3D Interactive Visual Simulations (VR) as an aid to Learning in Africa

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The Global Approach to Teaching and Learning

Dr RS Day

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VR in Africa – for Africa – by Africa

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CONTENTS

1 PREFACE

UNESCO has, since 2000, supported a number of initiatives with the Naledi3d Factory that have explored the potential of Virtual Reality (VR) as a learning tool in Africa, to date in Ethiopia, South Africa and Uganda (summarized in the box).

In order to define a way forward in this project area, UNESCO commissioned this report, which evaluates the comparative advantages of applying multimedia and interactive 3D tools to the learning environment. This project was divided into two parts:

1. An overview of the general practices and approaches to the use of multimedia and interactive 3D tools as learning aids, and
2. An evaluation programme in South Africa and Uganda covering a number of schools and community telecentres.

The authors prepared the overview with the collaboration of three other specialists which were commissioned to prepare four original papers: "VR from an African educational perspective" (Dr Rita Kizito, Learning Developer, UNISA); "Overview of the Brain" (Dr R.S. Day, ICT Executive, UNISA); "The Global Approach to Teaching and Learning" (Dr R.S Day, ICT Executive, UNISA); "Comparison of and the learning characteristics of educational multimedia" (Mr J. Hugo, Usability Sciences). These papers can be obtained on the Naledi3d Factory Publications Archive (http://www.naledi3d.com/navpage.html).

For the evaluation programme, the support of the UNESCO National Commission for Uganda (especially Ms Anastasia Nakkazi, Secretary-General, and Mr Martin Nsubuga who was responsible for the logistical and operational support during the survey) and the University of South Africa - UNISA (particularly Dr Rita Kizito who developed the survey methodology and questionnaires) is gratefully acknowledged.

Appreciation is also due to the two Local Coordination Committees:

Local Coordination - Uganda

Professor Paul Mugambi	Chairperson National UNESCO IIP Committee
Mr Lawrence Ssenkubuge	St. Henrys' College Kitovu Kings' College Budu
Mr Daniel Kakinda	SchoolNet Uganda
Professor Albert Lutalo-Bosa	Principal, Kyambogo University
Mr Walugembe	Kyambogo University

To date, VR initiatives in Africa have resulted in:

- The development of a VR model addressing the learning points around basic hygiene in rural African communities. The main aim of this project was to use interactive visual simulation as a means of demonstrating basic hygiene to rural communities and to focus primarily on sanitation, water and the prevention of associated diseases (such as malaria, bilharzia, dysentery and cholera). The resulting model was piloted and used at the Nakaseke Telecentre in Uganda. A second goal of this project was to pilot and test the use of VR as a computerised interactive training method in African Telecentres. Nakaseke is approximately 40 miles north of Kampala.
- The training at the Naledi3d Factory in Pretoria of two VR developers from Uganda. Since the completion of the second training session in early 2002, other pilot VR models have been developed, including "DC motors" and "French for Ugandans", both of which have been used in Kings College Budu and St Henry's Kitovo, both Ugandan schools.
- The creation of a formal VR Committee in Kampala, established to co-ordinate VR initiatives in the country; with representation from two universities (Makerere and Kyambogo), SchoolNet Uganda, the Uganda National Commission for UNESCO, the Department of Education, the National Curriculum Development Centre, as well as a number of local schools.
- A VR workshop, sponsored by IICBA (International Institute for Capacity Building in Africa) and hosted by the Naledi3d Factory of Pretoria, in March 2002 with representation form Uganda, Ethiopia and Nigeria, resulted in pilot models to describe levers, relative velocity and chemical elements.
- A project using VR as an aid to helping young people of all ages in Alexandra (Johannesburg) understand better the job application process, how to keep a job and how to create your own employment space.
- A project to help educators in Ethiopia better understand and teach about HIV/AIDS, including the associated social, cultural and psychological issues.

Mr David Kalanzi	Uganda National Commission for UNESCO
Mr Micheal Galiwago	Educational Consultant
Mr Musa Luyinda	Nakaseke MCT
Mr John Ssenkunja	Ndejje Senior Secondary School
Ms Victoria Kisaakye	National Curriculum Development Centre.
Mr John Ssemmondo	Mengo Senior Secondary school
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Mr Edward Jjuuko	Nabweru Telecenter

Local Coordination - South Africa

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2 The Global Approach to Teaching and Learning

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2.1 Summary

The Need for Fundamental Change is being amplified by the recent emergence of neuroscience, which is providing insights challenging conventional educational beliefs entrenched in the current 'factory model'. Modern learning must move from the memorisation of facts to the acquisition of cognitive skills - thinking, learning, and reasoning. Meaningful learning generally occurs through combinations of different approaches to memory. The mind recalls best with context, a global understanding, and complete pictures to remember. The current dominant 'show-and-tell' teaching methods do not take into account the strengths and weaknesses of the crucially important *working memory*. These methods inevitably overload the phonological loop (new and weak), whilst underutilising the visuo-spatial sketchpad (ancient and powerful).

The Role of Text needs urgent reappraisal. Employing the amazing power of vision, our primary sense, to detect text is like repeatedly using an articulated lorry to fetch sweets from the corner store. The alphabet is like a funnel, squeezing all sense data into and through the narrow passage of print. A wonderful tool has become a tyrannical master for many people who find reading too difficult - *'text-o-phobes'*. There were over 40 million adult text-o-phobes in the USA in 1997. Anyone who is not 100% proficient in reading and writing is seen as deficient across a whole range of skills. Yet, learning to read (and write) is no more natural than, but equally as complex as, learning to play the piano. However, no-one uses the inability to play the piano as a measure of one's lack of intelligence, or as a basis for discrimination. As long as we leave text in its dominant role in our global education system, that system can NEVER be equitable.

The Role of Technology in the form of ICT enhanced learning is starting to provide a wide range of improvements to current learning materials via the application of interactive digital multimedia, and via the asynchronous delivery of digital material, whether in a contact institution or in distance mode. We are at the early stages of a long and exciting global initiative where technology must not drive, but improved pedagogy should, based on our growing understanding of how the human brain/mind learns. Improved new learning environments can be built using a variety of digital multi-media, i.e. audio, graphics, visualisation, animation, simulation, and even text (but in the right contexts). However, only ***virtual reality*** is able to create environments combining ALL the required aspects, i.e.:

- the overall context, global understanding, and complete 'big' picture;
- fully utilising the many possible avenues for input and learning in the human mind;
- a wide variety of quality hands-on experiences which encourage learners to choose, explore, manipulate, and test the learning environment provided.

Teaching and Learning in the Developing World presents an extreme version of the global crisis. At all levels, and in all African countries, the education sector is struggling to maintain the status quo, let alone make radical changes. Yet traditional face-to-face delivery will simply not be able to scale up provision to the levels required by Africa's demand. If we in Africa are only prepared to tinker with the current bricks-and-mortar based education systems imported 'as-is' from the developed world, dominated by text-intensive 'show-and-tell' methods, and unresponsive to our knowledge of how the human mind best learns, then those systems will continue to deteriorate and fail. The changes need to be fundamental, and creating new learning materials relevant to Africa's situation is an excellent place

to start. The multi-media (especially virtual reality) based new learning environments that are essential in the developed world, are even more needed in Africa. These materials must not be imported, but must be locally produced to address the wide range of learning needs of Africa's excluded majority taking full account of the local literacy, language and cultural issues.

We know what to do, we have the global resources, but do we have the coordinated commitment? If the USA could mobilise itself between 1962 and '69 to reach the moon, surely the world can mobilise itself to achieve UNESCO's 'Education for All' within a decade or two. Are the world's hundreds of millions of excluded people more remote and less important than the moon?

2.2 The Need for Fundamental Change

The educational model that evolved during both the hunter-gatherer and agrarian periods of early human history was uncomplicated - an individual learned by becoming an apprentice to someone (usually within the same community) who was significantly more skilled and knowledgeable in that area.

But the Industrial Revolution fostered a new model, developed in the 1800s, which brought everyone together in a single place and offered a standardised, 'conveyor belt' curriculum. This paradigm of education (the 'factory model') became the global norm in the 20th century, and drew from fields of sociology, business, and religion, emphasising obedience, orderliness, unity, and respect for authority. The emergence and dominance of behaviourism in the mid 20th Century only served to reinforce the 'reward and punishment' emphasis that had grown to characterise the factory model.

However, the recent emergence of neuroscience, an exciting interdisciplinary approach to non-invasive brain research, is providing an ever growing wealth of major insights which are challenging many conventional educational beliefs, most of which have been entrenched in the current 'factory model'. Brain scanning devices like functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) enable us to analyse the living human brain whilst its owner was carrying out a wide variety of cognitive activities, including learning. During the '90s, (the decade of the brain), interdisciplinary brain research involved a growing number of sub-disciplines, e.g.: genetics, physics, and pharmacology[1].

Although to date we have hardly scratched the surface of understanding the most complex device on the planet, a coherent, preliminary model of how the brain works is emerging (as summarised in the first section) which makes it clear that significant changes are needed both in the ways we teach, and the ways we enable people to learn. A great deal of action research remains to be done, remembering that most paradigm changing breakthroughs have been caused by 'outside-the-box', multi-disciplinary insights. This section discuses some of the actions that can and should be taken.

2.2.1 Improving teaching and learning

Historically, the 'factory' model of education was seen as an environment where knowledge was a commodity that teachers could dispense. New models are emerging where learners construct their knowledge through their own activity and experience, forming and revising their beliefs about the world.

[1]Jensen, E.; "Teaching with the brain in mind". Association for Supervision and Curriculum Development (ASCD) Publications, pp1- 6, 1998.

In a rapidly changing society, we cannot teach people all the facts they will need to know in their lifetime. But we can teach them how to assess their knowledge state, how to find out things for themselves, and how to evaluate conflicting sources of information. The emphasis in modern learning must move from the memorisation of facts to the acquisition of cognitive skills - thinking, learning, and reasoning. Once the focus shifts, the learner's understanding (or theory) of mind becomes important[2]. Modern pedagogy is adopting the view that learners should be aware of their own thought processes, and that it is crucial for the pedagogical theorist and teacher alike to help them become more metacognitive - to be as aware of how they learn and think as they are about the study material[3]. Researchers have made strong claims regarding the importance of 'theory of mind' development for learning.

Theory of mind understanding is also linked to the development of scientific reasoning and critical thinking which depend upon the ability to reflect on one's own beliefs, to recognise where they are mistaken, and to take another's perspective. Learners need an appropriate metacognitive language to discuss literary and historical characters' motivations, to evaluate evidence, and to test scientific hypotheses.

With so much explicit knowledge about how the brain works and with data so clearly supportive of the fact that students construct knowledge for themselves, educators must be persuaded to change from overusing passive-learner instructional methods, such as show-and-tell teaching, to using more thoughtful learning methods, i.e.:

- Learners construct understanding for themselves.
- To understand is to know relationships.
- Knowing relationships depends on having prior knowledge [4].

In this context, examples of potential areas for major improvements to teaching and learning include:

Section 2 showed that there are many possible avenues for input and learning in the human mind, yet the dominant show-and-tell teaching methods, such as lectures, demonstrations, and textbook narratives, activate only a few of them.

Enriched learning environments need to be created that involve learners in a variety of inquiries within *rich content contexts*, thus increasing the likelihood that knowledge and thinking capabilities will be improved. Whenever bits of information are isolated from these rich contexts, they are usually forgotten and become inaccessible to memory[5]. Because the mind resists having meaninglessness imposed on it, effective education must give learners an opportunity to formulate their own contextualised patterns of understanding.

Written formats, such as textbooks, give minimal help because symbols are not reality. They cannot be acted upon or manipulated. Understanding what a symbol represents depends on prior experiential knowledge related to the symbol.

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[2]Astington, JW.; "Theory of Mind Goes to School"; in 'How the Brain Learns', Educational Leadership, ASCD, vol. 56, no 3, pp46-8, 1998.

[3]Bruner, J.; 'The culture of education'. Cambridge, MA: Harvard University Press, p 64, 1996.

[4]Lowery; L; "How New Science Curriculums Reflect Brain Research"; in 'How the Brain Learns', Educational Leadership, ASCD, vol. 56, no 3, pp26-30, 1998.

[5]Cowley, G. & Underwood, A.; 'Memory'. Newsweek, 131(24), 48-9, 51-4. June, 1998.

Learning environments allowing a rich variety of *quality hands-on experiences* need to be created within which *learners may choose, explore, manipulate, test, and make transformations* within the 'objects and ideas' environment provided. These contribute significantly to stimulating learners' interests and linking their perceptions stored within the brain, involving both newly acquired and prior knowledge.

Even for the vast majority of literate people on this planet, in cognitive terms, text is the least efficient and effective of all the available communications media.

Pedagogists and educators should be alerted to the unnatural nature of text, and its in-effectiveness for most aspects of learning. Alternative, *more appropriate delivery and communications media* should be employed.

Complex learning is enhanced by challenge and inhibited by threat.

For optimal learning, educators need to create and maintain an *atmosphere of relaxed alertness, involving low threat and high challenge.* Low threat, however, is NOT synonymous with simply 'feeling good'. The essential element of perceived threat is a feeling of helplessness or fatigue.

The brain is highly complex and adaptive. Educators who employ singular approaches and narrow, standardised tests to get the 'right' answers are neglecting the adaptive power of the developing brain. They are focussing on the measurement of learning, rather than the process of learning.

Good quality learning environments encourages the exploration of *alternative thinking, multiple answers, and creative insights* by learners.

Without an understanding of what the mind was designed to do in the environment in which we evolved, the unnatural activity called formal education is unlikely to succeed.

We need to know a great deal more about the innate component of each human ability, and the most appropriate stage in the development of the brain for it to be built upon and mastered. And we need to *take notice of what is already known*. For example, the dominant technique in American reading instruction, called 'whole language', is based on the erroneous deduction that since spoken language is a naturally developing human instinct, so is *reading*. As explained in section 1, reading is NOT innate, and must be taught via the 'old fashioned' method of practice at connecting letters to sounds. Instead, children are immersed in a text-rich social environment to encourage the innate ability of reading to manifest itself. But the children simply don't learn to read![6] Understanding how the mind learns does not eliminate hard work and practice, but should ensure that they are used only when appropriate (and they can still be fun).

2.2.2 Improving memory and retrieval

Certainly, there is more to a better education than memory. Although the emphasis is moving away from rote memorisation of volumes of material (perhaps less obviously at the tertiary levels in science, medicine, and law), it will continue to be a critical skill. For example, there are clear links between memory skills, better self esteem, and academic achievement. By breaking apart all of the ways we learn, rehearse, and assess, and by using the right system in the right way, learners can consistently

[6]Pinker, S.; "How the Mind Works". Penguin, p342, 1997.

experience better recall. Therefore, educators have an obligation to share with learners a better understanding of memory, and the related retrieval strategies[7].

Before looking at each type of retrieval in more detail, it must be emphasised that meaningful learning generally occurs through combinations of different approaches to memory. Evolution has supplied us biologically with the capacity to register complex experiences, and information is organised and stored differently depending on whether it is meaningful or meaningless to the learner (not the teacher!). Without exception, we remember material best when it is structured and meaningful. *Teaching the whole before the parts ensures better recall*, whichever type of retrieval is involved. The mind recalls best with context, a global understanding, and complete pictures to remember. Once learners understand the relevance and over-all themes, the details and deeper studying makes more sense.

2.2.3 Explicit/Declarative memory strategies:

Semantic memory

Text-based learning material dominates the global education system - 'book learning' is a preferred mode for most teachers for many reasons. But learners seldom find semantic learning interesting. Research shows that names, facts, figures, and textbook information seem to frustrate them the most. Much semantic learning proves to be irretrievable for a variety of reasons, e.g.: the original learning was out of context, trivial, too complex, lacked relevance, or lacked sufficient sensory stimulation. Teachers requiring large amounts of recall from texts are, at best, developing self-discipline in the learners. At worst, they are creating discouraged learners who feel unnecessarily incompetent. *This is, in fact, the weakest of the mind's retrieval systems, and there is growing concern that it is so dominant in the education system.*

Because of its weakness, this type of memory requires strong intrinsic motivation, and its retrieval requires effective activation via such prompts as visualisation, mnemonics, music, and discussion. Ways to improve semantic retrieval include:

- Novelty is known to improve recall dramatically.
- Semantic memory particularly needs time for quiet processing and reflection, otherwise little is transferred to long-term memory. Keeping 'chunks' to a minimum helps the working memory.
- Mind-maps and other graphic organisers have established significant value by drawing, organising, or symbolising key points.
- More visually effective contexts have high impact, e.g. illustrations featuring strong colours; cartoon-like story-boards of key ideas.
- Studies show that analysis of semantic material, particularly in group discussions, aids its recall[8].
- Recall improves when material is repeatedly reorganised and reviewed from various points of view.

Episodic memory

Episodic processing (loci, spatial, event, or contextual) has *unlimited capacity*, forms quickly, is easily updated, requires no practice, is effortless, and is used naturally by everyone. There is ample evidence that learners' recall improves when the learning involves location and/or context changes, e.g. a field trip, music, a guest speaker, or a novel learning location. Ideally, concepts should be learned in

[7]Jensen, E.; "Teaching with the brain in mind". Association for Supervision and Curriculum Development (ASCD) Publications, pp109-12, 1998.

[8]Matthews, RC.; 'Semantic Judgements as Encoding Operations: The Effects of Attention to Particular Semantic Categories on the Usefulness of Interim Relations in Recall'. Journal of Experimental Psychology: Human Learning and memory 3, 8: 160-173, 1977.

different, relevant locations, yet the dominant mechanism is to introduce new concepts in the same location, i.e. months of learning in the same classroom/lecture theatre seat. Physical location changes should be used more frequently, despite the additional administrative load. However, an additional way to take advantage of the power of episodic processing now exists by using technology to introduce appropriate *virtual* location and context changes.

2.2.4 Implicit memory strategies

Learners often know more than they realise, but tend to favour a subset of available pathways for retrieval, which are often inappropriate. They need to broaden their range, including the following implicit memory strategies.

- Procedural: Known as motor memory, body learning, or habit memory, such 'hands-on learning' creates a wider, more complex, and over-all greater source of sensory input to the brain than mere cognitive activity. A summary of the research confirms that this learning has unlimited storage, requires minimal review, is easier to master, and creates lasting positive memories. Unfortunately, in formal education environments (especially secondary and tertiary) this type of learning diminishes each year until it is virtually absent.

- Reflexive Strategies: This type of learning is automatic, almost permanently in use, and full of instant associations, and is brought into play the more learners practice. Although repetitive practice is inappropriate in many areas (especially where innate abilities exist), reflexive recall is powerful, and can be enhanced by games and other quick reaction activities.

2.2.5 Improving working memory

Working memory is of crucial importance (especially to learning) as the mechanism that permits performance of complex cognitive tasks through its ability to temporarily store information related to the various sensory modalities, *particularly those of vision and audition*. It enables us to:

- use our memory systems flexibly;
- hold onto information by rehearsing it in our minds;
- relate that information to older knowledge;
- plan our future actions.

The current dominant 'show-and-tell' teaching methods do not take into account the strengths and weaknesses of this 'rate limiting' system. For example, each of the two slave temporary storage systems, (i.e. the visuo-spatial sketchpad, and the phonological loop), can hold limited numbers of 'chunks' of information (7 +or- 2), BUT their ability to do this is independent (i.e. both can hold 7 chunks simultaneously). Yet 'show-and-tell' inevitably overloads the phonological loop, whilst underutilising the visuo-spatial sketchpad. This is particularly concerning when it is realised that the visuo-spatial sketchpad is by far the senior partner, since language has been acquired in the last few 10,000s of years (a second in evolutionary time scales), whereas vision has been and remains man's (and primate's) senior sense for 60 million years.

2.3 The Role of Text

We have seen how complex a challenge it is for the human mind to detect and interpret language, and that it is still in the process of evolving to best cope with this valuable emerging unique human ability. Reading is very more recent, and much more of a processing challenge. However, seeing, and identifying the code (letters and words) that make up written language are far from being a challenge to our visual perception (we have shown how the further interpretation and processing of the visually

detected code happens in the language centres, not the visual cortex). Employing the amazing power of our primary sense organ (almost 50% of the cerebral cortex) for hours to detect this small selection of stationary, repetitive, symbols is not like using a Rolls Royce to fetch food from the corner store. Worse, it is like repeatedly using an articulated lorry to fetch food from the corner store, bringing back just a few items at a time (due to the sequential nature of text). Some claim that 'speed-reading' utilises more of our visual power, but many who attempt to acquire this skill fail, whilst there is little sign of it being taught in primary schools.

So how and why did text acquire this dominant role in our lives? Cultural critic Marshall McLuhan points to Gutenberg's invention of movable type as the force behind a vast array of cultural effects. His major message was that societies and cultures are more shaped by the nature of their communication media, than by the content. According to John Culkin, one of Marshal McLuhan's major interpreters[9],

"The alphabet is a funnel. All sense data must henceforth be squeezed into and through the narrow passage of print. The audible, the pictorial, the tactile, the olfactory - all get translated into ... the abstract..... Reality is squeezed through the funnel of the alphabet. Reality comes out one drop at a time; it is segmented and sequential; it is fragmented along a straight line; it is analytic; it is abridged; it is reduced to one sense; it becomes susceptible to perspective and point of view; it becomes uniform and repeatable."

Certainly, the alphabet, text, and Gutenberg's movable type must rank amongst man's most impressive and important achievements. But a wonderful tool appears to have become a tyrannical master for the majority of the people on the planet. Is the problem with text, or with the ways society has grown to use it? Horn argues that the current split and imbalance between using words and using images (exemplified in the education system) parallels a historical split[10]. Just after the invention of the Phoenician alphabet, words and images (artistic pictures, sculptures, and drawings) began to take separate routes, becoming separate forms of communication. Each had its own vocabulary and syntax, each its own tools and concepts. Each had its own master craftsmen and teachers, each its own department in the university. Even in the elementary grades, teachers specialised in one subject or the other, seldom both. In school, everybody knew that you were either a word person or a picture person. It was all part of the great either/or division that our societies have relied upon for millennia.

It is natural that most of the people reading this article will disagree (probably very strongly) that text has so many problems associated with it. They will point out (quite rightly) that text has been a primary factor in their reaching the status that they currently have in society (usually in the top 25%). Once they had learned to read (and how many of us can remember how easy/difficult this was?) text-based material proved an invaluable resource in the many ways they continued to learn and grow (books, newspapers, journals, reports, emails, web-sites, etc.), as well as the many ways they learned to express themselves (letters, emails, reports, articles, books). The point is that these people are us, and we are ***'text-o-philes'***, who CAN read, enjoy reading, and have easy access to reports like this.

If we text-o-philes represent a significant majority of the people on this planet, then the problems with text spelled out above should still be addressed, but as important peripheral initiatives, rather than as a primary focus of the global education sector. But we are NOT the majority! The vast majority of the

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[9]Culkin, J.; 'Each culture develops its own sense-ratio to meet the demands of its environment'. In 'McLuhan: Hot and Cool', GE Stearn ed, 42-43, New York: dial, 1967.

[10]Horn, RE.; "Visual Language: Global Communication for the 21st Century". MacroVU Inc., Washington, p2, 1998.

people on this planet will NEVER read this report (or any other similar document) for a variety of reasons:

- it is so badly written;
- they can't read;
- they don't understand English;
- they don't have access (either in print or electronic form);
- even though they have been taught to read, they don't because: it is so difficult for them; they are so slow at reading; their understanding is poor; and their recall is even poorer. Let's call these people ***'text-o-phobes'***.

We will return to the issues around illiteracy, imposed languages, and the lack of access in the final section dealing with the developing world, since text does not appear to be the primary cause of these problems. As for improving this author's writing style, this has proved a hopeless task!

How serious a problem is 'text-o-phobia' in the developed world, where almost everyone is taught to read early in life, and has the opportunity to access a wide range of material in their natural language(s)? We can't answer this question with unequivocal statistics, since 'text-o-phobia' is not a recognised condition, but there are some strong pointers. Why does *Functional Illiteracy* remain a major problem in the developed world? As the World's most affluent society, the USA has been pumping $ billions into its education system for decades. Yet, according to Manuel Castells, over 40 million adults in the USA in 1997 (>25% of the adult population) had 'blatantly insufficient levels of reading and writing in English, as well as of elementary arithmetic'[11].

The importance of literacy and higher levels of language skills in modern society can hardly be exaggerated. People are judged on how they write and speak and, as we have seen, nearly all academic teaching is dominated by language ('text-and-tell'). Therefore, since it has become such a fundamental, cross-cutting tool, anyone who is not 100% proficient in reading and writing is likely to be seen as deficient across a whole range of skills[12].

How many people in modern developed societies are "100% proficient in reading and writing"? At the other extreme are people with dyslexia, who have a history of being severely discriminated against, and treated as if having little intelligence. Dyslexia takes many different forms and probably has many different causes. However, PET brain scans of dyslexic people doing word tasks have shown that, unlike in non-dyslexic people, their language processing areas fail to work in concert, so the incoming words get jumbled up and disjointed. The insula (the deep infold that lies between the language areas, and which appears to orchestrate their activity in non-dyslexic people) did not fire and each language area was activated singly.[13] It must be stressed that this dysfunction of a small area of the brain is NOT an inherited flaw, but a failure to fully develop an unnatural skill.

Learning to read (and write) is no more natural than, but equally as complex and difficult as, learning to play a musical instrument like the piano or the violin. How do you get to Carnegie Hall? Practice! But no matter how hard we practice; only a special few of us will develop the exquisite skills that get us to Carnegie Hall. A larger minority will be good enough to please themselves and others (tutors, pub pianists), many more of us (the majority?) can get to the level of 'banging out a tune' which is fun for 2

[11]Castells, M.; 'The Information Age: Economy, Society, and Culture'; vol. 3, "End of Millennium", Blackwell, p163, 1998.

[12]Carter, R.; "Mapping the mind". Phoenix, pp251-4, 1998.

[13]Paulesu, E, Frith, U, et al; "Is developmental dyslexia a disconnection syndrome?", Brain, 119 (1996), 143-7.

minutes, but becomes hugely painful for any audience for longer periods. And then there are those (>25 %?) who no matter how long or hard they practice have brain structures that cannot master just one of the many steps in the relevant combination of skills, including the 'tone deaf' (the musical equivalents of illiteracy and/or dyslexia?).

Although it is sad to discover that one cannot play the piano, no-one uses that inability as a measure of one's lack of intelligence, or as a basis for discrimination. So why does society (and especially the education sector) do exactly that with reading (and writing)? Isn't it because of the unfortunate, but widely held misconception that because we ARE all born with the innate ability to develop exquisite language skills (speech and hearing), we must also be born with similar innate skills for reading and writing?

To return to the range of skills in the music analogy, how meaningful is an IQ test, or how fair is any form of written examination when to a large extent what we are fundamentally re-measuring is the very wide range of abilities in the general population to read and write? Doesn't the incorrect assumption that we are all born with the ability to develop similarly high levels of reading and writing skills (whereas very few of us can ever get past the level of being able to 'bang out a tune') mean that as long as we leave text in its dominant role in our global education system, that system can NEVER be equitable, even in the developed world?

This is not a plea for the banning of text! It is a plea to re-examine the role of text in the light of our knowledge of how the brain works, and to replace its current dominance with a more balanced role where its strengths are accentuated, and its weaknesses avoided. The power of text rests in the author's ability to enrich and extend the ideas already within a reader's mind. New knowledge gained from reading is actually a rearrangement of prior knowledge into new connections. With something to work with, an author can help readers understand abstract ideas that they could never experience firsthand. But if readers have little in storage related to the content of what they read, they will gain little from reading.

Great fiction writers (who have an exquisite skill analogous, perhaps, to the playing skills of, say, a Rachmaninov) can rearrange what most of us know with such craft and sensitivity that it gives great pleasure, as well as new insights. They have the rare ability to excite our imaginations, and energise our 'mind's eye' to create intoxicating new worlds. They appreciate the abstract and vague nature of text, and realise that each reader's 'new world' that the text stimulates them to imagine may be dramatically different from one reader to the next. Their genius is that they don't use text as a control mechanism (as we MUST do when educating), but as a stimulant to set the reader's imagination free. They DO control the story line, but the imagined world created is the readers'.

Sadly, we can't use text this way in education, even if it were possible to raise every educational writer to the level of, say, a Wilbur Smith. In almost all subjects, education is not in the business of conjuring up imagined worlds, but of attempting to accurately describe and explain to learners REAL worlds (contexts, concepts) that many of them have not seen, and may never see. However, the more academically accurate the writer tries to make text, the more detailed it needs to be, the longer it becomes, the dryer it becomes, the less interesting it becomes, the less memorable it becomes, and the more difficult it becomes to write! This is not what text is good for - it is unfair to learners, to writers, and to text itself!

2.4 The Role of Technology

Technology has been used in education for centuries. Chalk is technology, a book is technology. However, what we are emphasising here is Information and Communications Technology (ICT). The arrival of personal computers (PCs) a quarter of a century ago turned everyone (theoretically) into a potential computer user. In the '80s and '90s, the PC/Internet combination converted the Internet from a tool used by some military and academic cliques into a global phenomenon which, in turn, has changed the nature of the PC (and its most popular applications) from being predominantly a processing tool into a powerful and highly flexible communications platform.

In the context of the PC/Internet combination three powerful trends can be identified that are driving the information revolution:

- Cost of communicating: The transmission cost of sending digital data has decreased by more than a factor of 10,000 since 1975.
- Power of computing: Computing power per dollar invested has also increased by well over a factor of 10,000 since 1975.
- Convergence: Analogue technologies are being replaced with digital technologies which are capable of dealing with voice, video and computer data over the same network.

2.4.1 Using technology in existing learning environments

Put simplistically ICTs can be used directly to improve teaching in two ways: via the delivery of teaching, and to create better teaching materials. However, both of these have many subcomponents, and the picture is further complicated by the mode of teaching, i.e. contact, distance or a combination of both.

Two concepts are frequently used in this area. Although they overlap, there are significant differences, and therefore they should not be confused with each other:

- *Technology mediated distance education:* This has long been used to increase the range of the traditional contact mode of teaching, often via broadcast media. The synchronous form uses TV, radio, and video and tele-conferencing, whereas the asynchronous form uses video- and audio-tapes via TV and radio, and more recently via the web. Here the pedagogy is fixed, i.e. the traditional contact or 'show-and-tell' mode.

- *Technology enhanced teaching:* This first emerged in the '70s as text based computer based education (CBE) and computer based training (CBT). More recently, a wide range of improvements to current learning materials has become possible via the application of interactive digital multimedia: text, graphic, audio, video, animation, simulation, virtual reality, etc.; and via the asynchronous delivery of digital material, whether in a contact institution or in distance mode. Here the pedagogy is often assumed to be contact, but a wide range of more appropriate alternatives are possible. This is the area we are addressing in this article.

Most residential higher education institutions (HEIs), and a few of the best funded schools have been experimenting for some time with both types of enhancement. The most strategic has been the adoption of broadcast mechanisms to provide lectures (usually live) at a distance, thereby reaching thousands more students at satellite campuses and other delivery sites. Less strategic has been the adoption by lecturers (individual and groups) of one or more aspects of ICT enhanced teaching, often to supplement their lecture material (verbal and textual).

The advent of the world wide web (web) is further complicating the above already complex picture. The web allows any learning material, once digitised (e.g. text, graphics, voice, video, animation, etc.) to be made available anywhere in the world that has internet connectivity, either synchronously or asynchronously. It should be emphasised that the web has introduced the additional major attribute of several levels of ***interactivity***, both synchronous and asynchronous, ranging from email and 'chat rooms', through interactive learning environments (taking much from the latest web-based multi-user games, and including virtual reality), to voice and/or video conferencing over IP.

Of course, availability of bandwidth and PCs with sufficient power at access points currently imposes a variety of restrictions on what can be received by whom, when and where. But the technology exists to enable us to develop a wide variety of improvements to our teaching materials and the ways in which it might best be delivered to a variety of learners (which go together to create the learning experience). The restrictions come from a combination of education sector 'traditionalism', fuzzy political vision, and private sector indifference. Technology is often used unfairly as the scapegoat for inaction in this complex, but exciting field of opportunity.

There are a growing number of schools and colleges where all learners have access to computers, and the trend in the developed world is to aim for every student having his/her own PC or Notebook. These learners are provided with learning programmes by the institutions, and can also search the web for a wide range of digitised material that is available. However, most of this material is either text-based learning material that has been digitised, or has been developed to 'push' a particular application of ICT, rather than enhanced pedagogy.

More and more teachers are using PCs or notebooks (sometimes with a digital projector) to enhance their study material. However, full ICT literacy is a problem with many of the older teachers (ICT appears to be one of the areas where young minds are much better adapted to learn). In most cases, these teachers are not developing technology enhanced new learning material (and do any of them have the time and resources to do so?), but are using ICTs to overcome the fact that semantic memory (names, facts, numbers, and textbook information) is the weakest of the mind's retrieval systems. Instead of redesigning the text-based material, they enhance its retrieval via such prompts as mnemonics, music, novelty, discussion, and visualisation tools (e.g. mind-maps - drawing, organising, or symbolising key points).

2.4.2 Using technology to create new learning material

As we create new technology enhanced learning materials, it must be recognised that we are only at the beginning of a long and exciting global initiative. It must not be technology that drives this development, but improved pedagogy based on our growing understanding of how the human brain/mind learns. Over the next two decades we will discover a great deal more about the innate component of each human ability, as well as the most appropriate stage in the development of the brain for it to be built upon and mastered. However, if we *take notice of what is already known*, as set out in section 1, there is a great deal we can already be doing.

We have established that the new learning material needs to break out of the current show -and-tell mode, and the related dominance of text based material, because:

- they activate only a few of many possible avenues for input and learning in the human mind;
- written formats, such as textbooks, cannot be acted upon or manipulated;
- for learning purposes, text is the least efficient and effective of all the communications media that technology now make easily available;

- singular approaches and narrow, standardised tests to get the 'right' answers are neglecting the adaptive power of the developing mind/brain;
- semantic memory (names, facts, numbers, and textbook information) is by far the weakest of the mind's retrieval systems;
- the power of the more natural episodic, procedural, and reflexive learning and retrieval systems are mostly neglected;
- they do not take into account the strengths and weaknesses of the crucially important, but 'rate limiting' working memory system. 'Show-and-tell' inevitably overloads the phonological loop, whilst underutilising the much better established visuo-spatial sketchpad.

What are the guidelines for building the new, technology enhanced learning environments?

Firstly, the material must be structured, meaningful and coherent. *Teaching the whole before the parts ensures better learning and recall.* The mind learns and recalls best with context, a global understanding, and complete pictures to process. Once learners understand the relevance and over-all themes, the details and deeper studying makes more sense, and help the learner to build a rich network of additional associations and relationships (contextualised patterns of understanding) on an ongoing basis. Such material begins to take advantage of the power and unlimited capacity of episodic processing. Historically, it has been very difficult to paint such big pictures in the classroom or lecture theatre other than descriptively. But now, ICTs can be used to introduce appropriate *virtual* location and context changes, drawn from what will become an almost infinite resource of real and abstract digital worlds.

Secondly, within the above holistic content contexts, enriched learning environments need to be created that involve learners in a variety of inquiries which much more fully *utilise the many possible avenues for input and learning in the human mind*. This increases the likelihood that the learner's knowledge and thinking capabilities will be improved, and also employs the power of episodic processing. Although one-on-one tutorials and small learning groups often, quite naturally, use this powerful learning regime, it cannot be properly set up or utilised in the classroom containing from 25 to 400 learners. However, modern ICTs can be used to create a variety of multi-media based digital learning avenues, with the additional power of allowing the learner to select whichever avenue he/she prefers at any particular time.

Thirdly, the effectiveness of these new learning environments will be greatly enhanced by providing *a wide variety of quality hands-on experiences* which encourage learners to choose, explore, manipulate, test, and make transformations within the 'objects and ideas' environment provided. Again, episodic processing is likely to be involved, but in addition, both the procedural and reflexive components of implicit memory are particularly employed. Specialised physical environments (e.g. laboratories) exist which, in part, address this need which cannot be addressed in the normal large classroom or lecture theatre. But these physical environments can only be made available to subsets of learners for short periods, and are costly, requiring significant set up costs, as well as ongoing maintenance and support. Alternatively, ICTs can now be used to establish interactive virtual learning environments which can stimulate a much larger number of learners, with the added advantages of safety and low maintenance overheads.

By employing the full potential of ICTs as introduced above, these new learning environments can at last be built to:

- encourages the exploration of alternative thinking, multiple answers, and creative insights by learners;

- establish a much more balanced use of working memory, by reducing the use (and overload) of the phonological loop, whilst fully utilising the more powerful visuo-spatial sketchpad.
- use more appropriate delivery and communications media as required, not just 'text-and-tell';
- create highly challenging experiences for the learners, thereby reducing the stressful atmosphere of perceived threat, and feelings of helplessness or fatigue so often experienced in large classes;

Several aspects of the ideal new learning environments described above can be built using a variety of digital multi-media, i.e. audio, graphics, visualisation, animation, simulation, and, yes, text (but in the right contexts). However, there is only one ICT application that is able to create environments combining ALL the required aspects, i.e.:

- the overall context, global understanding, and complete 'big' picture;
- a variety of learning avenues which much more fully utilise the many possible avenues for input and learning in the human mind;
- a wide variety of quality hands-on experiences which encourage learners to choose, explore, manipulate, test, and make transformations within the 'objects and ideas' environment provided.

That application is a fully interactive, simulated, virtual 3D environment, i.e. ***Virtual Reality***.

There is a great deal of energy currently being expended in digitising existing text-based learning material and making it available electronically (particularly via the web). This has some value, since it makes this learning material more easily available to those who can make use of it. However, it does not significantly address the fundamental learning issues described above (in fact, it perpetuates most of the problems). As multimedia-based new learning material is developed along the above guidelines, the importance of 'learning objects' will become clear. Another crucial issue that cannot be addressed in depth here, but is central to the new learning material, is the balance between independent and interactive learning. A greater understanding will emerge of which is the more appropriate learning/teaching mode, but it is highly complex since it depends on the age and sophistication of the learner; the subject material to be learned; the availability and capabilities of teachers, lecturers, tutors and mentors; and the possible groups of learners that can be formed. Indeed, a variety of group learning regimes (both physical and electronic) appears to have particular potential for improving learning experiences, and helping to improve the quality of the new learning material on an ongoing basis.

Who is going to produce this wealth of new learning material? It cannot be left to teachers and lecturers alone for several reasons. Most of them are already overloaded with expanding class sizes, and a growing administrative load that seems to take them ever further from their learners. But, perhaps more importantly, very few of them have the pedagogical expertise - they were usually employed as subject specialists, not pedagogists. The process must be driven both by current pedagogy and the major new insights that will emerge from the growing flood of brain research. So the primary players are most likely to emerge from the tertiary/research sector, but will need the support of teachers/lecturers, ICT experts, public and private sector stakeholders, and, of course, the learners themselves.

The questions of where will this be done, how, when, and who will fund it have yet to be addressed. Clearly, the necessary facilities and capacities do not exist, especially in the developing world, where the need is greatest.

2.5 Teaching and Learning in the Developing World

This article has not yet differentiated between education in the developed and developing worlds. The intention has been to emphasise that there is a *global* crisis in education, what the fundamental causes of that crisis are, and where the solutions lie. We educationalists have been doing the wrong things for too long. The good news is that, at least in the developed world, we have all the resources and capabilities to implement the solutions. If the USA could mobilise itself between 1962 and '69 to reach the moon, surely the world can mobilise itself along the above lines to achieve UNESCO's 'Education for All'[14] within a decade or two. Who will argue that EFA is less important than reaching the moon?

Although the education crisis is global, of course the situation is significantly worse in the developing world, and particularly in Africa. Many argue that poverty, and its 'high tech' manifestation, the 'digital divide', will always be with us. They shrug and say that it is not, and will never be possible to provide even second class education to the 70% of Africa's poor and remote population that lives beyond the main cities. But is this not the stuff of self-fulfilling prophecies? Are these hundreds of millions of excluded people more remote and less important than the moon?

2.5.1 Status of 'formal education' in the developing world

At all levels, and in all African countries, the education sector is struggling to maintain the status quo, let alone make radical changes. Of all the levels, the tertiary sector has the best resources and capabilities. Certainly, within most of Africa's Heir's there are many individuals who have the expertise to make a significant impact if we could pool their resources. But do the Heir's themselves (which maintain the elitism and traditionalism established by their colonial sponsors) have the vision and flexibility to allow this to happen?

The essence of UNESCO's "Education for All" challenge is to work towards the eradication of abject poverty throughout the world. The global tertiary sector, combined with their traditional values concerning the well-being of society, should be ideally positioned to address this. However, today's universities are faced with the perplexing task of balancing the tensions of Sir John Daniel's eternal triangle, i.e. to improve quality, cut their costs and to serve more and more students[15].

Global access to tertiary education has grown from 6.5 million enrolments in 1950 to 88.2 million in 1997, growth of more than 1200%. Although this growth appears remarkable, the global education crisis has deepened. In 1995 a little more than half of the world's tertiary students (47 million) lived in the developing world, with a gross enrolment ratio mostly below 15%. However, the average for Sub-Saharan Africa remains less than 4%. Saint[16] points out that at least 16 countries in Sub-Saharan Africa will need to double current tertiary enrolment in the coming decade just to maintain the existing and unacceptably low gross enrolment ratio.

Around the world today we need the equivalent of one large new university to open every week just to keep tertiary participation rates constant. But, most of the world cannot afford the established campus model. Traditional face-to-face delivery will simply not be able to scale up provision to the levels

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[14] UNESCO, 2000. Text adopted by the World Education Forum Dakar, Senegal, 26-28 April 2000. http://www2.unesco.org/wef/en-leadup/dakfram.shtm

[15] Daniel, JS, 1999. (reprint with revision) "Mega-universities and knowledge media: Technology strategies for higher education". Kogan Page: London.

[16] Saint, W, 1999. "Tertiary distance education and technology in Sub-Saharan Africa". Washington DC: Working group on Higher Education, Association for the Development of Education in Africa, The World Bank.

required by the global demand in a manner that is capable of maintaining a sustainable balance among the tensions of the eternal triangle.

"Under the conventional campus model, individual faculty members carry the responsibility for teaching. They have relative freedom in organizing the learning environment regarding the implementation of the curriculum, and in how to teach in the classroom and assess learners. The campus model is robust and easy to organize, but the quality of provision is highly variable (excellent subject specialists/researchers are seldom good teachers). This model is extremely difficult to scale up, limited by the physical campus facilities and the number of learners that an individual faculty member can realistically manage.

The distinguishing pedagogical feature of higher education (HE) massification (e.g. the mega-universities) is that, instead of giving individual faculty the responsibility for teaching, sophisticated learning systems have been developed based on innovative divisions of labour where the responsibility for teaching is carried collectively by the organization. The differentiating feature of mass provision via open learning systems is that the institution teaches, not the individual teacher. By replacing the traditional lecturer model with a total teaching system where the functions of teaching are divided into a range of specializations, HE massification is able to scale up the delivery of quality teaching to levels that simply are not possible in conventional campus-based or dual-mode models.[17]**"**

Whereas there is a growing realisation that ICT supported mass provision represents the only viable solution to this crisis, particularly in the developing world, there is a grave danger that many forms of technology mediated distance education currently being practised will be misinterpreted as the 'massification solution'.

Of all countries in Africa, South Africa's education system is probably healthiest. Yet a National Plan on Higher Education (NPHE) has recently been instituted because the higher education system is seen to be far from optimally organized to meet the county's human resource requirements. It is seen to be extremely wasteful and guilty of squandering valuable resources, delivering a poor return on investment measured in terms of graduate and research output. But the NPHE does not talk of the fundamental changes highlighted in this article, but instead advocates re-arranging the current systems, processes and curricula to provide more efficiency and effectiveness. This is understandable, since the motivation for change stems from the extreme frustration of external stakeholders in the public and private sectors, not from those academics and researchers with the relevant pedagogical expertise. But what does this say to the hundreds of thousands of potential students in South Africa's remote and rural areas who cannot be reached by the current system, re-arranged or not?

2.5.2 New learning materials for Africa

The message is clear. If we in Africa are only prepared to tinker with the current bricks-and-mortar based education systems imported 'as-is' from the developed world, dominated by text-intensive 'show-and-tell' methods, and unresponsive to our knowledge of how the human mind best learns, then that system will continue to deteriorate. Superficial tinkering has not worked to date, and cannot work as explained above. The changes need to be fundamental, and creating new learning materials relevant to Africa's situation is an excellent place to start.

An inevitable response is that the developing world, and particularly Africa, does not have sufficient resources to develop its own new learning materials. Instead, we should wait, observe and take from the

[17]Extracted from "Leading ODL futures in the eternal triangle: a mega-university response to the greatest moral challenge of our age", by Sir John Daniel and Wayne Mackintosh, 2002: in press.

developed world whatever they produce over the next few years. In the meantime, we should persevere with the text-based learning material (mostly imported, usually from the old colonial powers for language reasons), because it is 'better than nothing'. Perhaps, but we now know how far it is from the best we can do.

To illustrate how flawed this argument of self-perpetuating dependency is, it is useful to look at Africa's ICT Industry (or the lack of it). Almost all ICTs in Africa (hardware and even software) are imported from the developed world (at significantly higher prices), and are usually implemented in the larger organisations in the public and private sectors, often funded by developed world loans. These products may be 'customised' to partially fit the African circumstances of these large organisations (although they were in no way designed with such circumstances in mind - they will always be designed for developed world needs). But, how well do these developed world ICTs serve the needs of the vast majority of Africa's people, the poor, the disadvantaged, the excluded? They don't. They were not intended to.

Can importing and customising do anything other than increase the developed world dependency of the African elites whilst leaving the poor and remote majority even further behind? Manuel Castells argues that this process has stimulated the emergence of the 'Fourth World' made up of multiple 'black holes' of social exclusion, and including most of Sub-Saharan Africa. He warns that *"The rise of the Fourth World is inseparable from the rise of informational, global capitalism"*, and identifies illiteracy as a primary global cause of unemployability, poverty and social exclusion[18].

Is the situation any different if we continue to import and attempt to customise developed world learning materials, including their latest ICT enhanced new learning materials? If we examine the wide range of 'life-long-learning' needs of the broad spectrum of people in Africa, not just the elites, it becomes obvious that most imported learning materials are of little use to the hundreds of millions of excluded people for reasons of literacy, language and/or culture.

- *Literacy:* Accurate figures for literacy in Africa are problematic for several reasons, including the different definitions of literacy used. Certainly, if the same measures of 'functional illiteracy' for the USA used by Castells are employed for Africa, levels above 70% would be common, especially in populations outside the main cities. Hence, the problems with text described above are significantly amplified in Africa, which perhaps should be thought of as a *'text-o-phobic'* continent for the purposes of transforming education. Instead of importing the dominantly text-based new learning materials from the developed world, materials need to be developed locally that specifically address the needs of the majority by reducing text to a minimum. Can materials be produced where most text is replaced by the much more natural voice? Can these materials use visualisation techniques rather than text to more accurately describe places, people, events, etc.? Can these materials use interactive animation and simulation rather than text to allow learners to actively investigate how things dynamically happen and work? Yes, in every case - easily accessible digital multimedia tools exist for all these needs.

- *Language:* Many African people are at least bi-lingual, having both a local language, and a European language imposed during Africa's colonisation. Since most of Africa's education material is imported from the old colonial power, the colonial language, not the indigenous language(s) dominate the education systems. This may appear reasonable in the large cities, where many youngsters are exposed to and therefore naturally learn both colonial and indigenous

[18]Castells, M.; 'The Information Age: Economy, Society, and Culture'; vol. 3, "End of Millennium", Blackwell, pp70-165, 1998.

languages in their infancy. But in the remote and rural areas, where most of Africa's population lives, the picture is very different. Here, only local indigenous languages are heard and learned in infancy. The colonial languages are taught (usually not very well, by teachers who themselves are seldom fluent) to 8 - 14 year old learners, long after the 'natural window' for language acquisition has closed. Very few reach reasonable proficiency, even for speech, whilst the much more difficult reading skills are consequentially poorer. Learners in these remote, impoverished areas of Africa have enough disadvantages without being forced to read and listen in a medium which is, literally, alien to them, producing at best, rote learning, at worst, no learning. Therefore the locally produced new learning materials should allow the learners to choose whichever they prefer of several local indigenous languages, both for voice, and text. This is already technologically possible, and as African languages are added to the now mature language technology platforms, it can grow significantly. Now is the time to start the process.

- *Culture:* We have seen that for quality learning it is very important to contextualise the subject being learned - to paint the big picture first. This is particularly the case where learners are attempting to understand and master complex, often abstract concepts, which are especially common in maths, the natural sciences, and engineering. Man has always used analogies to handle such complexity, and they remain an excellent learning aid. However, analogies, like language, are highly culturally dependent, and the analogies commonly used (especially in imported textual material) reflect the colonial, not the indigenous culture. Using a London bus to contextualise the learning of Newton's Laws of Motion throughout much of rural Southern Africa (where London buses are even rarer than at London bus stops) has been failing for decades. Sadly, it has usually been the intelligence of the learners that has been questioned, rather than the quality of the learning material and teaching. Therefore, locally produced new learning materials should use culturally relevant analogies, often expressed via visualisation, animation, or simulation rather than text. But the supporting language material (voice especially) should be in the appropriate range of indigenous languages.

It should now be clear that the multi-media based new learning environments that are essential in the developed world, are even more needed in the developing world in general, and Africa in particular. It should be equally clear that these materials must not be imported, but must be locally produced to address the wide range of learning needs of Africa's excluded majority taking full account of the local literacy, language and cultural issues.

Again, there is only one ICT application that is able to satisfy ALL the above African learning requirements by creating fully interactive, simulated, virtual 3D environments, i.e. ***Virtual Reality***.