Original: English

EVALUATION OF VIRTUAL REALITY IN AFRICA

AN EDUCATIONAL PERSPECTIVE

United Nations Educational,
Scientific and Cultural Organization

Paris, 2004

Original: English (CI-2004/WS/1)

Evaluation of Virtual Reality In Africa An educational perspective

Prepared by

David Lockwood
The Naledi3d Factory (Pty) Ltd

United Nations Educational,
Scientific and Cultural Organization

Recommended catalogue entry:

Evaluation of virtual reality in Africa, an educational perspective / prepared by David Lockwood ; The Naledi3d Factory (Pty) Ltd. - Paris: UNESCO, 2004 - viii, 46 p. ; 30 cm. (CI-2004/WS/1)

I - Title

II - UNESCO

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 who 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 authors gratefully acknowledge 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 of the University of South Africa - UNISA (particularly Dr Rita Kizito who developed the survey methodology and questionnaires).

Appreciation is also due to the Local Coordination Committee in Uganda:

Professor Paul Mugambi	Chairperson National UNESCO IIP Committee
Mr Michael Galiwango	Educational Consultant
Mr Edward Jjuuko	Nabweru Telecenter
Mr Daniel Kakinda	SchoolNet Uganda
Mr David Kalanzi	Uganda National Commission for UNESCO
Ms Victoria Kisaakye	National Curriculum Development Centre.
Professor Albert Lutalo-Bosa	Principal, Kyambogo University
Mr Musa Luyinda	Nakaseke MCT

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 Fredrick Matovu	Buwama telecentre
Mr John Ssemmondo	Mengo Senior Secondary school
Mr Lawrence Ssenkubuge	St. Henrys’ College, Kitovu
Mr John Ssenkunja	Ndejje Senior Secondary School
Mr Christopher Walugembe	Kyambogo University

and to the hosting school officials in South Africa:

Mr C.M. Masuluke	Principal, Soshanguve High School
Mr J. Ramokwase (deceased)	Principal, Mamelodi High School
Mr R. Sebata	Principal, Mamelodi High School

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VR or 'interactive visual simulation' as it is sometimes known, can be defined as '*a computer-generated environment in which the user is able to both view and manipulate the contents of that environment*'. It allows for intuitive, real-time interaction, supported by an intelligent, realistic 3D environment.

VR technology ranges from full immersive (cave systems, head-mounted display and goggles, and the like) through semi-immersive (virtual theatre, immersive desks, etc.) to non-immersive systems that run on desktop PCs and can be either shown on the screen or projected onto a wall using a digital projector.

In an educational context, VR allows the learner to both view and manipulate virtual objects in a manner similar to that of a real environment. It does this in a way that heightens multi-sensory, multi-perceptual and multi-dimensional capabilities, thereby enhancing comprehension. VR also helps the learner contextualise learning material. When this is coupled to what we now know about the neurological processes of the human brain, how the brain creates mental images and how the brain learns, it is clear that VR becomes a very powerful visualisation tool, especially in the educational sector. This applies equally well in the contexts of both the developed and, more so, the developing world (where text and language often pose a barrier to learning).

The Brain, Neurological Processes and the Mind

Neuroscience is now at the stage where it can show us how the brain works and how the human mind is structured. It is the interaction between vision, touch and sound that is of most importance in enabling humans to understand and learn about the universe around them, their society and themselves.

Vision is man's primary sense around which our mind has evolved. This remarkable sense has the largest cortical area devoted to its activities. The visual cortex is not dedicated to any one kind of behaviour; but instead creates abstract representations of the world (mental images rather than retinal images), and inscribes them on a so-called 'mental commons' for general use by *all* the *mind's* other cognitive modules.

Sound has changed the human brain radically; but complex language has recently 'annexed' large parts of the left hemisphere, which was previously given over to visuo-spatial functions. In evolutionary terms, however, human language, which is very young, is still 'under construction', and is far from being fully integrated into the brain's natural functions, unlike vision and the visual cortex.

Memory is a process in which a transitional stimulus creates a persistent change in the brain. A complex set of multiple memory locations and systems are responsible for our best learning and recall. **Explicit/declarative memory** includes the word-based *semantic memory* as well as the *event-type episodic memory*. **Implicit memory** (also known as motor memory, body learning or habit memory) can be divided into the *procedural pathway*, which provides for 'hands-on' learning, and the *reflexive pathway*, which represents our reflexive retrieval system, which is automatic, permanently in use and full of instant associations.

However, the role of **working memory** in human cognition and learning could hardly be more important, since it integrates and coordinates memory, attention and perception. Our *working memory* comprises a central executive and two subsidiary slave systems, the *visuo-spatial sketch pad* (responsible for setting up and manipulating visuo-spatial imagery); and the *phonological loop* **(**maintains acoustic and speech-based information). *Working memory* is best regarded as a mental mechanism that permits performance of complex cognitive tasks through its ability to store temporarily information related to the various senses, *particularly those of vision and audition*. *Working memory* creates abstract representations or mental imagery of the world and inscribes them on a pseudo-3D sketchpad which manipulates images in the mind.

Finally, mental images are the engine that drives our thinking (real as well as abstract) about objects in space. To all intents and purposes, ***pictures in the mind*** represent the brain's most powerful ability to analyse, comprehend and visualise.

New Learning Methods

From the field of neuroscience, it follows that 'learning' would greatly benefit by moving from the memorisation of facts to the acquisition of cognitive skills – thinking, learning, and reasoning. The current 'show-and-tell' teaching methods do not take into account the strengths and weaknesses of the crucially important *working memory* and they under-utilise the visuo-spatial sketchpad.

This is where VR can play a powerful role in learning, as it is inherently based on pseudo-3D images and can exploit the characteristics of the most powerful components of the brain.

Technology in Learning

Whilst improved pedagogy and not technology should drive the development of education, technology is starting to provide a wide range of options and improvements to current learning materials through the application of interactive digital multimedia. We need, however, to bear in mind that sound guidelines should steer the creation of technology-enhanced learning environments. For example, learning material must be structured, meaningful and coherent, the environment should involve learners in a variety of enquiries, the environment should provide a variety of quality hands-on experiences which encourage learners to choose, explore, etc.

Teaching and Learning in the Developing World

It is clear the multimedia-based new learning environments that are essential in the developed world are even more needed in the developing world – and in Africa in particular. It is also important that these learning materials should not be imported, but should be locally produced in order to address the wide range of learning needs of Africa's excluded majority, whilst taking full account of local literacy, language and cultural issues.

*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 and that is **Virtual Reality**.*

The Benefits of VR

Virtual Reality:

- Allows the user to interact with the learning material in a more natural way
- Allows the learner to build a comprehensive and natural 'mental model' of the subject matter
- Allows the user to navigate easily through the information space
- Allows the learner to explore
- Is a powerful visualisation tool
- Helps overcome literacy barriers
- Facilitates a 'Look – see – do' mode of learning
- Minimises risk
- Is a powerful motivational tool for learners
- Can provide cost savings, for example in the case of school laboratories
- Can create 'impossible' learning environments.

Challenges of VR in Africa

Despite the potential benefits that can be derived from the application of VR in African learning, there are a number of challenges that still need to be overcome. In the main, these relate to issues dealing with equity and access to ICT facilities, but also to the cost of developing content for the African learning environment. However, the ever-increasing power of the PC graphics card has made VR more of a viable option for education during the last two to three years, a trend that will continue to grow. Also, as the capacity grows across the continent, so the cost of development will reduce. This is more so if developed VR content is shared amongst regions and countries.

The Way Forward

- Visual content is crucial to learning and interactive 3D content (VR) offers a powerful way of providing both context and content that can have a significant impact on improving education in Africa and in eliminating some of the continent's educational deficits.

- It is important that African countries be in a position to create their own local, unique VR content that will cater for the wide range of local learning needs, and also address differing local literacy, language and cultural issues.

Uganda is now at the stage where it is starting to create local content for use in schools. This process now involves a number of schools, government departments and learning institutions. An IICBA workshop on VR, held in Pretoria in March 2002, identified a strategic way forward that would take the Ugandan initiative to a Pan-African level. This strategic initiative would take the learning obtained in the Ugandan pilot project and implement local content development capacity in a number of other African countries.

This strategy entails the following crucial elements.

- **The establishment of a number of VR content development centres across Africa –** each driven by a local stakeholder group to facilitate usage across the local school, multi-purpose centre and library community, as well as being linked to other centres through a co-ordination group.

- **The small VR Overall Co-ordination Group** at the Pan-African level would not only ensure that experiences are shared, but also that developed content is shared across regions and countries.

- Thus, a process and an infrastructure are required to **ensure that any content developed is made available, on a shareware and 'open source' basis, to the other centres in Africa** and, in turn, to their local communities.

- Skills would be grown through a **central training mechanism to 'train the trainers'** who can provide first-level training of other local parties in their home countries.

- **Annual workshops for content developers and other stakeholders** would be needed to co-ordinate, share and update experiences, and further increase skills.

- Initial activities over the short to medium term could **focus on the creation of both classroom and adult learning content**, in areas such as science (physics, chemistry, biology, etc.), mathematics, engineering, statistics, economics, health, art and cultural exploration, etc.

- At some stage during this project **sustainability issues will need to be addressed**.

1 VR in Africa – an educational perspective

Virtual reality is one of those technologies that always seem to promise slightly more than it can deliver. The American marketing guru, *Faith Popcorn*, in her book '*Clicking*' (1996) for example, described the ability of VR in education to (amongst others) allow the user to take a painting lesson with Michelangelo or learn dramatic structure from Shakespeare. Clearly, we have not yet reached this level of technical sophistication. Commentators so often use the term VR to illustrate a bright and shiny hi-tech future whilst its rather more mundane uses have so often gone unrecognised.

However, over and above the more 'traditional' (first world) applications of VR, it is most important to consider whether the technology has an particular role to play in Africa and other developing regions of the world. The UNESCO-sponsored VR activities in Africa described in the Preface to this study were undertaken on the *premise* that VR offers a new way to visually communicate ideas, skills and knowledge. It is believed that VR offers an excellent way of overcoming the literacy barriers so often experienced in education and training. This report outlines the rationale behind these activities and thinking.

1.1 A Virtual Reality Promise?

VR prototypes offer many advantages. One can visualise an entire industrial process, a scientific or engineering principle, test ideas before investment is made in physical construction, as well as recreate long-gone historic and cultural worlds. VR allows us to view, and alter, proposed developments before they take place and to visualise processes in complete safety – impossible in the real world. Most importantly, VR can clearly illustrate how things work, and also allow the user to manipulate the content by taking advantage of VR's interactivity. Thus, the user can 'look' and 'see' as well as '***do***' in a safe, non-threatening environment.

Until recently, VR was confined to specialised and expensive defence or industrial simulations. It used high-end graphic computers and was associated with costly peripherals such as data-gloves, stereo glasses and head-mounted displays. However, because of advances in PC technologies, VR, in the form of an interactive 3D visual simulation, is now more readily available on standard PCs, which makes it accessible to a vast number of users.

The 21st century has seen an expanding awareness of the potential impact of ICT (Information and Communication Technology) in the promotion of economic growth in Africa. Modern PCs are now able to handle fairly intensive 3D graphics, and this ability to provide a platform for visually interactive applications can play a tremendous role in a VR roll-out in Africa. This is especially so in three areas:

- Education and training
- Preserving and promoting African culture
- Visually facilitating the transfer of context-specific knowledge, thereby overcoming traditional verbal and written barriers to communication.

For the first time, we have access to a communication tool that is both context-rich AND concept-rich, as well as being visual in experience.

1.2 What is VR?

VR or 'interactive visual simulation' as it is sometimes known, can be defined as '*a computer-generated environment in which the user is able to both view and manipulate the contents of that environment*'. It allows for intuitive, real-time interaction, supported by an intelligent, realistic 3D environment.

A more traditional definition of VR is that it is a technology that allows learners to become immersed in a computer-generated virtual world, hence redefining the human-computer interface (Bricken, 1990; Capanema[1] et al., 2001). VR has now evolved to the stage at which a computer-created sensory experience allows a participant to believe in a 'virtual' experience, as compared with a real one. In this definition, immersive VR technologies such as head-mounted displays are assumed.

In an educational context, VR can be defined as a mode of interaction between the user (learner) and a computer-generated environment, in which the learner is able to:

1. Both view and manipulate virtual objects in a manner similar to what he or she would do in a real environment (interactivity).
2. Heighten the use of multi-sensory, multi- perceptual and multi-dimensional capabilities (visual, sound, etc.) in order to increase understanding in learning (Fallman, 2000[2] ; Osberg[3], 1992).

These two aspects, namely the ability to interact with virtual objects in a natural way, and the heightened use of multi-sensory, multi-perceptual functioning by the learner, are what makes VR a powerful tool for learning. According to Fallman, VR can be used to "facilitate an interaction style of learning which stimulates, motivates and enhances student understanding of learning events", particularly in those areas in which uses of traditional methods of teaching have been inappropriate or inadequate.

One way of describing the degree of 'virtualness' of a virtual reality model is described by Crandall and Wallace[4], who see VR in two dimensions. The first dimension involves how good the overall system is at creating the virtual environment – the *Immersion* dimension. The second dimension involves how easy it is for a user to interact and move around within the virtual system

[1] Capanema, I.F., Santos Garcia, F.L. & Tissiani G. (2001). *Implications of Virtual Reality in Education.*

[2] Fällman, D. (2001). *Virtual Reality in Education: Online Survey.*

http://www.informatik.umu.se/~dfallman/projects/vrie/into.html

[3] Osberg, K.M. (1992). *Virtual Reality and Education: A Look atBoth Sides of the Sword.*

http://www.hitl.washington.edu/publications/r-93-7/

[4] Crandall, N. Fredric and Wallace, Marc J. Jr. (1998). *Work and Rewards in the Virtual Workplace.* American Management Association Center for Workforce Effectiveness.

– the *Navigation* dimension. How virtual a system is, is a function of the combination of the *Immersion* and *Navigation* dimensions.

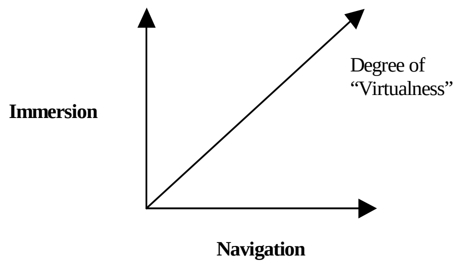


Figure 1: Immersion vs. navigation and VR effectiveness
(Adapted from Crandall and Wallace)

Arguably, this model again describes a traditional approach to VR, one which reflects a traditional pedagogy paradigm and one that does not reflect the power of VR as a visually interactive learning tool. Many of the expectations of VR referred to above arise because of the view that immersion is fundamental to the use of VR. Especially at the PC level, immersive technologies are not a prerequisite to harnessing the power of VR. Visualisation can produce powerful learning experiences, which can also greatly enhance the degree of understanding and comprehension of many subjects.

1.3 VR Technologies – Three Levels

VR technology uses computerised tools and platforms to represent or recreate reality. This involves the creation of virtual worlds, environments or learning spaces in which the learner is immersed. It also involves the creation of virtual objects which the learner manipulates. Cronin’s (1997) distinctions are helpful in defining variations in user levels of immersion with VR, namely:

Level of VR	Description	
Fully immersive	Head-mounted display (HMD) units (isolated from the real world)	Fully immersive VR is arguably the most beneficial, but the content is also the most costly and time-consuming to develop
Semi- immersive	Work benches; reach-in displays and virtual theatre	
Non-immersive , but still interactive	Desktop VR computers, the least expensive platform	

The levels of learner participation within the virtual environments and the extent to which these experiences will improve learning are key aspects that will determine whether VR has real benefits for education. Osberg (1992) envisaged that “the fusion of computers and telecommunications would lead to the development of highly realistic virtual environments that would be collaborative and interactive”. This is now becoming a reality in the early 21st century. For example, the Interactive Institute Umeå, Sweden, will be

Figure 2: SGI Immersive Theatre (Concaves)

celebrating the foundation of St. Petersburg by opening a virtual window to the cultural heritage of St. Petersburg showing different internet-distributed immersive VR scenarios. Anyone in the world with access to an internet-connected CAVE (Cave Automatic Virtual Environment) with tele-immersive VR facilities (head-mounted display or similar VR equipment) and tracking and steering equipment, will be able to enter and interact in the virtual world(s) that will be created (www.tii.se).

There have been other recent developments in this area. Maseda et al. (2001[5]) describe a successful initiative which has used virtual 3D environments together with other ‘intelligent agents’ to train teams of people working in emergency situations as part of the ETOILE (Environment for Team Organizational and Individual Learning in Emergencies) project. Another VR explorative initiative is reported in Ligorio’s (2001)[6] account of the activities in a virtual world, ‘Euroland’. These results show that a positive impact on learning is possible.

A similar visual representation of the levels, or types, of VR technologies is shown in the following diagram. Potentially, the most prolific uses of VR are at the desktop and internet levels. Immersive reality systems and concave reality systems (for example, virtual theatre) are found at a higher level, and can be more effective in terms of a personal immersive experience, but are also in many cases prohibitively expensive, especially in the context of the developing world.

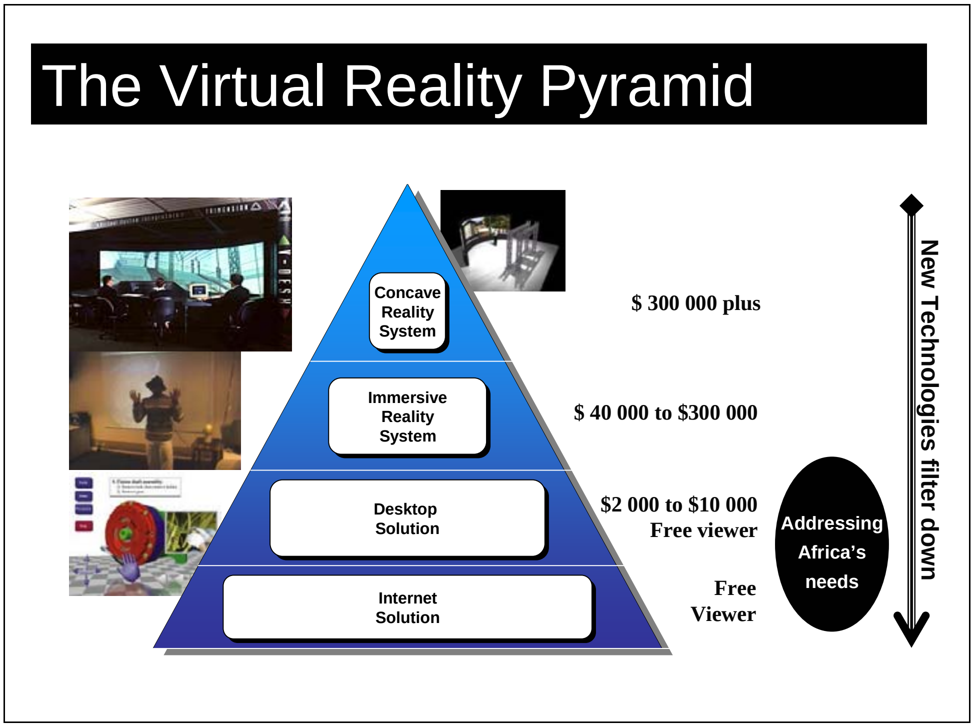


Figure 3: The VR Pyramid

[5] Maseda, J.M, Izkara, J.L, Mediavilla, A. & Romero, A. (2001). *An Application for Training and Improving Co-ordination between Team Members, using Information Technologies.* Society & Information Technology and Teacher Education International Conference proceedings, March 5-10, Orlando, Florida, USA.

[6] Ligorio, M. B. (2001). “Integrating Communication Formats: Synchronous versus Asynchronous and Text-based versus Visual Computers in Education”. Vol. 37, No. 2, Sept. pp 103-25.


Figure 4: Head-Mounted Display (5DT)

Many of the examples cited in the preceding paragraphs can be categorised at the higher end of the VR pyramid shown in Figure 3. However, such technologies are, in most cases, unaffordable in the African context. It is at the lower end, namely desktop solutions and in some cases also internet-based solutions (where bandwidth and connectivity are acceptable), that the short-term potential for VR in African education lies. CD-ROM technologies also have an important role to play as a delivery mechanism in areas where bandwidth is an issue, again at a very low-cost.

Before looking in more detail at VR in an educational context, it is important to understand a little more about how the human brain works, and learns. This has a direct impact on understanding the power of VR as an educational tool. Modern research is leading to a fuller understanding of the relationship between the brain's cognitive processes and learning, and to the subsequent role of VR as a learning tool.

1.4 Brain Research and Neurological Processes Involved in Learning

Many believe that in an ideal world, every human mind should be given the opportunity for optimal life-long learning, and there is a growing related belief that this represents a basic human right.

An understanding of how the human brain learns, as well as the results of modern research in this area, are fundamental to an understanding of how VR can be so effectively used in education – *especially* in developing world environments.

1.4.1 The human brain

The human brain is by far the most complex device on the planet, and yet often taken for granted. "*The human brain is made of many parts. Each part has a special function: to turn sounds into speech; to process colour; to register fear; to recognise a face or distinguish a fish from a fruit. But this is no static collection of components - each brain is unique, ever-changing and exquisitely sensitive to its environment….. It is probably so complex that it will never succeed in comprehending itself. Yet it never ceases to try.*" (Carter[7])

[7] Carter, R. (1988). Mapping the Mind. Phoenix, p 8.

Figure 5: The Brain – which is made up of many Modules and Organs

Humans have some 100 billion neurons (10 times more than the apes), and these neurally active cells (perceiving, thinking, learning, etc.) are connected by an amazing *1.5 million kilometres* of nerve fibres. Over the past 2 million years (a very short period in evolutionary terms), the hominid brain-body weight ratio has almost quadrupled, with most of this unprecedented growth being in the cerebral cortex.

Although *Homo sapiens* has been around for about 150,000 years, it is only in the past 50,000 years that a dramatic growth in artefacts beyond stone tools appeared. Why did it take man 100,000 years to develop these abilities? What does it tell us about the mind, intelligence *and learning*?

1.4.2 The human mind

The human mind is not the brain but what the brain does. The brain is not a single organ, but a system of modules and organs, each with a specialised design that makes it a 'specialist' in one area of interaction with the world. These interactions enter through the windows of the body's five senses. It is the interaction between vision, touch and sound that is of most importance in enabling humans to understand and learn about the universe around them, their society and themselves.

Vision is man's primary sense around which his mind has evolved. *This remarkable sense has the largest cortical area (almost 50%) devoted to its activities.* The visual cortex is split into many areas, each processing an aspect of sight such as colour, shape, size, stereo, depth, etc. Observed images are reflected by matching patterns of neuronal activity on the surface of the visual cortex which are then converted into higher-level abstract mental models.

The visual system as a whole is not dedicated to any one kind of behaviour, but instead creates abstract representations of the world (mental images rather than retinal images), and inscribes them on a 'mental commons[8]' for general use by *all* the mind's mental modules. *A mental image is simply a pseudo-3D sketch that is loaded from long-term memory rather than from the eyes.*

Sound has changed the human brain radically because complex language has recently annexed large parts of the left hemisphere (previously given over to visuo-spatial functions), thereby creating the asymmetry not found in any other animal. The implication is that, in evolutionary terms, human language, which is very young, is still 'under construction', and is far from being

[8] "*Mental Commons*". A term (derived from the medieval concept of shared communal land within the village or town) used to describe a part of the brain used to share mental images, which is used by all other components of the brain. Importantly, these mental images are stored in a pseudo-visual-3D form.

fully integrated into the brain. Although analysing a stream of spoken words is highly complex, infants do not need to be taught the basics of hearing and speaking language. By contrast, reading and writing are difficult to learn at any age. Printed text is only a few hundred years old, and therefore, on the evolutionary time-scale, reading has not even begun to become an innate ability. Hence, the unnatural nature of reading and writing has serious implications for learning (even for literate people, in cognitive terms, text is the least efficient and effective of all the available communications media).

Memory is not a fixed thing or singular skill, but rather a process in which a transient stimulus creates a persistent change in the brain. A complex set of multiple memory locations and systems are responsible for our best learning and recall. The variety of ways in which information is stored and retrieved provides a better route to the understanding of memory.

- ***Explicit/Declarative memory:*** comes in several forms, including the more word-based *semantic memory* (we had little need for semantic recall until recently when books and literacy became common) and the event-type *episodic memory* (also known as the loci, spatial, event or contextual recall process – a thematic map of daily experiences – and used naturally by everyone).

- ***Implicit memory:*** Although our minds are full of information, our ability to recall it depends on which pathway we use to access it, and whether we realise that we know that information in the first place. There are two distinct pathways: procedural and reflexive.

  - The ***procedural pathway*** (often known as motor memory, body learning, or habit memory) provides for 'hands-on learning' which creates a wider, more complex and overall greater source of sensory input to the brain than mere cognitive activity. This learning seems to be easier to master, is fairly well remembered, and creates lasting positive memories.

  - The ***reflexive pathway*** – our reflexive retrieval system is automatic, almost permanently in use, and full of instant associations. Emotionally laden experiences receive privileged treatment and are more easily recalled than neural experiences. Auditory memories are potent emotional triggers, e.g. a favourite song. Researchers speculate that this stimulation takes separate pathways from the more mundane content-laden ones.

- *Working memory* comprises a central executive and two subsidiary slave systems:

  - The **visuo-spatial sketch pad** (responsible for setting up and manipulating visuo-spatial imagery)
  - The **phonological loop** (maintains acoustic and speech-based information, and can be split into two components: a *phonological store* which holds a fast-decaying (1 - 2 seconds) speech-based trace and an *articulatory control mechanism* which plays a mediatory role).

  Working memory is best regarded as a mechanism that permits the performance of complex cognitive tasks through its ability to temporarily store information related to the various senses, 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.

Working memory's role in human cognition and learning could hardly be more important, since it integrates and co-ordinates memory, attention and perception.

1.4.3 Mental images

Mental imagery is the engine that drives our thinking (both real and abstract) about objects in space. Visualising a shape feels like placing a picture for inspection in the mind's eye, which is a very different experience from silently vocalising a discussion of abstract issues. Creative people are famous for 'seeing' in their mind's eye solutions to both real and abstract problems (which has obvious links to VR and visualisation):

- Faraday and Maxwell visualised electromagnetic fields as tiny tubes filled with fluid.
- Kekule found the benzene ring structure, after a visual dream of snakes biting their tails.
- Einstein mentally saw what it would be like to ride on a beam of light or to drop a penny in a plummeting elevator. He explained that, "My particular ability does not lie in mathematical calculation, but rather in visualising effects, possibilities, and consequences".
- Painters and sculptors try out ideas in their minds, and even novelists visualise scenes and plots in their mind's eye before putting pen to paper.

What is a *mental image?* The visual system uses a pseudo-three-dimensional (pseudo-3D) sketch which, in a very real sense, is a picture in the head. This topographically organised cortical map is a patch of cortex in which each neuron responds to contours in one part of the visual field, and in which neighbouring neurons respond to neighbouring parts. Shapes are represented by filling in some of the elements in a pattern that matches the shape's projected contours. Innate shape-analysis mechanisms process information in the sketch by imposing reference frames, etc.

A mental image is therefore simply a pseudo-3D sketch that loads from long-term memory rather than from the eyes.

The power of mental images in the human thought process can be reflected by our dreams. We naturally dream and our dreams take the form of moving imagery (pseudo-3D sketching) – we do not dream using text.

1.5 Natural Learning

Natural learning is what the human brain does best. There are predetermined sequences of development in early childhood, including windows of opportunity for laying down the basic hardware necessary for later learning. All babies are born with the innate potential to learn and speak any language and many languages. Natural selection also shaped people to be intuitive physicists, biologists, engineers, psychologists, and mathematicians so that they could master their local environment. Although these different ways of knowing are innate, this does NOT mean that knowledge is innate. The key to getting smarter is growing more dendrites and synaptic connections between neurons. The brain's architecture has the inherent capacity for every individual to significantly increase his or her intelligence. The mind learns optimally when it is appropriately challenged in an environment that encourages taking risks. Humans have survived by trying out new things, usually in small groups, NOT by always getting the 'right', tried-and-true answer – that is not healthy for growing smart, adaptive minds.

1.6 Improved Learning Methods - The Need for Fundamental Change

The need for fundamental change is amplified by the recent emergence of neurological science (Section 1.4), which provide insights that challenge conventional educational beliefs and models, especially as entrenched in the current school 'factory model'. It follows that modern learning should *move from the memorisation of facts to the acquisition of cognitive skills – thinking, learning, and reasoning*. *The mind recalls best with a context, a global understanding and a complete picture to remember.*

The variety of ways in which information is stored and retrieved indicates that our focus should move on from a simple concept of 'memory' to "which kind of memory and how it can be retrieved"[9].

The current 'show-and-tell' teaching methods do not take into account the strengths and weaknesses of the crucially important *working memory*. The visuo-spatial sketchpad and the phonological loop can each hold limited numbers of 'chunks' of information (7 ± 2). 'Show-and-tell' teaching methods inevitably overload the phonological loop, whilst *under-utilising the visuo-spatial sketchpad*. This is especially important when it is realised that the visuo-spatial sketchpad is by far the senior partner. Language has been acquired in the last few ten thousands of years, whereas vision has been and remains man's (and primates') primary sense for 60 million years.

To recap, 'show-and-tell' teaching methods inevitably overload the phonological loop (new and weak), whilst under-utilising the visuo-spatial sketchpad (ancient and powerful).

As the working of the mind is inherently based on pseudo-3D images, the role of VR in the true learning process. now becomes clearer.

1.7 The Role of Text in Learning

Employing the amazing power of vision to detect text is akin to using an articulated lorry to fetch sweets from the corner store - one sweet at a time. The alphabet is like a funnel, squeezing all sense data into and through the narrow passage of print. A wonderful tool has in many ways become a tyrannical master – especially for many people who find reading difficult. In 1997, there were over 40 million adult *text-o-phobes* (people who are functionally illiterate) in the USA. Anyone who is not 100% proficient in reading and writing is often 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

[9]Jensen, E. (1998). "Teaching with the Brain in Mind". Association for Supervision and Curriculum Development (ASCD) Publications, pp 99-109.

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, the system cannot ever be equitable.

This does not imply replacing text! It does, however, imply re-examining the role of text in the light of our knowledge of how the brain works. It also implies replacing its current dominance with a more balanced role in which 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 to 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.

Good fiction writers can rearrange what most of us know with such craft and sensitivity that it gives great pleasure, as well as new insights (Figure 6a). 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 do not 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 reader's.

However, text does not work the same 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 describe and explain accurately to learners REAL worlds (contexts, concepts) that many of them have not seen, and may never see (Figure 6b). 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!

"The dusk crept in from the desert, and shaded the dunes with purple. Like a thick velvet cloak it muted all sounds, so that the evening was tranquil and hushed. From where they stood on the crest of the dune they looked out over the oasis and the complex of small villages that surrounded it. The buildings were white with flat roofs and the date palms stood higher than any of them except the Islamic mosque and Coptic Christian church. These bastions of faith opposed each other across the lake.
The waters of the lake were darkling. A flight of duck slanted down on quick wings to land with a small splash of white close in against the reed bank.
The man and woman made a disparate couple. He was tall, though slightly bowed, his silvering hair catching the last of the sunlight. She was young, in her early thirties, slim, alert and vibrant. Her hair was…."
Wilbur Smith, The Seventh Scroll. *Pan* (1996).

Chandler's Wobble
"In order to describe this phenomenon, we define several axes. These have different physical meanings, but all pass through the earth in a roughly North-S th direction. Since these axes move relative to one another, it is simpler to consider the corresponding poles, which are the points where the axes intersect to surface of the Earth. In what follows, we shall only consider the North pole of each axis. The first axis that we shall need is the geographic axis. This is…."
Understanding the Earth. *Artemis Press, Open University Set Book* (1974).

Figure 6 (a&b): Mental Imagery in Action

Figure 7 shows schematically man's historical development of a range of codes to store information (cuneiform, numerals, roman, etc.). Early codified language was used for measuring and accounting rather than storage of knowledge.

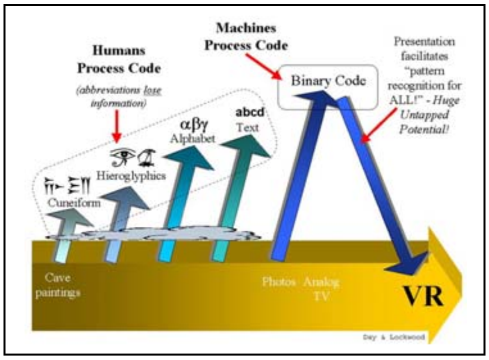


Figure 7: From Language codes to VR

As mankind developed complex societies, his communication activities also became more complex. With it, the mechanisms, signs, symbols and language that he used in the process also became more complex. Particularly since the invention of the camera, the way that man expresses himself through visual images has undergone a dramatic change. It has led to the development of non-realistic and non-figurative ways to express ideas and communicate them to other people.

Regardless of the level of realism in the visual codes used, the key to successful visual communication is inevitably the receiver's familiarity with the signs and symbols that the communicator is using. As a result of the infinite variety of visual signs, it inevitably happens that the difference between the communicator's and the receiver's visual knowledge may cause the whole or part of the message to be unintelligible. In order to ensure that communicating by means of images is as effective as possible, the communicator first has to ensure that his receiver is familiar with the visual codes used.

Modern digital technologies allow us to both code and display any information (multi-media). Humans do not read the code; computers do and display the images in their natural form. Thus, the human mind is freed to work on its strengths (pattern recognition, creative learning, association, knowledge production, etc.) as opposed to the decoding and encoding of text This implies that VR is not a peripheral technology, as many currently view it, but will increasingly become central to the human communication process.

1.8 The Role of Technology (and VR) in Learning

As learning tools, both levels are important when used appropriately. At both levels however, Technology Enhanced Learning (TEL) can be used to create new learning environments for both contact and distance learning.

The role of technology in 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 through a contact institution or in distance learning mode.

1.8.1 Using technology to create new learning material

As we create new technology-enhanced learning materials, it must be recognised that we are in the early stages of a long and exciting global initiative where improved pedagogy should be based on our growing understanding of how the human brain/mind learns. New pedagogies should, however, be the major driver, not the underlying technologies themselves. Technology should not drive this development, but improved pedagogy should, 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 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*, 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.

What other guidelines should we use for building technology-enhanced learning environments?

1. 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. Visualisation and VR can play a major role in this context.

2. 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 and memory.

3. 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, the interactive and explorative nature of VR makes it an ideal tool.

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

- Encourage 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.

Aspects of these ideal new learning environments can already be built using a variety of digital multi-media, including audio, graphics, animation, simulation and visualisation. Text can also be included – but used in the right context.

However, there is only one ICT application that is able to create environments combining ALL the above required aspects. That application is a fully interactive, simulated, virtual 3D environment, **namely Virtual Reality,** because it provides**:**

- 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.

1.9 Teaching and Learning in the Developing World

Although the education crisis that we face is global, 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 argue 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, especially those who live outside of the main cities. But, this is also a self-fulfilling prophecy. Are hundreds of millions of excluded people more remote and less important than the moon? Is the education of an African child less important than the education of a European or American child?

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. Traditional face-to-face delivery cannot be simply scaled up to the levels required to meet Africa's needs. If we only continue to 'tinker' with the current bricks-and-mortar-based education systems imported 'as-is' from the developed world (which is also dominated by text-intensive 'show-and-tell' methods), then Africa's educational systems will continue to deteriorate and fail as these imported systems are unresponsive not only to the resources available in Africa, but also (and importantly) to new knowledge on how the human mind best learns.

The changes required are fundamental and creating new learning materials relevant to Africa's situation is an excellent place to start. The multimedia (especially virtual reality)-based new learning environments are even more needed, and more appropriate in Africa.

Locally produced content is required to address the wide range of learning needs of Africa's excluded majority, taking into account local literacy, language and cultural issues.

Literacy: If the same measures of 'functional illiteracy' for the USA used by Castells[10] are employed for Africa, illiteracy levels above 70% would be common, especially outside the main cities. Hence, the problems with text described above are significantly amplified in Africa. Instead of importing dominantly text-based learning materials from the developed world, local materials

[10] Castells, M. (1998). 'The Information Age: Economy, Society, and Culture'. Vol. 3, "End of Millennium", Blackwell, p 163.

need to be developed that reduce 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 bilingual, with many of these people able to speak both a local language and a European language. Since most of Africa's education material is imported, the overlying former colonial language, not the indigenous language(s), dominates the education system. This may appear reasonable in the large cities, where many youngsters are exposed to and therefore naturally learn both European and indigenous 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 tend to be heard and learned in infancy. European 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 consequently poorer.

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, especially common in mathematics, 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. The analogies commonly used (especially in imported textual material) do not reflect the indigenous culture. Using a London bus to contextualise the learning of Newton's Laws of Motion is an example often used. Sadly, it is often the intelligence of the learners that is questioned, not the quality of the learning material and teaching.

We know what to do, we have the global resources, but do we have the coordinated commitment? Put another way, if the USA could mobilise itself between 1962 and 1969 to reach the moon, surely the world can mobilise itself to achieve vision of UNESCO's 'Education for All' within a decade or two? The world's hundreds of millions of excluded people are surely not as remote, nor less important than the moon!

It should now be clear that the multimedia-based new learning environments that are essential in the developed world are even more needed in the developing world and in 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 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 and that is ***Virtual Reality****.*

1.10 Some Recent Uses of VR in Education

There are a large number of global initiatives in which VR is being used in the educational arena. A selection of projects, usually using higher-end VR technologies includes:

- As an exploratory tool for simulation and training, VR has been used widely used in the teaching of dangerous phenomena at the University of Illinois at Urbana-Champaign[11]. Projects such as Severe storm analysis or the teaching of abstract and difficult concepts in Tracking and visualizing complex biological structures fall into this category.

- The creation of virtual laboratories and the performing virtual experiments, for example:
  - National Taiwan Teacher's college – the creation of a geochemistry lab of virtual reality (Fung–Chun et al., 2000[12]).
  - Physics experimental training such as at Kongju National University[13]

- The use of visualisation to demonstrate or understand difficult concepts. Examples include Long-Chyr Chang et al. (2000[14]) – building of a web-based adaptive and interactive teaching zone for teaching mathematics – and Stephen Chan et al. (2000[15]) – computer-aided learning systems for appreciation of 3D geometry. The Pauling, Maxwell and Newton[16] worlds are also examples of this type of application.

There are also a number of educational areas in that UNESCO has worked (together with the authors). These, which are typically PC-based applications designed to be more relevant to African development needs, include:

- The development of a VR model addressing the learning points around basic hygiene in rural African communities. The aim of this project was to use interactive visual simulation (VR) as a means of demonstrating basic hygiene to rural communities and to focus primarily on sanitation, water and the prevention of associated disease (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.

- The training 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

[11] University of Illinois at Urbana-Champaign VR projects. http://redrock.ncsa.uiuc.edu

[12] Fung-Chun Li, Lin Jer-Yann, Shyh-Jiung L, -Hua Hsu, Chau-Rong T, Cahu-Fu Y, & Tzong-Yiing, Wu. (2000). A Case Study of Creating Geo-Chemistry Lab of Virtual Reality in Education.

[13] Kim Jong-Heon, Sang-Tae Park, Heebok Lee, Keun-Cheol Yuk & Heeman Lee. (2001). *Virtual Reality Simulations in Physics Education* (2001). http://imej.wfu.edu/articles/2001/2/02/printver.asp

[14] Chang Long-Chyr, Chiang Heien-Kun & Wey Pi-Shin (2000). *WALTZ: A Web-based Adaptive /Interactive Learning and Teaching Zone.*

[15] Chan, S. C. F., Wai, A., Chow, J. & Ng Vincentm, T. Y. (2000). *A CAL System for Appreciation of 3D Shapes by Surface Development (C3D-SD).*

[16] Dede, C. (2001). Six Challenges for Educational Technology http://www.virtual.gmu.edu/SS_research/cdpapers/ascdpdf.htm

'French for Ugandans', both of which have been used in King's College Budu and St Henry's Kitovo, both secondary schools.

- The establishment of a formal VR Committee in Kampala, to co-ordinate VR initiatives in the country, with representation from two universities (Makerere and Kyambogo), SchoolNet Uganda, Uganda National Commission for UNESCO, the Department of Education, 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 senior representation from Uganda, Ethiopia and Nigeria and which also resulted in pilot models to describe levers, relative velocity and chemical elements.

- A project using VR as an aid to helping young people in Alexandra (Johannesburg) to understand 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 HIV/AIDS, with the aim of helping to empower educators to better teach more, and younger, learners.

1.11 What are the Educational Benefits of VR?

"The unique capabilities of VR technology include allowing students to see the effects of changing physical law, observe events at an atomic scale, visualise abstract concepts and visit environments and interact with events that distance, time or safety factors normally preclude. Studies show that these unique capabilities of VR technologies allow VR worlds to support a wide range of types of experiential, conceptual and discovery learning that is otherwise not available" (Javidi, 1999[17])

Conventional visual displays (user interfaces) interfere with our natural ability to transform data into information into knowledge, mainly because they remove most of the direct experience. Virtual Reality therefore helps a person to:

- Exploit the third dimension
- Interact in a more natural way
- Build a more comprehensive and natural mental model of the subject matter and the task
- Navigate easily through the information space.

We have seen (Section 1.8) that VR has a powerful role to play in addressing educational needs:

- VR can show the overall context, global understanding and the complete 'big' picture.
- VR offers a variety of learning avenues that (much more fully) utilise the many possible channels for input and learning in the human mind.
- VR offers a variety of quality hands-on experiences which encourage learners to choose, explore, manipulate, test and make transformations within the environment provided.

As a learning tool, other advantages of using VR include:

[17] Javidi, Giti (1999). "Virtual Reality and Education". University of South Florida.

- VR is non-linear – it allows the learner to explore at will.
- A number of multimedia formats are used, including pictures, sound. animation and visualisation.
- VR has the ability to show spatial relationships and look at three-dimensional objects from any angle.
- VR has the ability to zoom in to show detail, or zoom out to show context.
- In terms of differentiation and individualisation:
  - One can repeat the learning as often as is necessary
  - Familiar parts can be passed over.
  - One can progress at one's own speed.
  - Interactivity leads to significant learning as learners are required to interact with *and* react to the content. Studies have shown that interactivity is an important feature, much more so than immersion (Gay, 1994[18]).
- It provides levels of interactivity – the data glove and HMD (head-mounted display).

In summary, VR:

- Allows the user to interact with the learning material in a more natural way
- Allows the learner to build a comprehensive and natural 'mental model' of the subject matter
- Allows the user to navigate easily through the 3D information space
- Allows the learner to explore
- Is a powerful visualisation tool
- Allows us to show an environment, object, process, etc., rather than describing using text
- Helps overcome literacy barriers
- Facilitates a 'look – see – do' mode of learning
- Minimises risk
- Is a powerful motivational tool for learners
- Can provide for cost savings, for example, in school laboratories
- Allows for a richer and more stimulating learning experience
- Provides a visual and spatial framework upon which more detailed learning can take place.

> Learning activities promote retention. We remember:
> - 10% of what you read
> - 20% of what you hear
> - 30% of what you see
> - 50% of what you hear and see
> - 70% of what *you* say
> - 90% of what you see and say, *whilst doing it.*

1.12 What are the drawbacks of VR in Africa?

Despite the potential benefits that can be derived from the application of VR in African learning, there are a number of challenges that still need to be overcome. These relate mainly to issues dealing with equity and accessibility, as well as the cost of developing content for the African learning environment.

However, these are issues that not only impact on the applicability of VR to African education, but also relate to broader digital divide issues and the impact of ICT in general. Looking at the development of the PC/internet connectivity in Africa, three powerful trends can be identified that are driving this information revolution:

[18] Gay, E. (1994). "Is Virtual Reality a Good Teaching Tool?" VR Special Report; pp 51-59.

- *Communication cost*: The transmission cost of sending digital data has decreased by more than a factor of 10,000 since 1975 and at ever-faster speeds.
- *Computing power*: 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.

It is for these reasons, together with the increased power of the PC graphics cards now available, that VR has to become a more viable option for education and training.

As the number of PCs on the African continent continues to grow and the specifications of these machines increasingly allow for the running of interactive VR models, the importance of hardware will decrease over time. In turn, accessibility is being addressed through other programmes (involving a number of funding agencies) to improve the availability of such machines in multi-purpose community centres, schools, etc.

Development costs can also be a real issue, but in many ways, the development of VR and visualisation technologies is only now moving towards the mature stage. Over time, as the skills base broadens and as the library of available models grows, the unit cost of development will decrease. It is important, however, that local initiatives are undertaken now to create local content and to develop this capacity in order that, over time, LOCAL, interactive content is developed for LOCAL use.

There are also four other more generic key disadvantages of VR (the first three of which are common to all electronic multimedia):

- There is inevitably a loss of human contact when using VR in training.
- Although VR eliminates risk and cost, there is no substitute for practice and training on the real thing.
- There are ethical concerns with regard to what is allowable in the virtual versus the real world.
- Research has revealed some serious psychophysical problems with certain types of virtual reality – especially higher-end immersive VR, which can lead to motion sickness!

While these disadvantages are in many ways genuine, they may not be as relevant in the African context. VR has the capability to simulate reality much better and much closer to reality than any other form of multimedia. Although there is no substitute for the real thing, it is also true that most African school children will, for example, never experience an actual physics or chemical laboratory in any event due to the lack of physical resources in many of our schools.

1.13 To which Learning Areas is VR best suited?

If one takes a conventional perspective on VR in education, and especially considering immersive VR, VR would usually be used in areas where the experiments are expensive or difficult to perform in natural teaching and learning environments, or when the concepts being taught are difficult to understand using normal textbook methods. The greatest VR potential would then be in areas where VR supports experiences impossible to achieve in current learning environments.

Osberg (1992) describes this as “a sense of immersion and inclusion in a virtual environment, which allows the learner an opportunity to interpret and encode their perceptions in a broader, deeper set of experiences than those existing in current educational environments”. These would include areas where changes in the relative sizes and perspectives or views are necessary for learning, where multi-sensory cues and dimensions would enrich learning and in areas that require the creation of abstract learning objects which currently have no physical representations.

To better understand the areas of education and learning to which VR is *potentially* best suited, it is useful to look at three aspects of VR in education:

- Potential uses of VR
- A comparison of andragogy (adult) vs. pedagogy (child) in terms of learning characteristics
- The compatibility of training methods and training media.

1.13.1 Potential uses of VR

To set the scene, some potential uses of VR in learning and education, as described by G Bester (2002)[19] are:

Table 1: Potential Uses of VR in Learning (after Bester[19])

Potential Use	Application Area
To demonstrate concepts	• Processes that would be difficult to carry out in the classroom • Abstract concepts • Psycho-motor sequences
To illustrate and explain concepts	• Principles involved in dynamic changes or movement • Abstract principles through the use of models • Principles involved in two-, three- or multi-dimensional space • Advanced scientific or technological concepts through animation and visualisation models
To substitute for real life	• Field or site visits that are too far, or out of reach • Laboratories • Workshops
To reduce and synthesise knowledge / information into coherent whole	• Contextualising seemingly unrelated information which in printed form appears complex or remote
To analyse complex reality	• Forms, structures and processes, particularly through combinations of animation, graphics and sound

1.13.2 Andragogy vs. pedagogy

VR can *potentially* be used in both child learning (pedagogy) as well as adult learning (andragogy). Are there reasons to give one priority over the other?

[19] Bester, G. (2002). “The Application of VR in Education and Training”. Paper presented at IICBA VR in Africa Workshop, the Naledi3d Factory, Pretoria.

Andragogy is loosely defined as 'adult learning', but more specifically it is the formal term used to describe the process of educating and leading adults to fulfil their roles as parents, educators, citizens or workers. There are *apparent* important differences in the way adults learn and, traditionally, this requires that they be treated differently from children. The adult is more than just a grown-up child. The adult and child learner have unique characteristics that require teaching principles and techniques that exploit these characteristics (Table 2).

Table 2: Pedagogy versus andragogy (from J. Hugo)

Characteristic	Traditional Pedagogy	Andragogy
Concept of self	Total dependency Submissive authoritarian relationships Does not accept responsibility for learning Decisions taken on behalf of learner Fulfils passive role in educational activities Self-identity created through external determinants	Responsible, autonomous and independent Partnership with educator (joint exploration of knowledge) Co-responsible for own development Actively involved in decision-making and educational activities
Experience	Little life experience that can serve as source for learning	Rich experience - wider range, varying quality Strong source of development during education Experience increasingly a source of self-identity
Readiness to learn	Is a function of the learner's age (educator must decide when it is time to know certain things and when to progress to the next level)	Experiences a need to handle an actual life situation more effectively
Learning orientation	Subject-centred orientation to learning Must learn a process to acquire prescribed subject matter Time perspective: the knowledge acquired now may or may not be applicable later	Experiences a life-, task- or problem-centred orientation to learning Experiences a need to apply knowledge immediately
Motivation to learn	Extrinsic motivation (reward or punishment)	Intrinsic motivation due to a need for self-actualisation

The learning characteristics of adults are, according to this model (and upon which many of today's educational practices are based) very different from those of children. However, in the light of recent neurological research, does this model still hold water? The principles of andragogy may well be much closer to how a child really learns than the traditional thinking around pedagogy. In the words of Einstein (loosely quoted): "*If you get through the 12 years of school without damaging your mind, you have done well*". It took physicists many years to understand and accept Einstein's insights into physics in general, and especially relativity. After 100 years, many educationalists still have not understood, let alone accepted, Einstein's insights into education. Thus, current understanding of pedagogy itself may also need to be reviewed in terms of today's understanding of how the brain learns and grows – and especially in terms of the formative childhood years (be they preprimary, primary, secondary or tertiary).

At first glance from the above table, VR would appear to lend itself more to adult learning. Adults are more prone to self-learning through exploration, etc. Children, on the other hand, need to be guided by educators as they have no life experiences to which they can relate the learning.

It is clear from recent neurological research that VR can also be used with great success by teachers / educators as part of the facilitated classroom learning process. 3D representation is still a powerful demonstration medium, even if the interactivity is only taken advantage of by the educator as part of the classroom teaching process. This, of course, does not preclude the child learner from exploring the material individually.

To recapitulate, given what we now know about the neurological processes of the brain, there is a need to question in particular the traditional approach to pedagogy. This needs to be explored further. However, in either case, VR is equally applicable, but with a differing approach to Instructional Design (ISD) in the fields of pedagogy and andragogy.

1.13.3 Compatibility of training methods and training media

The basis for the selection of training methods is that topics or subjects to be trained differ with regard to complexity, scope, environment, target group, circumstances, the nature of the learning domain and the tasks that must be performed – in others words, cognitive, affective or psychomotor. These factors must be reconciled with the different training methods and media available with regard to their unique features and suitability for the particular topic or course.

Other factors to be considered include the characteristics of the subject matter expert, the training situation, the students and the performance aims of a particular learning system or device. The learning aims relate to the tasks to be performed, as well as the skills needed for the task – that is, the aims of the learning objectives must be defined before the training objectives can be derived.

When the most common training methods are mapped to the various compatible educational media, the following matrix (Table 3) with an indication of their advantages and disadvantages is produced:

Table 3: Training Methods versus Media Types (from J. Hugo)

Training Methods	CBT	Books	Models	Video	Multi-media	Low-fidelity simulations (1)	High-fidelity simulations (2)
Classroom courses (facilitated)	O	X	X	X	X	X	X
Seminars (facilitated)	/	X	/	X	X	X	X
Part-time courses (facilitated)	X	X	O	X	X	X	X
Correspondence (facilitated)	/	X	/	X	X	X	O
On-the-job training (facilitated)	X	X	X	`X	X	X	X
Self-study (individual)	X	X	O	X	X	X	/
On-line (e-learning) (individual)	X	X	O	X	X	X	O
Workshops (group)	O	X	O	X	/	X	/
Simulations/Games (business) (group)	X	/	X	O	O	X	X

Task support systems (individual / group)	X	/	/	O	X	X	O

[(1)] Includes low-fidelity 3D visualisation (PC-based VR)

[(2)] Includes high-fidelity 3D visualisation (high-end graphics VR, e.g. SGI computing, etc.)

KEY:
X = fully usable (can be used to good effect in the learning / training method)
/ = partly usable (can be used to some effect in the learning / training method)
O = not usable (technology not at all applicable)

Note: The result in this table differs slightly from that J Hugo (see the Preface), in which the case of using VR as a facilitated learning tool was not considered.

From the table, it is clear that a range of technologies can be used across a range of teaching methods. However, where, for example, multimedia tools can be used, as well as low-fidelity VR, there are a number of advantages that VR brings to the learning process, especially in terms of interactivity and visualisation; which have greater compatibility with current knowledge on how our brains learn.

In the case of 'low-fidelity simulations', the technology lends itself to all listed training methods. However, the higher-end 'hi-fidelity' VR is more restricted in its usage, mainly due to higher implementation costs. In practice, 'hi-fidelity' VR is typically used in industry (especially the automotive industry and in oil/gas exploration), as well as in audience-immersive virtual theatre, as in tourism and heritage applications.

1.14 Conclusions

1.14.1 It is time to adopt improved learning methods

The emergence of neuroscience has shown recently that mankind's visuo-spatial abilities are far more powerful than our phonological (speech and text) capabilities. This is not surprising considering that vision is our primary sense and uses nearly 50% of the brain's cortex. This fact has been overlooked by educators for centuries in favour of an essentially speech-and-text-based approach to learning. Modern learning should shift from the memorisation of facts to the acquisition of cognitive skills. The mind recalls best with context, a global understanding and complete pictures to remember. The current speech-and-text-based 'show-and-tell' teaching methods do not make proper use of our working memories' strongest component – our visuo-spatial sketchpad which forms mental imagery in the mind.

1.14.2 VR is well suited to the needs of human memory

VR is inherently based on pseudo-3D images and, therefore, utilises the most ancient and powerful part of our memories' pathways for significantly enhanced comprehension and learning. By allowing learners to both view and manipulate virtual objects in a computer environment, one can heighten their visuo-spatial experience, thereby increasing comprehension, understanding and, especially, their motivation for learning.

1.14.3 VR can play a vital role in African education

African education is in crisis and literacy in Africa is one of the lowest in the world. A radical intervention is required to address education on the continent. We have seen how text-based learning materials are not the best solution and traditional face-to-face 'show-and-tell' delivery cannot simply be ramped up to cater for this enormous deficit. We need to develop local learning material that makes less use of text and more use of voice and imagery and interactive VR simulation.

However, there are challenges: the PC population density is also one of the lowest in the world, as are levels of connectivity. However, there are other strategic initiatives such as the implementation of multi-purpose community centre facilities and computers in schools, which will, over time, reduce this challenge. Secondly, the cost of content development can be a barrier. However, if VR content is shared across the continent, then the cost of use becomes minimal, possibly even below the cost of textbooks.

1.14.4 VR is a powerful educational tool

Possibly in the form of immersive VR, but definitely in the form of the much simpler desktop PC format, VR is a powerful technology that can:

- Demonstrate both simple and complex concepts
- Illustrate and explain concepts
- Substitute safe virtual environments for real life
- Synthesise knowledge / information into a coherent whole
- Analyse complex realities.

There are few, if any, tools that can satisfy as many learning requirements in one package as VR can.

A summary of the advantages of VR includes:

- Allows the user to interact with the learning material in a more natural way
- Allows the learner to build a comprehensive and natural 'mental model' of the subject matter
- Allows the user to navigate easily through the 3D information space
- Allows the learner to explore
- Is a powerful visualisation tool
- Helps overcome literacy barriers
- Facilitates a 'look – see – do' mode of learning
- Minimises risk
- Is a powerful motivational tool for learners
- Can provide cost savings, for example where physical school laboratories are not affordable
- Allows for a richer and more stimulating learning experience
- Provides a visual and spatial framework upon which more detailed learning can take place.

1.14.5 VR is suited to both adult and child learning

VR, at first examination, lends itself more to adult learning in which learning is based more on freer, self-guided learning and exploration (Section 1.13.2). However, VR is also very powerful in supporting conventional child learning in a classroom environment where the educator utilises VR in a group environment, using a PC and data projector to communicate the interactive learning content to a group of learners.

However, this does not also preclude learners from exploring as individuals should they wish to or should they have the opportunity at school. In Uganda, this is one way that VR is being used in four pilot school projects. It is of interest to note that senior school pupils are also allowed to develop VR models themselves as part of their learning experience!

1.14.6 The application of VR in education

Educational content can be built using a variety of digital multimedia, i.e. audio, graphics, visualisation, animation, simulation and, also, text. *However, there is only one ICT application that is able to create environments combining all required aspects (Section 1.8) and that application is a fully interactive, simulated, virtual 3D environment, i.e.* ***Virtual Reality.***

Technological reforms such as VR need to take place along with simultaneous innovations in pedagogy, curriculum assessment, school organisation and instructional technology. Extended professional development of teachers in deploying and using these new innovative technologies is also critical to sustainable implementation.

VR, and especially lower-end, PC-based VR, can be used with benefit across a broad spectrum of learning and training methods, including the classroom and lecture room, seminars and workshops, part-time courses, on the job training, on-line learning, as well as in simulation and games.

Further, maximum effort should be devoted to developing and sustaining strategies and delivery platforms suitable for the African context.

As a lot of learning takes place visually, the areas where one needs to demonstrate difficult concepts, relying on the full range of audio-visual and movement capabilities, should be the first to be considered for the application of these technologies. Such areas would include services and products in engineering, prototyping, architecture, science and technology, tourism and culture-ware, to name but a few.

In the school classroom and adult spheres, learning domains would include: science, mathematics, engineering, statistics, economic and financial sciences, art and cultural exploration, etc.

This study shows conclusively that, in terms of how the human brain learns, visual content is crucial to learning – and that interactive 3D content (VR) offers a powerful way of providing both context and content. This can have a significant impact on improving education in Africa. Although not a panacea for all of Africa's education problems, VR technologies, and especially PC-based VR, can make a huge contribution to eliminating some of the continent's educational deficits.

1.15 The Way Forward

One of the most important findings of this study is that much of our learning and training is based on text, which in turn is not truly compatible with how the brain actually learns. Visual media and, in particular, interactive, 3D visual media is much more compatible with the brain's learning processes. The study has also highlighted that learning material must be developed in Africa to cater for the wide range of learning needs, and differing local literacy, language and cultural issues.

It is therefore important to build up the capacity for developing VR *content* in Africa so that African countries can create their own local, unique VR content.

UNESCO, together with the Naledi3d Factory, has over the last two years worked in Uganda to create VR content development capacity, at Kyambogo University in Kampala. This initiative has now developed to the stage where Ugandans themselves are taking this initiative forward and creating local content for use in Ugandan schools. The parties now involved include four schools, SchoolNet Uganda, the Department of Education, Makerere University, the National Curriculum Development Centre, representatives from Multi-Purpose Community Centres, as well as the UNESCO Ugandan National Commission.

An IICBA VR workshop [20] identified a strategic way forward, which would take the Ugandan initiative to a continental level. This report now shows that there are good, pedagogical reasons to support this strategy.

This strategic initiative would build on the Ugandan experience and develop local content development capacity in a number (four to five) of other African countries – as shown in Figure 8 below:

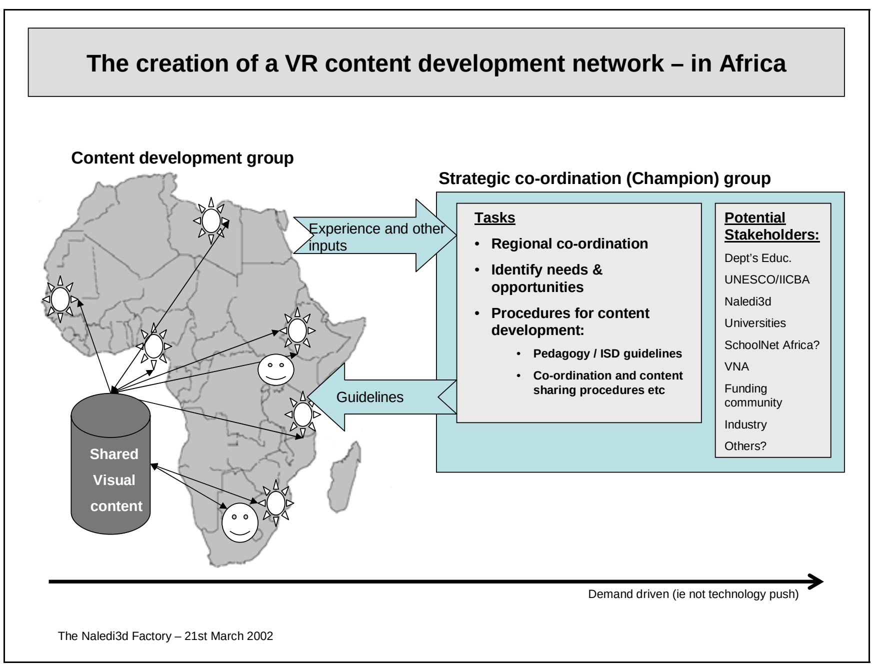


Figure 8: A Pan-African VR development network

[20] IICBA (2002). VR in Africa workshop. The Naledi3d Factory, Pretoria, March.

There are a number of key elements to this proposed concept, outlined below:

- A number of development centres across the continent – each driven by a local stakeholder group to facilitate usage across the local school, multi-purpose centre and library community. The countries shown in the above diagram are not in any way fixed, but are indicative of countries that could potentially become involved in such an initiative.

- A small VR overall Pan-African co-ordination group.

- A process and infrastructure to ensure that any content developed is made available to the other centres and, in turn, to their local communities.

- Licensing agreements to be put in place to ensure that any educational content is not only shared freely, but also that other centres are able to modify any shared content. This would imply that the content developed is licensed along the principles of open source agreements.

- Central training is undertaken to 'train the trainers' who then become champion developers in their own countries – and undertake at least first-level training of other local parties.

- Annual workshops for content developers and other stakeholders to co-ordinate share and update experiences and skills.

Initial activities (years one to five?) would focus on creating classroom or adult learning content. Learning domains would include: science (physics, chemistry, biology, etc.), mathematics, engineering, statistics, economics, health, art and cultural exploration, etc.

At some stage during this project, future sustainability issues would need to be addressed, which would imply eventually, moving to a commercial content-development model.

2 Survey Methodology

An evaluation programme was undertaken in South Africa and Uganda in a number of schools and community tele-centres to test the validity of the theoretical results reported in the first part of this study. The remainder of the study summarizes the findings of actual surveys undertaken.

The rationale behind the survey methodology (designed by Rita Kizito of UNISA - an educational specialist) was to assess whether using visually interactive interventions can potentially have a positive impact on student learning. This would be achieved by mapping out the perceived value and initial impact of Virtual reality (VR) on student learning in different African learning contexts by focussing on the following questions:

- Does VR affect the understanding of the topic being taught?
- Does use of VR affect learning retention?
- Does use of VR influence motivation towards learning?
- Is there any evidence of the application of the knowledge learnt after using VR?

The Institutions surveyed were:

Country	Institution	No. of Students	No. of Teachers
Uganda	Buwana tele-centre	17	1
	Nakaseke tele-centre	45	7
	Kings College Budu Secondary School	25	1
	Makerere College School	19	7
	Mengo Secondary School	20	2
	Ndejje Secondary School	26	5
	St Henry's Secondary School	29	6
South Africa	Soshanguve High School	28	1
	Mamelodi High School	71	2
Total		280	32

Separate questionnaires were designed for the students and the teachers. Each was divided into four parts as follows:

Questionnaire Part A (Pre VR Demonstration): The first step in each of the survey sessions was to ask a range of questions to assess the respondents' exposure to computer based learning, as well as the subject material, before being exposed to the eight VR models.

Questionnaire Part B (Post VR Demonstration): Exposure to the eight VR models took the form of a series of simulated teaching lessons. The respondents' opinions of this material were subsequently surveyed through a series of questions designed to test their responses to the visual learning material; where they had difficulties; and, in a series of open-ended questions, their ideas on what could be done to make the learning easier.

The models used as part of simulated lessons in associated subject areas were:

Title	Description	Comments
Sand filter	What a sand-based water filter is, how it operates. Allows the user to build a water filter by selecting sand layers and tests for correctness.	
Plastic moulder	Shows how a low-cost single phase plastic moulding machine works. Allows the user to go through the moulding steps in real-time.	Resulted in a Community leader in Buwama tele-centre wanting to source a machine for the community.
Gun	A good example of a machine, which can be taken apart and the audience can see how this particular machine works, in this case, the firing pin. Being pushed by a spring mechanism.	
Lalibela	A model that shows a rock hewn church in Lalibela, Ethiopia (Bet St Giorgis) ; both an external and internal tour.	Children in particular didn't recognise the name, but as soon as they saw the model, recognised it as something they had seen on the Internet.
Levers	A model (developed for IICBA) that shows the principles of 1st-class; 2nd-class and 3rd-class levers.	
French	Developed in Uganda, this model (a living room) facilitates the learning of French pronunciation and vocabulary.	
Steam locomotive	A model developed for Delft Museum of Technology shows how a steam locomotive works. Encourages the user to assemble the five main components of a steam loco.	
Rural Hygiene	Developed with UNESCO for Nakaseke in Uganda. Basic-hygiene (including washing hands, washing fruit, smoking the toilet, bathing in the right area, etc. A 3d village is used as a base model.	This model was commonly related to, especially with rural learners.

Questionnaire Part C (About the VR Lesson): This section followed on from the previous Section B and tested the respondents' opinions on VR as a potential learning tool.

Questionnaire Part D (About yourself): was used to obtain demographics of the respondents.

The content and structure of the questionnaires can be easily seen from the presentation of the data; the questionnaires are thus not reproduced here, but can be obtained in the full survey report in the Naledi3d Factory Publications Archive (http://www.naledi3d.com/navpage.html).

The sample contained individuals from rural communities; townships and cities over a fairly wide age spread (10 to 25+). The demographic details are as follows:

Student demographics - 280 respondents

Age

1=Below 10	0.76%
2=11 to 14	6.08%
3=15 to 19	71.1%
4=20 to 24	10.65%
5=above 25	11.41%

Location of school

Rural Community	32.28%
Township	50.39%
City	17.33%

Gender

Female	35.11%
Male	64.89%

Teacher demographics - 32 respondents

Age

1 = 20 to 24	14%
2 = 25 to 34	40%
3 = 35 to 44	30%
4 = 45 to 54	8%
5 = above 55	8%

Extent of VR training

1 = extensive	0%
2 = adequate	15%
3 = very little	26%
4 = none	59%

Teaching experience

Mean number of years	7.2 years
Median	5 years

Gender

Male	81%
Female	19%

In total, written feedback was obtained from 280 students and 32 teachers. Some questions were not answered by all respondents.

3 Analysis of survey results

This section analyses in detail the aggregate data obtained from all students and teachers that completed our questionnaire. Where possible, the data has been represented in a graphical format to facilitate interpretation.

Annex 1 provides the aggregated responses from the teachers which provide further insight into the pedagogical implications of VR.

3.1 Findings - Pre-and Post VR Evaluation: Confidence in Topics & Classroom Experience

3.1.1 Confidence in each of the topics before and after the VR lesson

There was a very significant shift in the students' confidence levels in each of the subject areas after viewing the visual / VR learning material.

Before being exposed to the material, there was "little confidence" or "no confidence" in most of the topics shown. After being exposed to the VR learning material, the responses typically were "very confident", "confident" or "some confidence".

The results of the before and after responses are shown in the Table below.

Pre-VR Session					Post-VR Session				
Question: *How confident are you about the following topics?*	**No**	**Mean**	**St. Dev.**	**Median**	**Question:** *How confident are you about the following topics?*	**No**	**Mean**	**St. Dev.**	**Median**
A1.1 – Sand-filter	265	4.0	1.3	5	B1.1	252	2.2	1.0	2
A1.2 – Plastic Moulder	259	4.4	1.0	5	B1.2	245	2.4	1.2	2
A1.3 – Gun	262	3.6	1.3	4	B1.3	250	2.1	1.2	2
A1.4 – Lalibela	259	4.6	1.0	5	B1.4	241	2.6	1.3	3
A1.5 – Levers	261	3.6	1.5	4	B1.5	247	1.9	1.1	2
A1.6 – French	265	4.3	1.1	5	B1.6	242	3.2	1.2	3
A1.7 – Steam Locomotive	256	4.5	0.9	5	B1.7	238	3.0	1.2	3
A1.8 – Rural Hygiene	199	3.1	1.5	3	B1.8	172	1.6	1.0	1

1 = Very confident; 2 = confident; 3 = some confidence; 4 = little confidence; 5 = no confidence

Clearly, the level of confidence in knowledge of the subject matter has increased significantly. VR also seems to be capable of tackling a wide range of subjects, including traditionally "difficult" subjects such as languages. The French language model elicited one of the poorer responses, but still increased from 5 (no confidence) to 3 (some confidence). This underscores the flexibility of the technology and its broad range of application areas.

3.1.2 Rating the experience

On average, students felt that the VR experience was "highly satisfactory" to "satisfactory". This underscores the fun element in VR learning. Whereas many students can find traditional teaching methods boring and not particularly stimulating, VR learning materials demand constant student input and participation, but also retain attention and motivation, thus challenging the learner more.

Question	# Responses	Mean	St. Dev.	Median
How would you rate your experience?	164	1.7	1.0	2

1=extremely enjoyable; 2=satisfactory; 3=not enjoyable

3.1.3 A Comparison between Ugandan and South African Students

- Both countries' students displayed similar levels of pre- and post-VR confidence.
- South African students had more difficulty (91% of respondents) than the Ugandans (72% of the respondents) with the topics concerned.

There is little difference in learners' experience of VR from one African country to the next, which points to the possibility and usefulness of increased sharing of VR models within Africa.

3.2 Findings - Post VR Demonstration: Teachers' Rating of VR Software

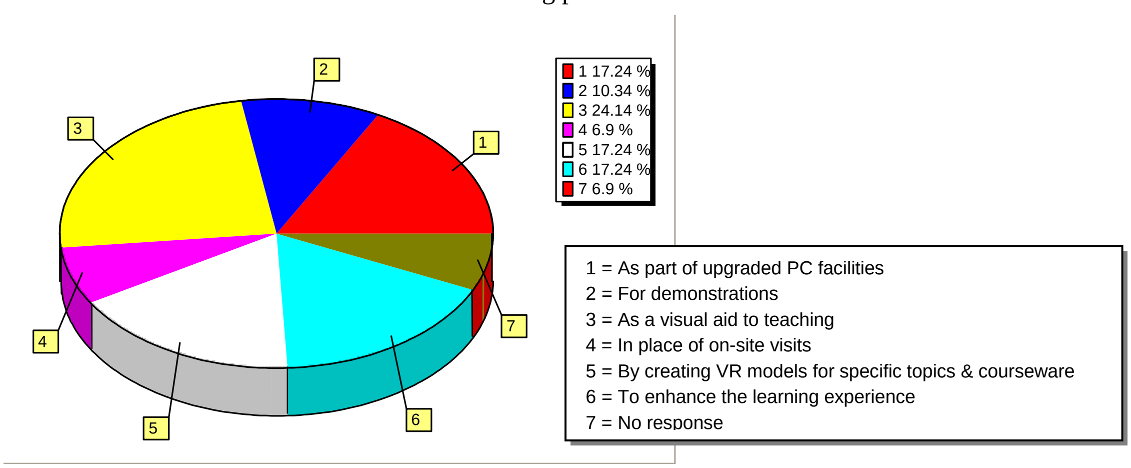
Teachers were asked to rate the VR software, the VR lesson and their experience of using VR as teaching tool.

- Teachers rated the usability, layout, academic content and attainment of learning objectives as good to excellent.

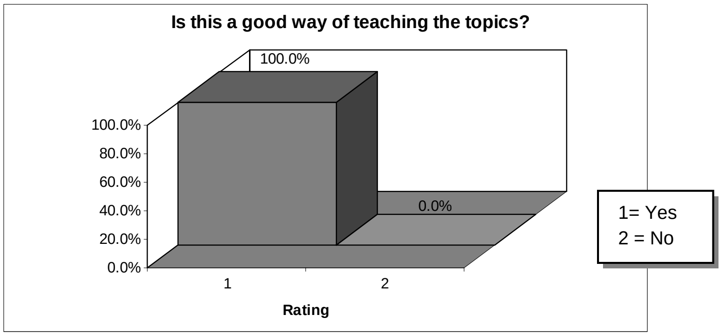
Question: *How would you rate the following:*	No	Mean	St. Dev.	Median
A1. Usability	31	7.9	1.6	8
A2. Layout	31	8.6	1.5	9
A3. Academic Content	30	8.1	1.4	9
A4. Attainment of learning Objectives	30	8.7	1.3	9

Rated from **1 = poor** through to **10 = excellent**

- All respondents indicated that VR could be used as part of their courses or lessons. How this could be achieved is reflected in the following pie chart:



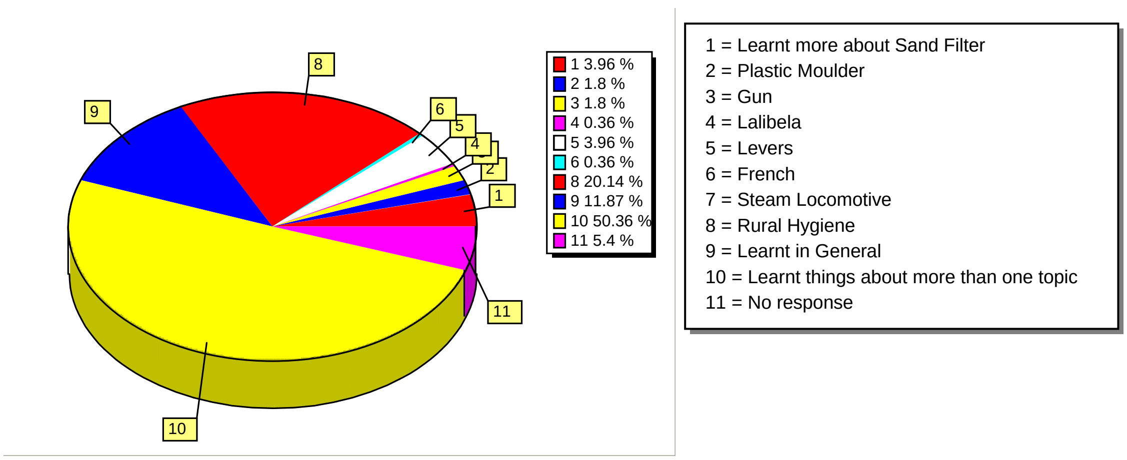
- All teachers interviewed (100%) also indicated that this was a good way of teaching subject material.



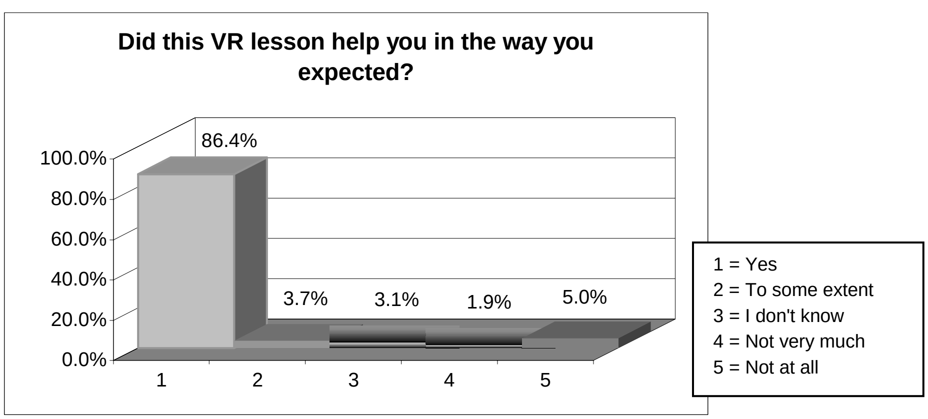
3.3 Findings - Post VR Demonstration: Students' Learning Experience

3.3.1 Views on the extent and value of the learning obtained from the demonstration

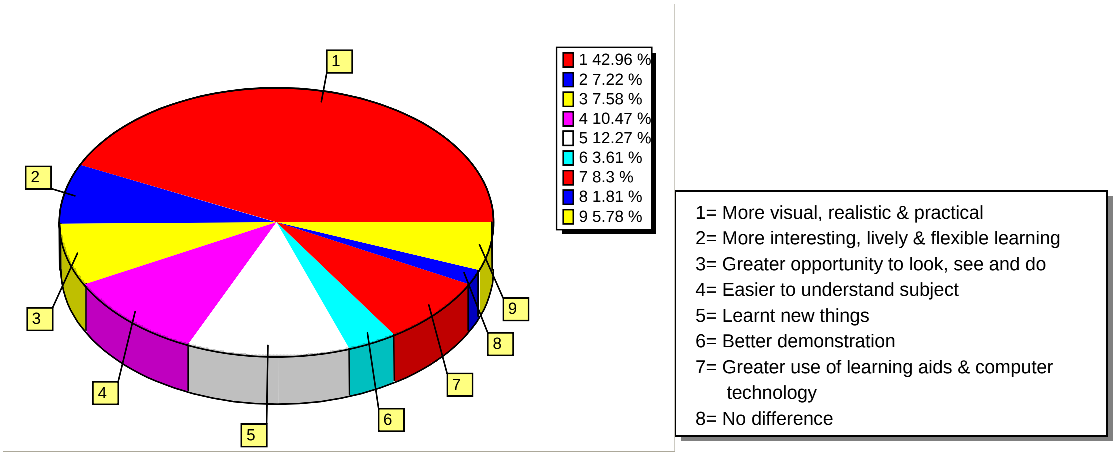
- Overall, 50% of the students learnt about more than one topic. Interestingly, 27% of the students indicated that Rural Hygiene was the most important topic they learnt about, although half indicated that they learnt about more than one topic.



- 86% of students said that the VR lesson had helped in the way they had expected.



- 43% of students said that the VR lessons were more practical, realistic and visual than normal lessons. Another 50% of the respondents cited other advantages to learning with VR (categories 2-7). Only 2% said that VR made no difference.



3.3.2 A Comparison between Ugandan and South African Students

- Interestingly, 42% of South African students felt that the rural hygiene VR model provided the most important learning experience. 30% of the South Africans learnt things about more than one topic compared to 62% of the Ugandans students.

- 85% of the Ugandan students and 87% of the South African students said that the VR lesson had helped in the way they had expected.

- 46% of the Ugandan and 38% of the South African students said that the VR lessons were more practical, realistic and visual than normal lessons, they learnt new things, it was a better demonstration of the subject; and finally, a better use of learning aids & computer technology was experienced.

- 36% of SA students had difficulty with only one topic after the VR lessons and 18% still had difficulty with two topics. 18% of the students had no difficulty at all after the lessons. In Uganda only 29% still had difficulty with one topic whilst 20% had difficulty with two topics. 13% of the Ugandan students had no difficulty at all.

3.4 Students' Assessment of VR Lessons

3.4.1 The quality of the VR lesson overall

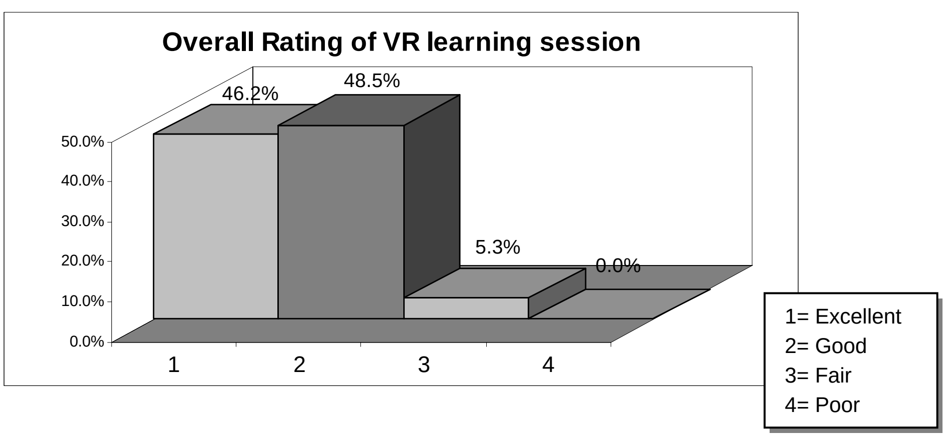
- Students were asked to rate the VR lesson in terms of the following criteria.

Questions	# of responses	Mean	St. Dev.	Median
C1.1 - The computer visuals make the learning easier	256	1.3	0.5	1
C1.2 - I understand better with the computer visuals	255	1.8	0.9	2
C1.3 - I understand better without the computer visuals	245	3.9	1.1	4
C1.4 - It is the teacher's explanation which makes me understand	239	2.4	1.0	2
C1.5 - The computer visuals make the learning more enjoyable	245	1.4	0.8	1
C1.6 - The computer visuals complicate the learning process	231	3.8	1.4	4
C1.7 - The computer visuals help me to remember what I have learnt	244	1.7	1.0	1
C1.8 - The VR session cannot help me revise the topic	242	4.0	1.2	4
C1.9 - This VR session fits well with the rest of my lessons	236	2.0	1.0	2
C1.10 – Given the opportunity, I would like to have another VR	250	1.4	0.9	1

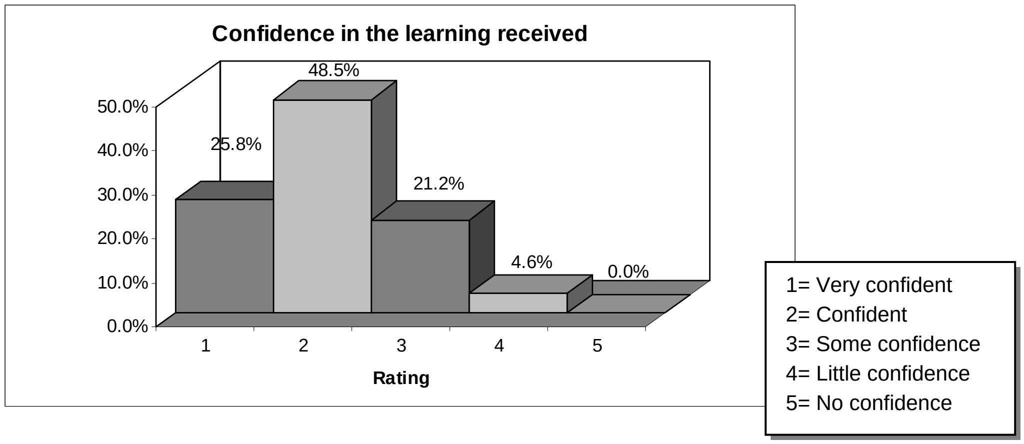
Rating: 1= strongly agree, 2=agree, 3=neutral, 4=disagree, 5=strongly disagree

The above responses speak for themselves. It should be noted that, within the 10 questions, there are three which test for opposite responses (C1.3; C1.6; and C1.8) which was intended to test whether, due either to a weaker understanding of English or through lack of attentiveness, the subtle opposite nature of these questions would be missed, especially by the younger students. It is an additional support for the result, and a reflection of the efforts made by the respondents, that the opposite meaning was picked up and responded to accordingly.

- Students were asked to provide an overall rating of the VR lesson.



- Students also rated the lesson in terms of the learning received.



3.4.2 A Comparison between Ugandan and South African Students

- Both the Ugandan and the South African students responded in similar fashion. The overall response to the VR lesson was very positive.
- The majority of both countries' students rated the VR lesson as good to excellent.
- In South Africa 32% of the students were very confident after the VR lesson, whereas a further 50% felt confident in the concepts learnt. In Uganda 21% of the students expressed high confidence and 48% expressed confidence in the concepts learnt.

3.5 Teachers' Assessment of VR Lessons

Teachers were asked to assess the quality of the VR lesson overall, using a number of criteria, as shown in the following Table:

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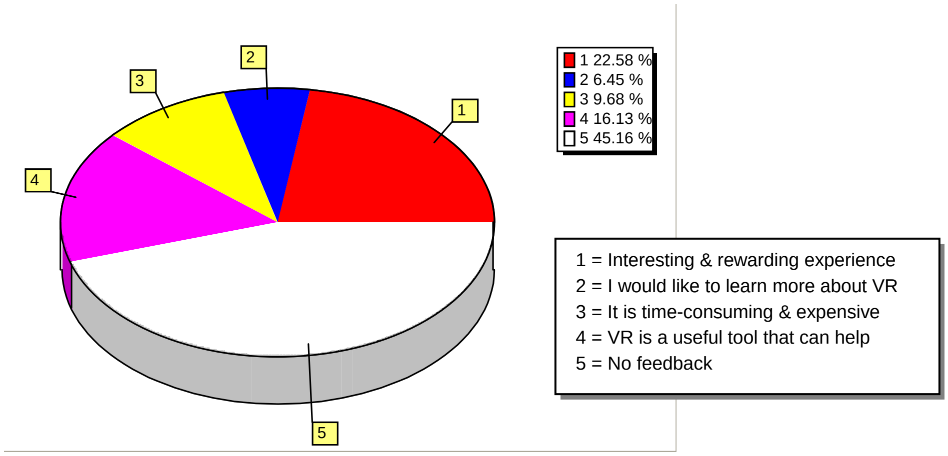
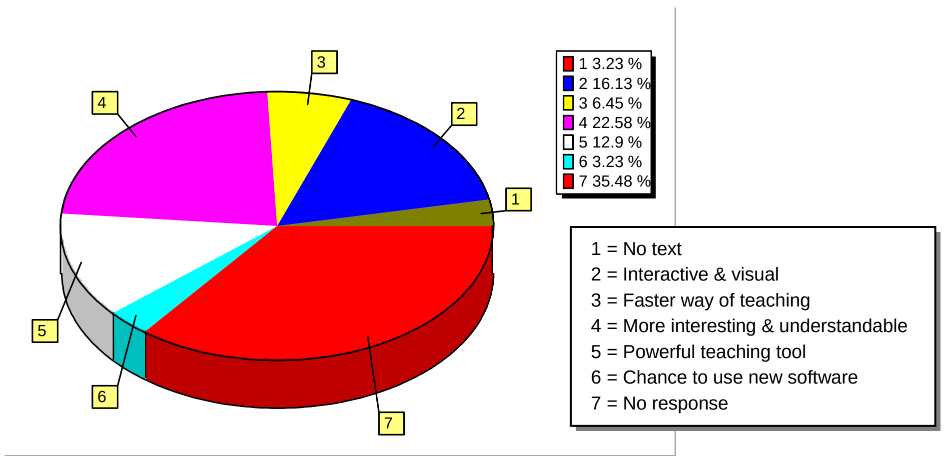
Questions	# of Response	Mean	St. Dev.	Median
B1 - The preparation for this VR lesson was easy	28	2.8	1.3	2.5
B2 - I feel confident using this method to teach	28	2.0	1.1	2.0
B3 - My students enjoyed the VR lesson	28	1.8	1.1	2.0
B4 - The material was challenging for my students	27	2.7	1.3	3.0
B5 - The teaching time using VR was less than for my normal lessons	25	2.2	1.0	2.0
B6 - VR can be useful for learners with difficulties in the topics	29	1.6	0.9	1.0
B7 - It is easy to integrate the VR lesson into my course	28	1.9	0.9	2.0
B8 - The VR session can help with the revision of the topics	28	1.6	1.0	1.0
B9 - This software can be used in more than one course	28	1.6	0.8	1.0
B10 - I would like to use VR more often	29	1.8	0.9	2.0
B11 - VR Lessons are too expensive	26	2.3	1.3	2.0

Rating: 1= Strongly agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly disagree

- Teachers were also asked to comment (in their own words) on their experience of teaching with VR.



- Teachers were then asked (again, in their own words) to highlight the best aspect of the lesson



4 Summary of survey results

This section highlights the most important conclusions to be drawn based on the available data for both students and teachers.

4.1 Students' Rating of the VR Lesson

The students felt that the computer visuals made the learning easier, the topic easier to understand, learning more enjoyable, learning easier to remember, fitted in well with other lessons and helps with the revision of topics. In addition, nearly 95% of the students rated the VR lesson as good to excellent.

4.2 Teachers' Rating of the VR Lesson

Overall, the teachers felt confident that VR was an effective teaching tool that could be integrated into courses. All teachers believed VR offered a good way of teaching the topics concerned.

There was a strong correlation between teachers and students in that both groups agreed that the VR lessons were enjoyable, easy to integrate into courses and could help with the revision of topics. 74% of the students felt confident to very confident in the learning received. Both groups also agreed that the software could be used in more than one course. 50% of the students learnt things about more than one topic.

There was an indication that software and hardware expenses and lesson preparation might be an issue. This may be due to a shortage of computers in schools and the anticipated cost of rectifying the problem.

As to lesson preparation, one can expect an initial learning curve for teachers as they adopt VR as a teaching tool (experience in previous projects in Uganda with the UNESCO National Commission show that there are ways to overcome this entry barrier).

4.3 Rating of the VR Software

Teachers rated the usability, layout, academic content and attainment of learning objectives as good to excellent. This correlates strongly with the students' responses, 95% of whom rated the VR session as good to excellent.

Here again, there was a strong correlation between the teachers' and the students' experiences. The three most important needs that came to the fore were:

1. the shortage of computer equipment;
2. clear instruction/teaching; and
3. training.

- 19% of both students and teachers indicated that better equipment, software, etc. was required;
- 19% of both students and teachers said that more lessons, practice and training were required;
- 23% of teachers and 14% of students wanted clearer instruction, guidance and teaching.

There is clearly a need for more computers in schools, which strongly relates to the apparent lack of computers already mentioned.

More than 24% of teachers felt that VR could be used as a visual aid to teaching. This correlates strongly with the response from students where 44% felt VR was more visual, realistic and practical than their normal lessons.

17% emphasized the importance of making the acquisition and installation of VR software an integral part of the upgrading of computer facilities.

Other aspects that came to the fore were the belief that VR could enhance the learning experience (17% of respondents) and that VR models should be created for specific topics (again, 17% of respondents).

All teachers (100%) believed VR was a good way of teaching the topics concerned. 86% of the students said the VR lesson helped in the way they had expected.

4.4 Experience of Teachers with VR

Overall the experience was a positive one with nearly 40% of the teachers rating VR as interesting, rewarding and useful in their teaching, even though there was strong indication that the perceived costs involved in getting computer hardware and developing VR models was for some, too high.

What stood out for nearly 40% of the teachers was that VR lessons were more interesting, understandable, visual and interactive. This correlates strongly with 44% of the students who rated the visual, realistic and practical aspects as being the major differences from normal lessons.

However, 26% of the teachers thought that VR was complex to learn. This would seem to indicate that there is a learning curve to be addressed, especially in the teacher community.

Both teachers (16%) and students (19%) said they needed better training to use VR models to improve their experience of VR.

10% of teachers felt that the VR models should make more use of African languages. Obviously locally developed African content will have to cater to the language needs of students.

4.5 Conclusion

This field study has confirmed the findings of our previous, theoretical research as contained in the first part of this report.

The data analysed and represented in this report confirms the previous findings that VR is a powerful new educational tool. Responses of both teachers and students show that the learning process can be greatly enhanced by the use of VR learning materials.

All teachers believed VR was a good teaching medium and most of the teachers indicated that they could integrate VR into their lessons.

The majority of students benefited from the visual and interactive power of the technology thus leaving them more confident in respect of the subjects concerned. This is very encouraging given the relatively brief exposure to each VR model and underscores the speed and ease of learning associated with VR.

There are also challenges in implementing this technology in Africa. One of the problems that came out clearly in the study is the lack of computer equipment in many schools. Obviously, computer hardware and software shortages need to be addressed to roll out VR to educational institutions.

Additionally, due to the differences between VR and traditional teaching methods, teachers face a learning curve in respect of using the technology.

Finally, the importance of having African VR learning material in local African languages cannot be overemphasised. To unlock the full potential of VR in African education requires locally developed content.

ANNEX 1 - Statistical Analyses – All Teachers

Section A: Rating of VR Software (questions are numbered as on the questionnaire)

1. How would you rate the VR software packages in terms of:

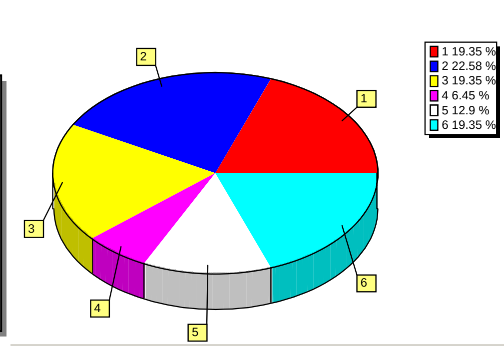
*Rated from **1 = Poor** through to **10 = Excellent***

Question: *How would you rate the following:*	No	Mean	St. Dev.	Median
A1. Usability	31	7.9	1.6	8
A2. Layout	31	8.6	1.5	9
A3. Academic Content	30	8.1	1.4	9
A4. Attainment of Learning Objectives	30	8.7	1.3	9

- The mean value represents the average value obtained for the particular response
- The standard deviation is an indication of how closely values are clustered around the mean.
- The median represents the middle value.
  - If the median is smaller than the mean, this indicates that most values are smaller than the mean while a few values are much larger than the mean.
  - If the median is larger than the mean, this indicates that most values are larger than the mean while a few values are much smaller than the mean

5. What kind of additional support would be required for students to work through the package by themselves?

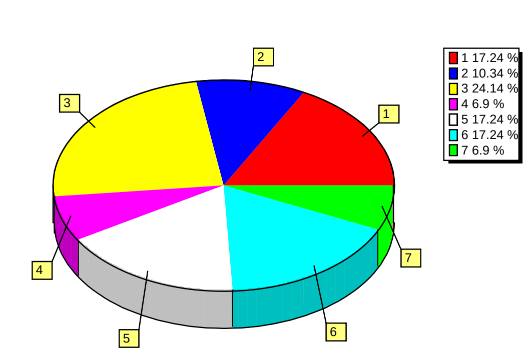
1 = Provide computer hardware, software & peripherals
2 = Provide clear instructions, guidance and explanations
3 = Provide more training
4 = Explain the relevance of VR to learning
5 = No response
6 = More reference material



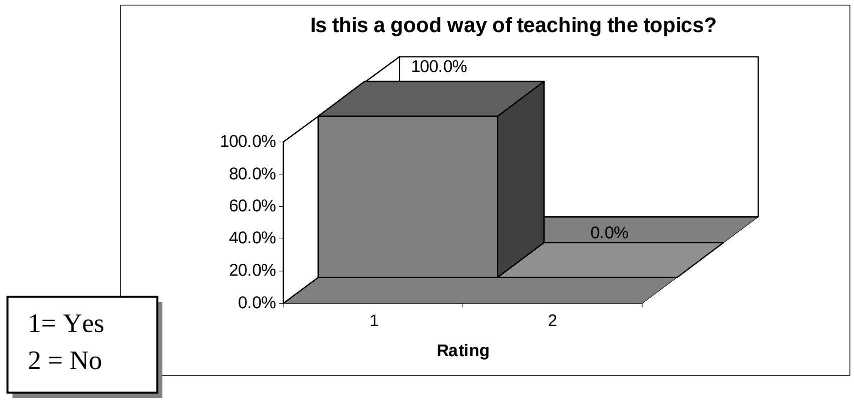
6. Could this VR software be used as part of your courses/lessons and if so, how?

All 32 respondents indicated that VR could be used as part of their courses or lessons. How this could be achieved is reflected in the pie chart.

1 = As part of upgraded PC facilities
2 = For demonstrations
3 = As a visual aid to teaching
4 = In place of on-site visits
5 = By creating VR models for specific topics & courseware
6 = To enhance the learning experience



7. Is this a good way of teaching the topic?



Section B : About the VR Lesson

1. To what extent do you agree with the descriptions of the VR lesson?

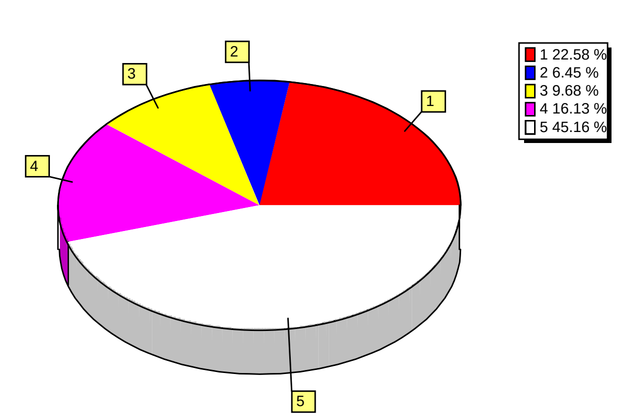
Questions	# of Responses	Mean	St. Dev.	Median
B1 - The preparation for this VR lesson was easy	28	2.8	1.3	2.5
B2 - I feel confident using this method to teach	28	2.0	1.1	2.0
B3 - My students enjoyed the VR lesson	28	1.8	1.1	2.0
B4 - The material was challenging for my students	27	2.7	1.3	3.0
B5 - The teaching time using VR was less than for my normal lessons	25	2.2	1.0	2.0
B6 - VR can be useful for learners with difficulties in the topics	29	1.6	0.9	1.0
B7 - It is easy to integrate the VR lesson into my course	28	1.9	0.9	2.0
B8 - The VR session can help with the revision of the topics	28	1.6	1.0	1.0
B9 - This software can be used in more than one course	28	1.6	0.8	1.0
B10 - I would like to use VR more often	29	1.8	0.9	2.0
B11 - VR Lessons are too expensive	26	2.3	1.3	2.0

Rating: 1= Strongly agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly disagree

Section C: Teacher's experience of using VR

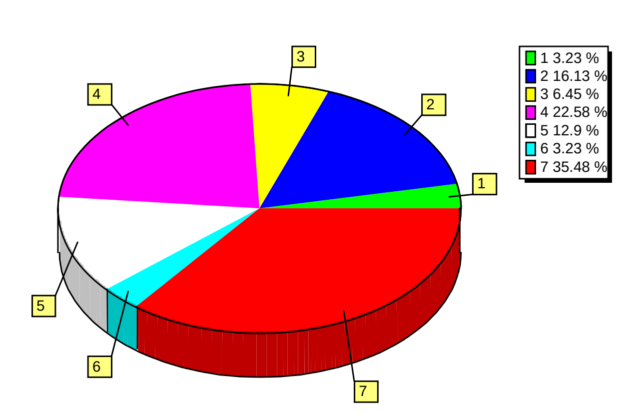
1. Comment on your experience of teaching with VR.

1 = Interesting & rewarding experience
2 = I would like to learn more about VR
3 = It is time-consuming & expensive
4 = VR is a useful tool that can help
5 = No feedback



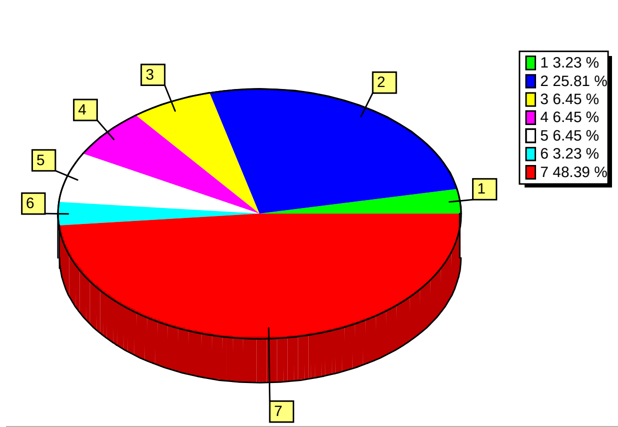
2. What was good about it?

1 = No text
2 = Interactive & visual
3 = Faster way of teaching
4 = More interesting & understandable
5 = Powerful teaching tool
6 = Chance to use new software
7 = No response



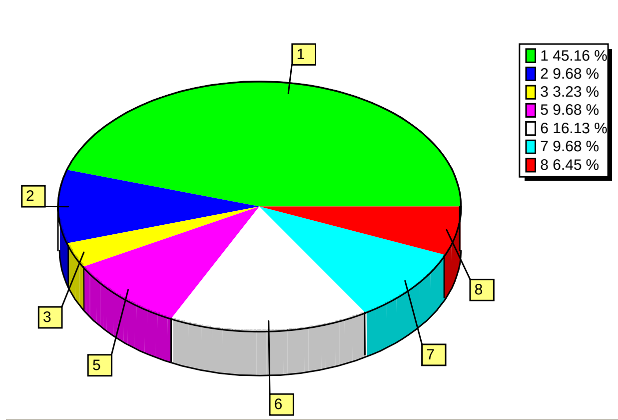
3. What was bad about it?

1 = Nothing
2 = Complex to learn to use
3 = Requires special computer equipment
4 = Could discourage real-life experimentation
5 = Not proven technology
6 = VR models should be more African



4. How can it be improved?

1 = No suggestions
2 = Make less complex models
3 = Use more video clips
4 = Include more African content
5 = Use more African languages
6 = Better training to use VR models
7 = Combine theory with VR learning
8 = Provide VR software



Section D: Teacher assessment of student work

None of the 32 respondents provided any assessments of the student learning and performance for the topics covered.

Section E: About Yourself (Demographics)

What is your age?

1 = 20 to 24	14%
2 = 25 to 34	40%
3 = 35 to 44	30%
4 = 45 to 54	8%
5 = above 55	8%

What VR training do you have?

1 = extensive	0%
2 = adequate	15%
3 = very little	26%
4 = none	59%

What is your gender?

Male	81%
Female	19%

How many years of teaching experience do you have?

Mean number of years	7.2 years
Median	5 years