairs Initiative (SARCHI) <http://www.dst.gov.za/media-room/speeches/address-by-minister-mosibudi-mangena-at-the-press-launch-of-the-south-african-research-chairs-initiative-sarchi/?searchterm=PhD%20Innovation%20target> Date of access: 04 August 2010.
- MARTIN, R. 2009. *The Design of Business: Why Design Thinking is the Next Competitive Advantage*. Boston: Harvard Business Press. p.
- MCKENZIE, J. 2007. Digital Nativism Digital Delusions and Digital Deprivation. *From Now On - The Educational Technology Journal*, 17(2).

- MILLER, R. 2000. From schools to learning communities: A historic shift.
<http://www.creatinglearningcommunities.org/book/overview/miller1.htm> Date of access: 26 February 2009.
- MILNER, H. 2007, 10 February 2009. Understanding digital inclusion.
<http://www.egovmonitor.com/node/12519> Date of access: 03 August 2010.
- NAIMAN, L. 2007. Creativity at work: Articles & tips.
<http://www.creativityatwork.com/articlesContent/whatis.htm> Date of access: 26 October 2009.
- NATIONAL ADVISORY COUNCIL ON INNOVATION. 2006. Development through human capital.
http://www.naci.org.za/Innovation_gateway/downloads/Development%20through%20Human%20Capital.pdf Date of access: 6 January 2010.
- NATIONAL ADVISORY COUNCIL ON INNOVATION. 2009. About NACI.
<http://www.naci.org.za/about/index.html> Date of access: 10 October 2009.
- NATIONAL RESEARCH FOUNDATION. 2009. A better life for everybody.
<http://www.nrf.ac.za/> Date of access: 10 October 2009.
- NEGROPONTE, N. 1998. *Being digital*. New York: Random House. 255 p.
- NORRIS, P. 2001. *Digital Divide: civic engagement, information poverty, and the internet worldwide*. Cambridge: Cambridge University Press. 303 p.
- O'SULLIVAN, A. & SHEFFRIN, S.M. 2003. *Economics: Principles in action*. New Jersey: Pearson Prentice Hall. 592 p.
- OBBERG, L. 2004. Technology for knowledge's sake. (In Selinger, M., ed. *Connected schools. Thought leaders. Essays from innovators*. London: Premium Publishing. p. 122-129)
- OBLINGER, D.G. & OBLINGER, J.L. 2005. Is it age or IT: First steps toward understanding the net generation. (In Oblinger, D.G. & Oblinger J.L., eds. *Educating the net generation*. Washington: Educause. p. 2.1-2.20)
- PANDOR, N. 2009a. Address by the Minister of Science and Technology, Naledi Pandor (MP) during the launch of Technology Innovation Agency in Sandton.
<http://www.info.gov.za/speeches/2009/09071009151001.htm> Date of access: 10 October 2009.

- PANDOR, N. 2009b. Speech by Minister Naledi Pandor MP, at the 60th anniversary function of the Sugar Milling Research Institute, Durban Country Club.
<http://www.dst.gov.za/speech-by-minister-naledi-pandor-mp-at-the-60th-anniversary-function-of-the-sugar-milling-research-institute-durban-country-club/?searchterm=Innovation%20and%20Patents> Date of access: 04 August 2010.
- PARTNERSHIP FOR 21ST CENTURY SKILLS. 2004. Partnership for 21st Century Skills.
<http://www.p21.org/> Date of access: 05 August 2010.
- PERKINS, D. 1991. What Constructivism Demands of the Learner. *Educational Technology*, 31(9): 19-21.
- PRENSKY, M. 2001. Digital natives, digital immigrants. *On the Horizon*, 9(5): 1-6.
- REEVES, T.C., HERRINGTON, J. & OLIVER, R. 2005. Design Research: A Socially Responsible Approach to Instructional Technology Research in Higher Education. *Journal of Computing in Higher Education*, 16(2): 97-116.
- ROUX, K. 2009. Broadband4All. <http://www.broadband4all.co.za/Homepage> Date of access: 11 February 2010.
- SCHALL, J. 2006. The influence of constructivism on the instructional practices of teachers. <http://www.bsu.edu/web/jmschall/edpsy3.html> Date of access: 25 October 2009.
- SCHULMEISTER, R. 2008. Is There a Net Gener in the House? [1] Dispelling a Mystification [2].
http://eeced.campussource.de/archive/5/1587/index_html/?searchterm=deutschland
 Date of access: 04 August 2010.
- SCHULZE, S. 2003. The courage to change: challenges for teacher educators. *South African Journal of Education*, 23(1): 6-12.
- SEEBER, R. 2010. Verbal communication with the author on the Ulwazi and Parliamentary Portfolio Committee on Communications. Johannesburg.
- SENGE, P.M., CAMBRON-MCCABE, N.H., LUCAS, T., SMITH, B., DUTTON, J. & KLEINER, A. 2000. *Schools that learn: A fifth discipline fieldbook for educators, parents and everyone who cares about education*. New York: Doubleday. 593 p.
- SNSA. 2003. SchoolNet SA - Yesterday.
http://www.schoolnet.org.za/about/abt_yesterday.htm Date of access: 18 February 2010.

- SOUTH AFRICAN GOVERNMENT INFORMATION. 2005. *No. 36 of 2005: Electronic Communications Act, 2005.*
<http://www.info.gov.za/view/DownloadFileAction?id=67890> Date of access: 22 February 2010.
- TAPSCOTT, D. 2009. *Grown up digital: How the Net Generation is changing your world.* New York: McGraw-Hill. 384 p.
- TAPSCOTT, D. & WILLIAMS, A.D. 2008. *Wikinomics: how mass collaboration changes everything.* New York: Portfolio. 351 p.
- TARLOW, M. & TARLOW, P. 2002. *Digital aboriginal: radical business strategies for a world without rules.* London: Piatkus Books. 224 p.
- THE DESIGN-BASED RESEARCH COLLECTIVE. 2003. Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1): 5-8.
- TIFFIN, J. & RAJASINGHAM, L. 1995. *In search of the virtual class: Education in an information society.* New York: Routledge. 197 p.
- TRILLING, B. & FADEL, C. 2009. *21st Century skills: Learning for life in our times.* 1st ed. San Francisco: Jossey-Bass. 240 p.
- UK ONLINE CENTRES. 2007. *Understanding digital inclusion - A research summary.* Retrieved 10 February 2009, from
http://research.freshminds.co.uk/files/u1/shminds_report_understandingdigitalinclusion.pdf.
- VALCKE, M., et al. 2005. Collaborative learning and ICT: The Flemish experiences. *Educational Technology Magazine*, 45(5): 13-17.
- VAN DEN AKKER, J. 1999. Principles and methods of development research. (In Van Den Akker, J., Nieveen N., Branch R.M., Gustafson K.L. & T P., eds. *Design methodology and developmental research in education and training.* The Netherlands: Kluwer Academic Publishers. p. 1-14)
- VAN DER ZANDEN, P. 2009. *The Facilitating University. Positioning Next Generation Educational Technology.* Uitgeverij Eburon.
- VAN DIJK, J.A.G.M. 1999. *The network society, social aspects of new media.* London: Sage. 267 p.

- VAN RENSBURG, J.F.J., VELDSMAN, A. & LAHDE, K. 2008. *Social entrepreneurship: A foundation for "creative capitalism" in rural African communities*. Paper presented at the Science Real and Relevant: 2nd CSIR Biennial Conference.
- VON GLASERFELD, E. 2005. Introduction: Aspects of constructivism. (In Fosnot, C.T., ed. *Constructivism: Theory, perspectives and practice*. 2nd ed. New York: Teachers College Press. p. 3-7)
- WARSCHAUER, M. 2004. *Technology and social inclusion: Rethinking the digital divide*. Cambridge: MIT Press. 274 p.
- WEINREICH, N.K. 2006. Integrating quantitative and qualitative methods in social marketing research. <http://www.social-marketing.com/research.html> Date of access: 10 March 2010.
- WESTERN CAPE EDUCATION DEPARTMENT. 2006. A human capital development strategy for the Western Cape: A focus on youth. http://wced.wcape.gov.za/documents/human_capital/eng_HCDS.zip Date of access: 16 April 2009.
- WHITE, C. 2005. *Research: A practical guide*. Pretoria: Groep 7 Drukkers en Uitgewers. 262 p.
- WHITNEY, B. 2007. *Social inclusion in schools: Improving outcomes, raising standards*. New York: Routledge. 122 p.
- ZACHARY, G.P. 2010. South Africa Promotes Techno-Scientific Development of Its People To Address Human Needs [Electronic Version]. *Earth Zine; Fostering Earth Observation & Global Awareness* from <http://www.earthzine.org/2010/04/19/south-africa-promotes-techno-scientific-development-of-its-people-to-address-human-needs/>.

ADDENDA

Please refer to the attached CD for the following documents:

- Addendum A: FabKids Questionnaire
- Addendum B: Permission from the Gauteng Education Department to conduct FabKids research in Gauteng schools
- Addendum C: Ethical Clearance from Tshwane University of Technology
- Addendum D: Ethical Application Approval letter
- Addendum E: Article 1: The Ulwazi Concept -Virtual Interactive and Collaborative Classrooms of the Future
- Addendum F: Article 2: A Five Dimensional Model for Educating the Net Generation
- Addendum G: Article 3: Extending the Education and Social Benefits through 'Hub Schools'
- Addendum H: Article 4: Nurturing Creativity and Innovation through Fabkids: A Case Study
- Addendum I: Article 5: The Broader Issues of Introducing a Digital Kids Programme
- Addendum J: Permission to Reprint Article 1
- Addendum K: Permission to Reprint Article 2
- Addendum L: Permission to Reprint Article 3
- Addendum M: Permission to Reprint Article 4