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

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An Evaluation

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VR in Africa – for Africa – by Africa

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CONTENTS

EXECUTIVE SUMMARY

Introduction

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.

This report addresses the first area and contains five sections:

Section 1

VR in Africa – an educational perspective

D Lockwood, CEO, Naledi3d Factory

This overview provides a summary of the following sections of the document and looks at:

- What is VR?
- Brain research and the neurological processes involved in learning
- The role of text and technology (VR) in learning
- The benefits and drawbacks of VR in African learning
- A way forward.

Section 2

VR from an African educational perspective

Dr Rita Kizito, Learning Developer, UNISA

Section 2 looks at VR from the perspective of an educational specialist. While it tends to consider VR as a higher-end, personal, immersive experience, it looks at the various types of VR that are available; some recent uses of VR in education; educational benefits, as well as the challenges and drawbacks of the technology – especially in an African context.

Section 3

Overview of the brain

Dr RS Day, ICT Executive, UNISA

Section 3 puts visual learning into context by looking at the brain, the mind, the senses and memory. It concludes by looking at natural learning in terms of brain development, how we learn, improving learning as well as the learning process. We all have a brain, we use them mercilessly, take them for granted in a wide

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 (VR) 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.

variety of ways, and seldom stop to think what unique devices they are. Developing an understanding of how the brain learns leads to many new insights into how new learning material could be structured.

Section 4

The global approach to teaching and learning

Dr RS Day, ICT Executive, UNISA

Section 4 takes a critical look at current methods of education, in the context of 'the brain and learning' (described in Section 3). It argues the need for fundamental change and examines the roles of both text and technology, and finally addresses teaching and learning in the context of the developing world. To quote: "The Industrial Revolution fostered a new model for education, developed in the early 1800s, which brought everyone together in a single place and offered a standardised curriculum to learners. This paradigm of education remains the global norm in the 21st century, and draws from fields of sociology, business, and religion. However, the recent emergence of neuroscience, an exciting interdisciplinary approach to non-invasive brain research, is providing major insights which are challenging many conventional educational beliefs, many of which are entrenched in the current education model".

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

Section 5

Comparison of and the learning characteristics of educational multimedia

J Hugo, Usability Sciences

Section 5 summarises the key characteristics of learners and mediated learning scenarios, with special reference to the potential role of Interactive 3D visualisation and VR. The brief summary of these key characteristics lends an insight into general practices and approaches in the use of multimedia and interactive 3D tools, which are compared with other technologies and methods, including traditional methods such as classroom training and self-study using media such as text, broadcast, video and audio, as well as a range of other computer-based approaches.

This section also identifies the learning areas in which visually interactive applications could have a comparative advantage over other learning methods.

VR Technologies

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 should 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

Dave Lockwood, CEO, the Naledi3d Factory, Pretoria, South Africa

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.

Over and above the more 'traditional' (first world) applications of VR, it is believed by UNESCO, IICBA (International Institute for Capacity Building in Africa) and others that the technology has an important role to play in Africa and other developing regions of the world. Previous VR work in Africa described in the Executive Summary (to this report) was 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 Technologies) 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 – the *Navigation* dimension. How virtual a system is, is a function of the combination of the *Immersion* and *Navigation* dimensions.

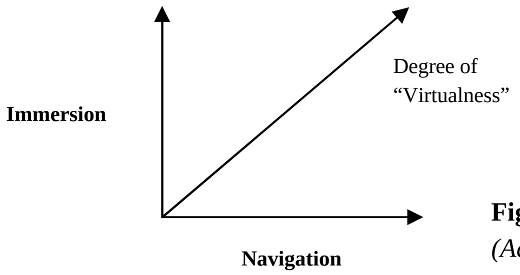

Figure 1: Immersion vs. navigation and VR effectiveness
(Adapted from Crandall and Wallace)

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[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.

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 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).

Figure 2: SGI Immersive Theatre (Concaves)

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

[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.

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.

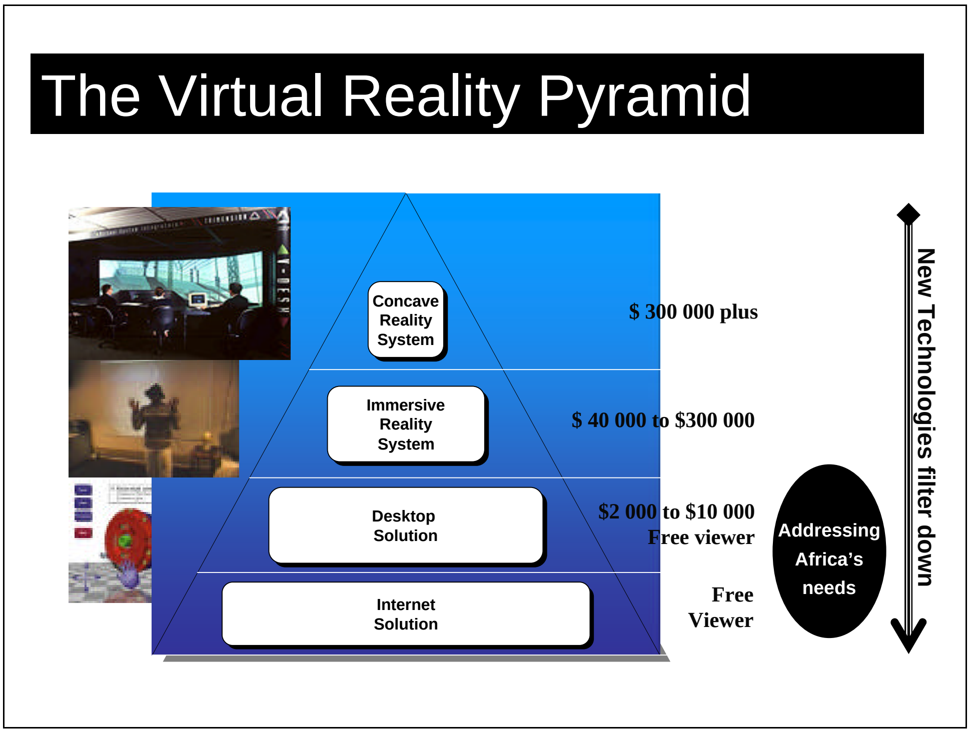

Figure 3: The VR Pyramid

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

Figure 4: Head-Mounted Display (5DT)

[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.

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 (Section 3) 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])

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

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

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 (Section 3.4).

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 (Section 3.6) 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 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 (Section 3.7) 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. Two distinct pathways are discussed in Section 3.7.2 – 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.

[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.

- 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 (Section 3.7.3):

  - 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 (Section 3.8). 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' (Section 4.1). 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] (Section 3.7.2).

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.

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

1.7 The Role of Text in Learning

Employing the amazing power of vision (our primary sense - Section 4.2) 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 – so called *'text-o-phobes'* (a term coined by Day, Section 3). In 1997, there were over 40 million adult text-o-phobes in the USA (so labelled as people who are functionally illiterate). 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 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.

The role of text needs to be reappraised, especially so when one considers the working of the mind as described above (and in Section 4.2).

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 5). 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.

> "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…."
> *(With apologies to Wilbur Smith – The Seventh Scroll)*

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 6).

Figure 6: (1) Mental Imagery in Action

> **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-South 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. (1974). *Artemis Press. Open University Set Book.*

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!

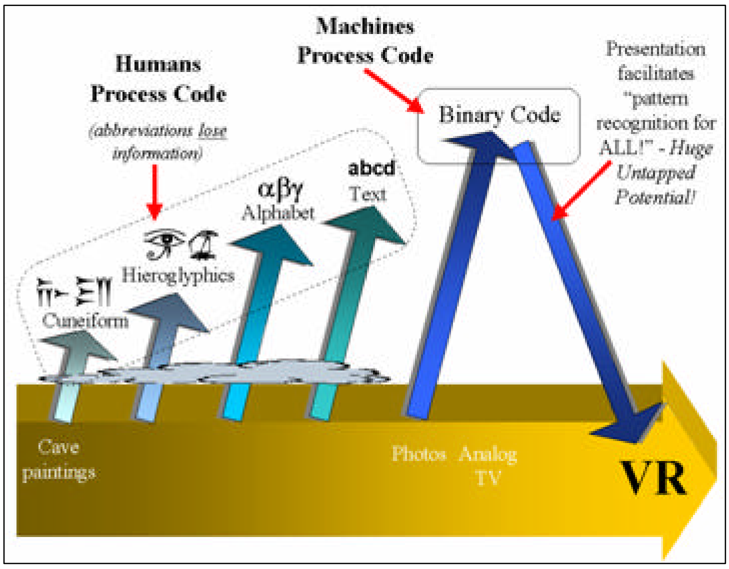

Figure 1: From Language codes to VR

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.

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 (Section 4.3.2). 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*, as described in Sections 3 and 4, 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 ICTs 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 (Section 4.4). 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 (Section 4.4.2).

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 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

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

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, able to speak both a local language and a European language. Since most of Africa's education material is imported, the overlying 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 colonial 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. Colonial languages are taught (usually not very well, by teachers who themselves are seldom fluent) to 8 - 14 year old learners, long after the 'natural window' for language acquisition has closed. Very few reach reasonable proficiency, even for speech, whilst the much more difficult reading skills are 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

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

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]
  - Developing 3D-web biology worlds and virtual experiments (Anon, 2002).

- 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 that UNESCO has worked on (together with the authors). These, which are typically PC-based applications and also more appropriate, 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 '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.

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[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

- 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 other, 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:

- 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

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

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

- 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 ICTs 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:

- *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 (Kizito, Section 2).

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?

Andragogy (J Hugo, Section 5) 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).

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

Table 2: Pedagogy versus andragogy (from J Hugo – Section 5)

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 described herein (R Day, Sections 3and 4), 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. Sections 3 and 4 (R Day) show that 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 recap, 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.

Section 5.6 (J Hugo) provides a comprehensive summary of the key features of the most common training methods, with an indication of their advantages and disadvantages. When the methods shown in this summary are mapped to the various compatible educational media, the following matrix (Table 3) is produced:

Table 3: Training Methods versus Media Types (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 does differ slightly to that of Section 5.6 (J Hugo), 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 7 below:

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

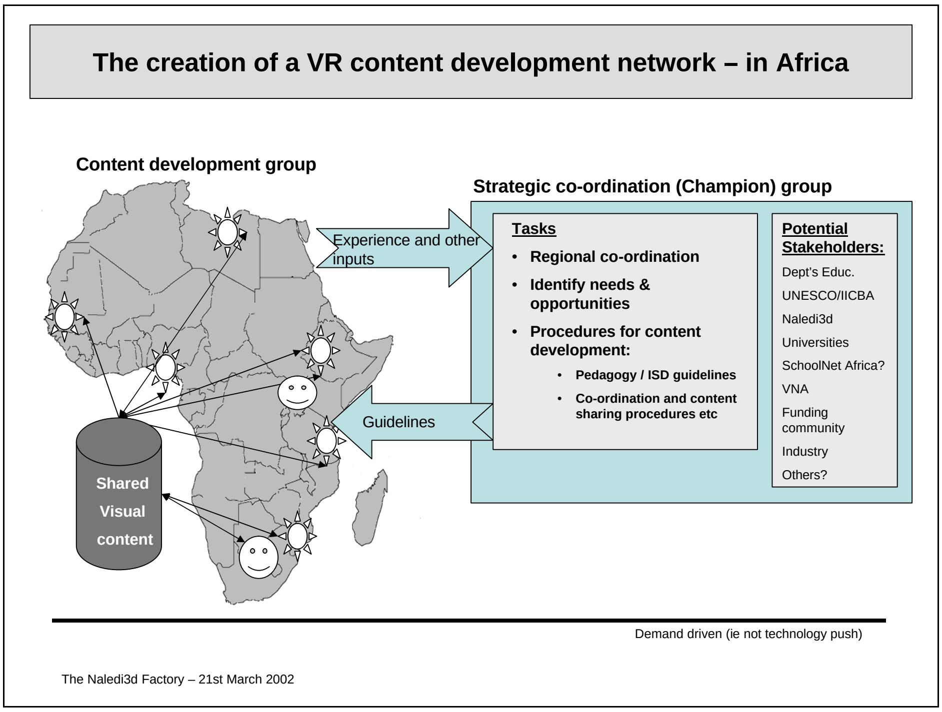

Figure 2: A Pan-African VR development network

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 VR from an African Educational Perspective

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Virtual Reality (VR) is the technology that allows learners to become immersed in a computer-generated virtual world, redefining the human-computer interface (Bricken, 1990; Capanema et al, 2001). VR has now evolved into a computer-created sensory experience that allows a participant to believe in and barely distinguish a 'virtual' experience from a real one.

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:

a) Both view and manipulate virtual objects in a manner similar to what he or she would do in a real environment.
b) Heighten use of multi-sensory, multi- perceptual and multi-dimensional capabilities (visual, sound etc) in order to increase understanding in learning. (Fallom,2000; Osberg, 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 make VR a potentially powerful tool in 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.

2.1 VR forms

VR technology uses computerized tools and platforms to represent or re-create 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 in Fällman (2001) are helpful in defining variations of user levels of immersion with VR, namely as:-

Un-immersive , non real interaction	Using desktop VR computer, the least expensive form.
Semi- immersive	Using work benches and reach-in displays
Fully immersive	Using head mounted display units isolated from the real world.

Fully immersive VR is the most beneficial but also the most costly and time consuming to develop.

The levels of learner participation within the virtual environments and the extent, to which these experiences will improve learning, are the key aspects which 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".

There have been recent development in this area. (Maseda et al, 2001) outline a successful initiative which has used virtual 3D environments together with intelligent agents to train teams of people working in emergence 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) account on the activities in a virtual world 'Euroland'. The results show a positive impact on learning but the recommendation is towards further research to validate findings.

2.2 Some recent educational uses of VR

The educational benefits of VR depend on how its role in the educational process is defined. Recent uses:

- As an exploratory tool for simulation and training, VR has been used widely used in areas involving the teaching and learning about dangerous phenomenon University of Illinois at Urbana-Champaign, Projects such as such as the Severe storm analysis or the teaching of abstract and difficult concepts in Tracking and visualizing complex biological structures are in this category.

- Another area equally significant is the creation of virtual laboratories and the performing virtual experiments. Examples include :
  - Work at the National Taiwan Teacher's college in their creation of a Geochemistry lab of virtual reality (Fung–Chun et al, 2000);
  - carrying out of Physics experimental training such as that done at Kongju national University ;
  - work in developing web 3D Biology worlds and virtual experiments (Anon, 2002).

- The last area is where significant visualization is required to demonstrate or understand difficult concepts. Examples here are Long-Chyr Chang et al (2000) building of a web-based adaptive and interactive teaching zone for teaching mathematics and Stephen Chan et al. (2000) Computer aided learning systems for appreciation of 3D geometry. The Pauling, Maxwell and Newton worlds are all demonstrations within this area.

VR is usually used in areas where the experiments are expensive or difficult to perform in natural teaching and learning environments, or the concepts being taught are difficult to understand using normal textbook methods. The greatest VR potential use is in the area in which VR support experiences unavailable or impossible to achieve in current learning environments. Osberg (1992) describes this as "a sense of immersion and inclusion in a virtual environments which allows the learner an opportunity to interpret and encode his or her perceptions in a broader , deeper set of experiences than those existing in current standard educational environments".

These would include areas where changes in the relative sizes and perspectives or views are necessary for learning, cases where multi- sensory cues and dimensions would enrich learning, and in the areas which require the creation of abstract learning objects which have no physical representations at the moment. Many learning domains including Sciences, Mathematics, Engineering, Statistics, Economic and Financial Sciences, Art and Cultural exploration have such learning areas.

2.3 What are the educational benefits of using VR?

Previous and recent studies confirm that the benefits of VR use occur because of [Maseda et al, (2000); Fällman, (2000) Osberg (1992); Bricken,(1990); Capanema et al, (2001)].

- The similarity between the psychological processes in virtual and real environments
- The fact that VR gives students the opportunity to manipulate and interact with learning objects
- Increased activity and motivation towards learning that the VR environment induces. The excitement about a subject or the encouragement about learning through exploration, or the

opportunity to give students a taste or glimpse of what it is like to be a research scientist in a deprived world such as the one we live in is worth the expense.

There is however emphasis on the fact VR should be used in those areas where text-based or other traditional methods are inappropriate or inadequate. All the recent studies suggest that there is more research still required to understand how and when this new instructional tool with instructional concepts can be effectively used. We need more studies with feedback from pupils collected and analyzed in order to quantify the pedagogical usefulness of this from of instruction.

2.4 The educational challenges of using VR

Osberg (1992) mentions several challenges, including;

- the transferability of the skills gained from the virtual to real environments
- how creativity is encouraged or rewarded in either environment
- the issue of who is really at the base of control of this environment

2.5 Drawbacks of VR in Africa

The potential for using VR has been exploited in areas such as pharmaceuticals, agrochemical and biotechnology research. VR has an important role to play in Africa and other regions of the world. It offers a new way to visually communicate ideas, skills and knowledge in a way that overcomes literacy barriers that are often experienced in education and training (Lockwood, 2002).

The challenges within the African context still lie with issues dealing with equity and accessibility. And as Osberg suggests, there are still questions that will have to be answered; questions such as:

- How is learning in VR beneficially different from that in a traditional learning environment?
- How can individual or collaborative learning be enhanced by using VR?
- How can we ensure that VR learning is empowering and not detrimental to the entire learning spectrum?

2.6 The way forward

There are many applications for VR but as educationists, we should be looking for ways of linking educational VR to real VR uses so as to justify the amount of time and resources that need to be spent on developing VR learning environments. For example, it is purported that surgeons may soon use VR to rehearse surgical operations on virtual patients and that these virtual surgical operations could revolutionize medical training. Scientists could explore celestial bodies; trace the generation and re-generation of harmful viruses using VR applications. Disabled persons, may one day be able to use tele-robotics to perform tasks unthinkable now.

It is time now for Africa to find solutions in which the use of modern technologies such as VR are developed to function in each contextual environment Dede suggests introducing technological reforms in the context of a systemic reform with simultaneous innovations in pedagogy, curriculum assessment , school organization and instructional technology. Extended professional development for teachers in innovative ways of deploying and sustaining technologies implementations is critical. Maximum efforts should be geared to wards developing and sustaining Strategies and delivery platforms suitable for the African context.

The main goal should be to empower the learner by maximizing the potential for learning. (Osberg, 1992).

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3 The Human Brain and Mind

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3.1 Summary

Many believe that, to move towards 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.

The human brain is by far the most complex device on the planet, and yet most of us take it for granted. We 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. This article emphasises the dynamic, "under-construction" nature of the brain/mind of homo sapiens sapiens. Although we have been around for about 150,000 years, it is only in the past approximately 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?

The human mind is not the brain but what the brain does. It is not a single organ, but a system of modules and organs whose operation was shaped by natural selection. They can be thought of as psychological faculties, each with a specialised design that makes it an expert in one arena of interaction with the world. These interactions enter through the windows of the body's five senses, which do not have equal standing in humans. 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' 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 is very young, is still 'under construction', and is far from being 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 the literate people on this planet, 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 is a process where 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 platform for understanding memory. *Explicit/Declarative Memory* comes in several forms, including the more word-based semantic memory (by far the weakest of our retrieval systems) and the event-type episodic memory (unlimited capacity, and used naturally by everyone). *Implicit memory* includes both the procedural and reflexive retrieval pathways. *Working memory* comprises a central executive and two subsidiary slave systems; i.e. the visuo-spatial sketch pad and the phonological loop. Working memory's role in human cognition and learning could hardly be more important, since it integrates and coordinates memory, attention and perception.

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 man to be intuitive physicists, biologists, engineers, psychologists, and mathematicians so that he could master his 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 their 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's not healthy for growing smart, adaptive minds.

3.2 Overview of the Brain

We each have our brains, use them mercilessly, take them for granted in a wide variety of ways, and seldom stop to think what unique devices they are. It is generally agreed that the human brain is by far the most complex device on the planet. According to Rita Carter[21]:

"The human brain is made of many parts. Each 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. Its modules are interdependent and interactive and their functions are not rigidly fixed.... The whole is bound together in a dynamic system of systems that does millions of different things in parallel. It is probably so complex that it will never succeed in comprehending itself. Yet it never ceases to try."

Figure 9: The human brain

[21]Carter, R.; "Mapping the mind". Phoenix, p 8, 1998.

The adult human brain weighs about 1350 grams. Whereas this represents about 2% of an adult human's weight, the brain accounts, on average, for 20% of our energy consumption. Surprisingly, the brain needs 8 to 12 glasses of water a day for optimal functioning, hence dehydration is a common problem. The cerebral cortex, the most recently evolved component, constitutes the highly folded outer region of the brain. The folds maximise the brain's surface area, but if laid flat on a surface, the cortex has the size of a large napkin. The brain is made up of cells, 90% of which are gill cells which give the brain structure, and handle the boring administrative duties. The 'exciting' cells which are actively involved in perceiving, thinking, learning, etc., (the neurons) take up the remaining 10%. Fruit flies have 100,000 neurons, monkeys have 10 billion neurons, whilst we humans have some 100 billion neurons. On average, adults lose about 10,000 neurons per day, and have half the number of a 2 year old.

The content of brain activity lies in the patterns of connections and patterns of activity among neurons. In particular, learning is a critical function of neurons that cannot be accomplished individually - it requires groups of neurons[22].

Neurons have very specialised cell shapes, with a cell body, one axon, and many dendrites. Each axon usually splits to connect, via synapses, with thousands of dendrites from many other neurons (see Figure 10).

To help understand the amazing level of connectivity this produces, it is useful to know that each brain's nerve cells are connected by *1.5 million kilometres* of nerve fibres[23]. Neurons are electro-chemical devices, converting chemical and electrical signals back and forth, as they integrate, generate and process information. The information impulse always flows from the cell, to the axon, then via the synapse to the dendrites of the next cells. Whether or not a particular part of the brain is 'active', all normal neurons are continuously firing.

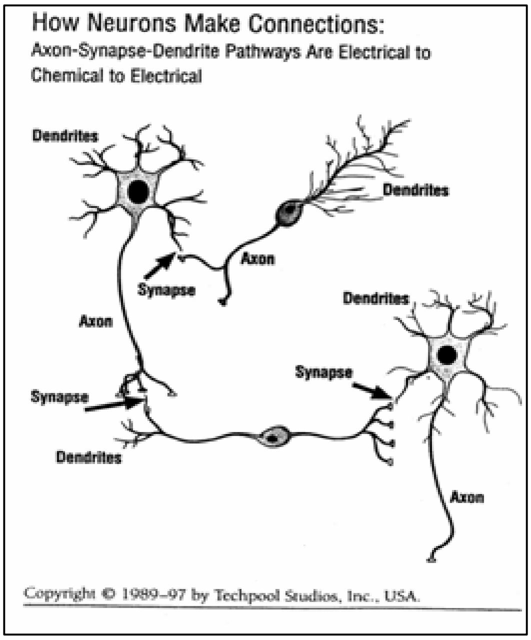

Figure 10: Neuron structure and connections

3.3 Overview of Brain Evolution

The first "brains" are thought to have emerged about 500 million years ago. These were very simple compared with the wide range of such organs which abound on the planet today - brains have proved beneficial for survival, and so have developed dramatically!

Humans and chimpanzees appear to have had a common ancestor between 6 and 9 million years ago, when the hominid line broke away. Over the past 50 million years of primate evolution, the brain-body weight ratio of all off-shoots of our common lineage remained within a fairly small range (see fig 11).

[22] Greenfield, S.; 'Journey to the Centres of the Mind'. New York: WH Freeman Company, 1995.

[23] Jensen, E.; "Teaching with the brain in mind". Association for Supervision and Curriculum Development (ASCD) Publications, pp1-3, 1998.

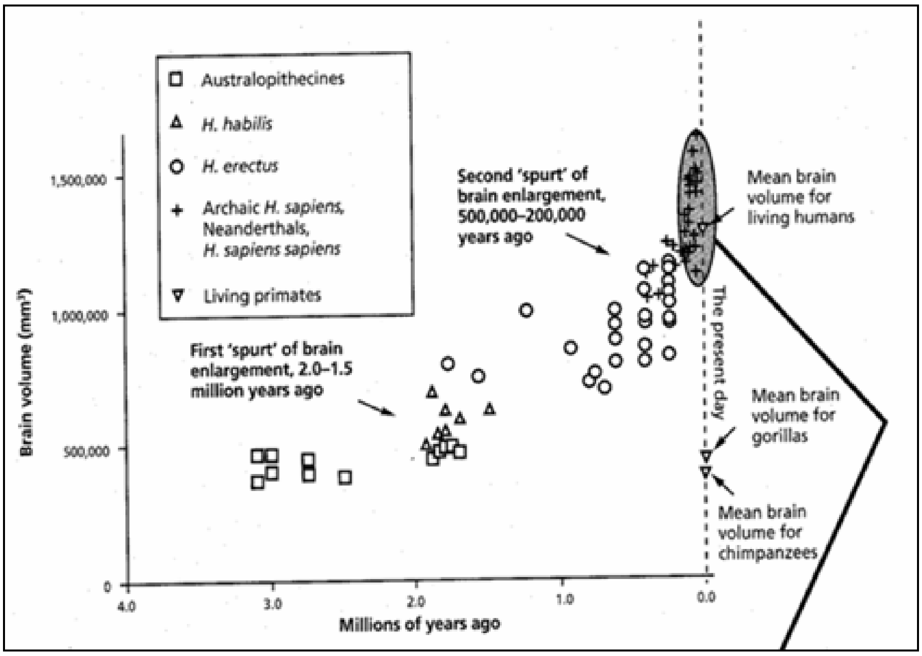

Figure 11: Evolution of the Human brain

This was also true of the early hominids, until over the past 2 million years (a very short period in evolutionary terms), the hominid brain-body weight ratio almost quadrupled[24]. Most of this growth was in the cerebral cortex, where humans have developed the largest area of uncommitted cortex of any species on earth[25]. No specific function has been identified so far, so it is sometimes referred to as the 'association cortex'.

Man's outsize brain is, by any standard, an extraordinary adaptation from our common ape ancestors. Controversy is rife around a range of interesting theories to explain this phenomenal growth. One such theory postulates that complex human language emerged first, and stimulated the growth. However, as described below, this is highly unlikely. Complex human language appears to be a recent emergent property of the fully *physically* grown brain of homo sapiens sapiens. Complex language appears to have emerged as the human mind developed within that brain.

Homo sapiens sapiens, with the current brain size, appeared on the planet only about 150,000 years ago. In evolutionary terms, this means that the human brain is very young, and the mind even younger. These facts raise two fascinating, fundamental questions:

- In the longer term, over the next 2 million years, will the brain continue to grow at the current accelerated rate? Why should it stop with the current version of humans?
- In the shorter (but still quite long) term, over the next 150,000 years (and with our current brain size), how much more will the human mind develop? How will our consciousness, intelligence, and learning grow?

The second of these questions is particularly relevant to this article, which emphasises the dynamic, 'under-construction' nature of the human brain/mind. Although we have been around for about 150,000 years, it is only in the past approximately 50,000 years that a dramatic growth in artefacts

[24]Mithen, S.; ' The Prehistory of the Mind'. 1997.

[25]Howard, P.; 'Owner's Manual for the Brain'. Austin, Tex: Leornian Press, 1994.

beyond stone tools appeared. Why did it take 100,000 years to develop these abilities? Were we physically able, but not yet mentally ready? At that stage, did we *consciously realise that we can learn* (rather than the automatic learning that all animals experience), and find that to pass on this learning to other humans, we needed to leave some kind of record in the form of cave paintings, artefacts, etc.?

3.4 The Mind

The relationship between the human brain and mind is thought by many to be one of the oldest and most fundamental of mysteries. The mind is not the brain but what the brain does (in particular, the brain processes information), and not even everything it does, e.g. metabolising fat and giving off heat.

The mind is not a single organ, but a system of modules and organs whose operation was shaped by natural selection to solve the problems of the hunting and gathering life led by our ancestors throughout most of our evolutionary history. Whether or not we establish exact boundaries for each module, it is clear that the mind has a heterogeneous structure of many specialised parts. These modules or organs can be thought of as psychological faculties or ‘mental modules’, each with a specialised design that makes it an expert in one arena of interaction with the world.

The human mind is a product of evolution, so the basic logic of our mental modules (and their combinations as ‘mental organs’) is specified by our genetic programme. The mental modules are either present in the minds of apes (and perhaps other mammals and vertebrates), or arose as further adaptations of the minds of the common ancestors of humans and chimpanzees that lived in Africa between 6 and 9 million years ago.

A remarkable feature of the mind/brain is its capacity to function as a complex adaptive system on many levels and in many ways simultaneously. There are emergent properties of the mind as a whole system that cannot be recognised or understood when the parts alone are explored[26]. Underlying this, thoughts, emotions, imagination, predispositions, and physiology operate concurrently and interactively as the entire system interacts and exchanges information with its environment. But how does it sense its environment?

3.5 An overview of the senses

For the mind to function, it must take in data that it can use for its processing. The only way the mind can do this is through the sensory perceptions that enter through the windows of the body’s five senses. These senses do not have equal standing in primates or humans. What is sensed, how quickly does it reach our senses, how useful is it to the human mind throughout its development and learning?

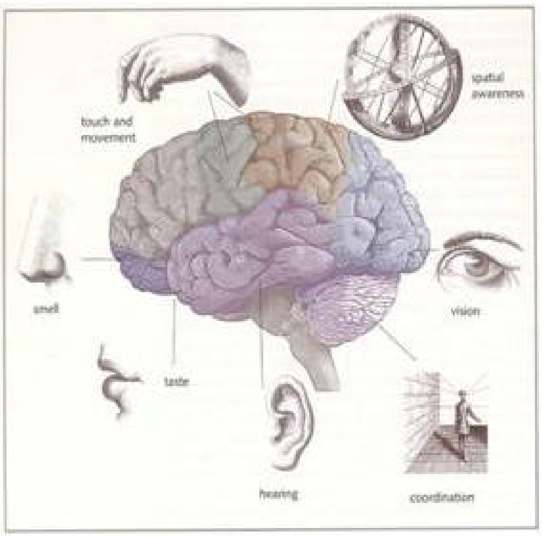

Figure 12: The human senses

3.5.1 Touch

Touch involves physical contact with the environment using the entire surface of our body as the sense organ (but with dramatic variations in sensitivity in different regions of the body). It

[26]Caine, RN. & Caine, G.; “Education on the Edge of possibility”. ASCD Publications, p104, 1997.

happens as quickly as the contact process involved, whether we are being touched (a handshake, a bullet), or we are touching (a footstep, typing). It is particularly important during infant development, with much of its activity becoming subconscious with frequent repetition. It retains its importance throughout life by confirming our immediate surroundings, what is happening to us, what we are doing, and providing feedback on what we have just done. But it tells us little of our more distant surroundings, and provides little information on what might be about to happen, both in the short and longer terms. Of particular importance is its collaboration with visual perception (‘touch-eye coordination’, and especially ‘hand-eye coordination’), which will be shown to be of major importance to learning, memory, and retrieval.

3.5.2 Taste and smell

Taste and smell also involve physical contact, but at the molecular level, coupled with sophisticated chemical analysis within highly specialised (and related) parts of the body (mouth/tongue and nose). Smell provides some indirect information on what may be happening even in our more distant surroundings, but it arrives very slowly and with no clear directional data. Hence smell relies on touch, sound and vision to give better quality backup information based on its initial input. Taste plays a crucial role in our primary process of life sustaining energy provision, but tells us almost nothing about the dynamics of our external environment. Neither sense appears to play a significant role in our conscious understanding of and learning about the world about us, especially after early development.

3.5.3 Sound

Sound, again, involves physical contact, but this time by sensing pressure variations in the air via the diaphragms in two highly sensitive and specialised organs (the ears). It provides a great deal of information about the dynamic external environment, but of varying quality (due to many disturbances of the medium, distortion, interference, and falling off significantly with distance). The two ears provide directional and distance information fairly quickly (at the speed of sound), but of fairly poor quality so that the mind usually transfers attention to touch and particularly, vision. Sound is good for monitoring the dynamics of our near to medium environment (stationary, inert objects create no sound, and we do not project clicks to investigate the environment, unlike bats and cetaceans for whom sound is the primary sense). Unlike touch, taste and smell, sound provides a great deal of information that allows creatures to anticipate what might be about to happen, particularly in the short term. Sound appears to have several unique strengths, including its obvious value at night (not just for nocturnal creatures), as well as being the primary medium used by creatures that have developed the wish to express themselves (especially consciously). Emitting sound provides a much wider spectrum (amplitude, frequency, types) than touch or smell, and with a sustainably low energy bill. Emitting light of sufficient intensity and variability for day time broadcast has proved too energy expensive for most animals to date, although some nocturnal (e.g. fireflies), and aquatic (e.g. angler fish, squid) creatures have developed very limited capabilities.

3.5.4 Vision

Vision, unlike the other four senses, is non tactile, since photons of light are discrete quanta of energy, with no mass. In the other senses, the stimulus interacts indirectly with the brain via intermediary sense organs, which inevitably reduces the quality and speed of the impulse. But, since the retina is an integral component of the brain, light is unique in that it interacts directly with the mind as each photon is absorbed by a rod or cone in the retina. Vision provides a flood of information of excellent quality, under normal daylight conditions, about both the dynamic and the inert external environment, and virtually instantaneously (at the speed of light!). The two eyes provide immediate and highly accurate directional and distance information, as well as shapes, colour, orientation, shading, relative size, relative speed, and much more. Vision is excellent for monitoring most aspects of the near, medium and distant environment - most sound waves are dissipated over a few hundred metres, but photons can and do reach us from the horizon, and even the edge of the universe! Vision provides an order of magnitude more information than sound, thereby allowing creatures to anticipate what might be about to happen, not only in the short term, but also in the medium and even long terms. It is clear that for daytime, land based creatures, vision is uniquely powerful amongst the five senses. But it cannot do everything alone. We have already mentioned the crucial role of 'touch-eye' coordination, and that sound ably supplements vision's weaknesses (at night, when something happens behind us, etc.). But it will be shown below that visual perception relies on a wide range of inputs from all the other senses (but particularly touch and sound) to complete the mental models we use to think.

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. How well are we mixing the combination of these to satisfy the learning needs of the world's wide variety of learners, particularly the billions in the disadvantaged world with the greatest need?

3.6 Vision and Perception

Man, like all primates, is primarily a visual creature, and his mind has evolved around this remarkable sense[27]. Vision is the sense which has the largest cortical area devoted to its activities, and is referred to as the 'senior sense'[28].

3.6.1 Seeing

Each visual stimulus, having been converted to electric signals in the retina, is shunted on to the visual cortex at the back of the brain. The visual cortex (see figure 13) is split into many areas, each processing an aspect of sight such as colour, shape, size, stereo, depth, etc. The heart of the visual cortex, V1, mirrors the world outside in which each point in the external visual field matches a corresponding point on the V1 cortex[29]. Hence, when simple shapes (e.g. a honeycomb) are observed, the image is reflected by a matching pattern of neuronal activity on the surface of the visual cortex. The centre of the retina, the fovea, is much more densely packed with neurons and therefore captures far more detail. As a result, the cortical 'map' is distorted, as the neurons responding to the dense central area of the visual field take up a much greater cortical area, i.e. the 'picture' produced on V1 is a little like that seen through a fish-eye camera lens.

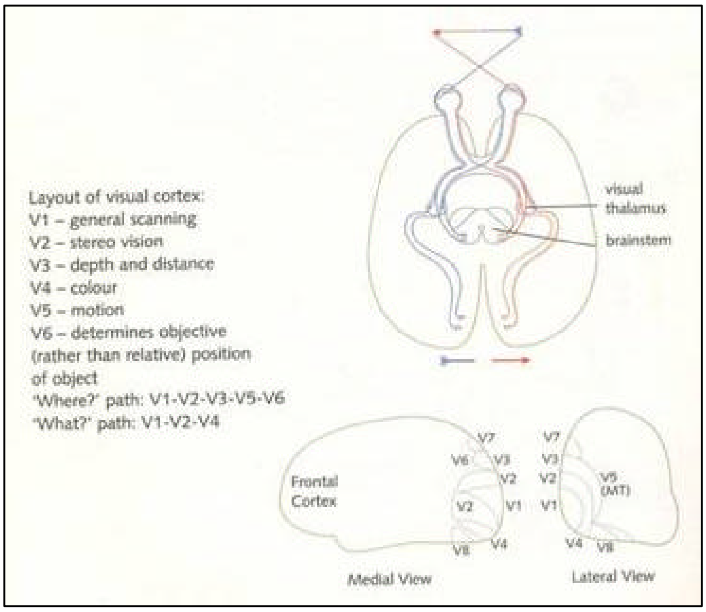

Figure 13: The visual cortex

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[27]Pinker, S.; "How the Mind Works". Penguin, p211-20, 1997.

[28]Cotterill, R.; "Enchanted Looms: Conscious Networks in Brains and Computers". Cambridge University Press, p 384, 1998.

[29]Carter, R.; "Mapping the mind". Phoenix, pp 184-5, 1998.

Vision is much more than the capturing of these cortical ‘maps’. Hubel and Wiesel proposed their classic theory which provides a credible mechanism for how the visual system goes to the next level, and detects patterns[30]. Following their lead, other researchers have proposed that groups of cells in the V1 visual cortex are at the bottom of a hierarchy of feature detectors. The idea is that a cluster of these cells feed into a single higher-level pattern detector, or complex cell, in another part of the visual cortex; and, similarly, many of these complex cells feed into a hyper-complex cell. It is argued that these high-level cells fire only in response to a very specific feature or stimulus, such as a face, a car, a deer, or a tree.[31]

Visual perception is one of the most complex processing tasks that the brain is called upon to perform. It is not surprising, therefore, that when it goes wrong, the results can be dramatic. It is significant that unlike ‘seeing disorders’, which may cause degradation of the image, blurring, loss of colour vision and so on, ‘visual perception disorders’, e.g. agnosia, cause only gross errors in perception (sufferers are unable to identify objects as a whole, e.g. a face, a deer..). This suggests that perception works through a higher level ‘language’ that can be compared with the written word in its level of specificity. Our visual perception seems to work in the same way, by ‘seeing’ or perceiving objects as complete forms, not as sums of their constituent parts.

3.6.2 Visual perception and the mind’s eye

Intuitively, it seems unlikely that analysis of lines and curves can fully account for the richness of our perceptions, which involve knowing what the patterns represent - recognising what is ‘out there’. A wide range of indirect functions of the visual cortex converts these retinal depictions and patterns into higher level abstract mental descriptions, or mental models, which underlie the interaction between seeing and thinking known as ‘*mental imagery*’.

As all sighted people know from personal experience, the brain somehow analyses, in real time, these moving cortical ‘pictures’ produced on each retina and arrives at an impressively accurate sense of the objects being observed. The accuracy is impressive because the problems the brain is solving are, literally, unsolvable. David Marr was the first to describe vision as having evolved to convert these ‘ill-posed problems’ into solvable ones by adding *assumptions* about the world[32]. These inherent visual ‘assumptions’ are revealed by the many well known artificial and natural optical illusions used in party games (and psychology research, see figure 14). Hence, illusions unmask the assumptions that natural selection installed to allow our large visual cortex to solve unsolvable problems and know, much of the time, what is out there.

Figure 14: Optical illusions – chalice or face

Marr described vision as a process that produces from images of the external world a description, or mental model, that is useful to the viewer, but that is NOT a verbal one. It is an internal, abstract model (Pinker might say it is in ‘mentalese’). If vision did not deliver such abstract mental models, every

[30]Hubel, DH.; ‘Eye, Brain, and Vision’. New York, Scientific American, 1988.

[31]Cohen, D.; “ The secret language of the mind”. San Fransisco, Chronicle Books, pp 52-3, 1996.

[32]Marr, D. & Nishihara, HK.; ‘Representation and recognition of the spatial organisation of three-dimensional shapes’. Proceedings of the Royal Society of London, B, 200, 269-294, 1978.

other mental faculty (e.g. language, walking, grasping, planning, imagining, etc.) would need its *own* procedure for creating one. For example, when vision deduces the shape of an object that gave rise to a pattern on the retina, *all* parts of the mind can (and do) exploit vision's abstract mental model. Some components of the visual system siphon off information to motor-control circuits that need to react quickly to moving targets. However, the visual system as a whole (almost 50% of the cerebral 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 'mental commons' for general use by *all* the mind's mental modules.

In other words, *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 form 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, e.g.:

- 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.

The brain is capable of satisfying the demands of such a mental imagery system where information must flow freely from memory instead of up from the eyes, since the fibre pathways to the visual areas of the brain are two-way. They carry as much information down from the higher, conceptual levels as up from the lower, sensory levels, and therefore are equipped to download memory images into visual maps.

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. It is a mosaic of elements that stand for neurons in the visual field. 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 simply a pseudo-3D sketch that is loaded from long-term memory rather than from the eyes.

3.7 Sound and Language

The process of hearing is itself a fascinating, multi-disciplinary subject, and the detailed workings of the ear and the neural pathways carrying sound inputs from each ear to the brain's hemispheres reveal much about evolution. For example, each hemisphere has evolved a distinct role in sound processing, so sounds are processed (and therefore experienced) differently depending on which ear they enter. However, in this section the intention is to focus not on how sounds are detected by humans, but on how and when the processing of a special range of sounds associated with man's uniquely complex language evolved, as well as on how man has developed this capability to express himself first in speech and very recently in text.

3.7.1 The evolution of complex language

Man's development of complex language changed the landscape of the brain radically because once language had taken hold it appears to have rapidly annexed large parts of the left hemisphere, previously given over to visuo-spatial functions. In doing so it created the asymmetry that distinguishes the human brain from that of any other animal. The reason for the emergence of complex language remains unknown, but the brain itself provides some clues[33].

Animals do not have specialised language areas - their brains are more or less symmetrical, and their own noises are produced and processed along with environmental noises on both sides. Similarly, language initially develops in infant humans, together with other sound processing, in both hemispheres of the brain. By the age of five, however, in 95% of cases language, but NOT any other sound processing, shifts to lodge only in the left hemisphere, in the temporal (side) and frontal lobes, areas which are marked by a distinct, one-sided bulge (not seen in any animals, even chimpanzees). After this migration, the abandoned early speech areas in the right hemisphere are given 'back' to the activities for which they were probably previously being used. These involve the processing of environmental noises and spatial skills, i.e.:

- the rhythm and melody of music;
- the 'where' of things in the outside world;
- fine hand movements - including gestures, but NOT formal sign language.

So human language appears to have behaved like a hermit crab, moving around the brain until it finds a location which, though alien, best fits its structure. What does this behaviour tell us? According to William Calvin, most brain regions are, to some extent, multifunctional. As a result, this often enables *new functions* to first appear by making spare-time use of some pre-existing part of the brain[34]. The implication is that, in evolutionary terms, human language is very young, is still 'under construction', and is far from being fully integrated into the brain. Rodney Cotterill comes to a similar conclusion:[35]

"There is a growing body of evidence which suggests that no new neural systems evolved to exclusively serve language[36], and that there was no discontinuity of language from other cognitive systems[37]. Instead, language appears to be a new mechanism that Nature constructed out of old parts,[38] these being cortical maps of sensorimotor origin."[39]

The previously visuo-spatial region where language has recently taken up tenancy is also rich in connections to deeper brain structures that process sensory stimuli. It is one of the places where stored

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[33]Carter, R.; "Mapping the mind". Phoenix, Pp224-9, 1998.

[34]Calvin, WH.; "How brains think". Basic Books, p12, 1996.

[35]Cotterill, R.; "Enchanted Looms: Conscious Networks in Brains and Computers". Cambridge University Press, p 388, 1998.

[36]Deacon, T.; 'Brain-language coevolution'. In JA Hawkins & M Gell-Mann eds. 'The Evolution of Human Languages: Proceedings of the Santa Fe Institute Studies in the Sciences of Complexity'; San Franscisco: Addison Wesley, 1990.

[37]Deacon, T.; 'Rethinking mammalian brain evolution'. American Zoologist, 30, 629-705, 1990.

[38]Bates, E., Thal, D., & Marchman, V.; 'Symbols and syntax: a Darwinian approach to language development'. In N. Krasnegor, D. Rumbaugh, E. Schiefelbusch, & M. Studdert-Kennedy eds. 'Biological and Behavioural Determinants of Language Development'. Hillsdale, NJ: Erlbaum, 1991.

[39]Sereno, M.; 'Language and the Primate Brain'. San Diego: California University Centre for Research in Language, 1990.

impressions from different senses, particularly touch and hearing, are brought together and reassembled into coherent memories - i.e. it seems that language 'best fits' in a region where several different and important functions converged.

The language cortex completely surrounds the auditory, but with two main areas - *Wernicke's* and *Broca's* - having been recognised for more than a century. Recent brain imaging studies suggest that other areas are also involved, including part of the insula (see Figure 15). It is thought that the language cortex is probably split, like the sensory cortices, into many different processing regions and sub-regions, but brain imaging studies have yet to fully confirm this. However, damage to cortical areas adjacent to these two main ones can cause a wide range of very specific language problems, providing indirect evidence of the functional subdivision of the auditory cortex.

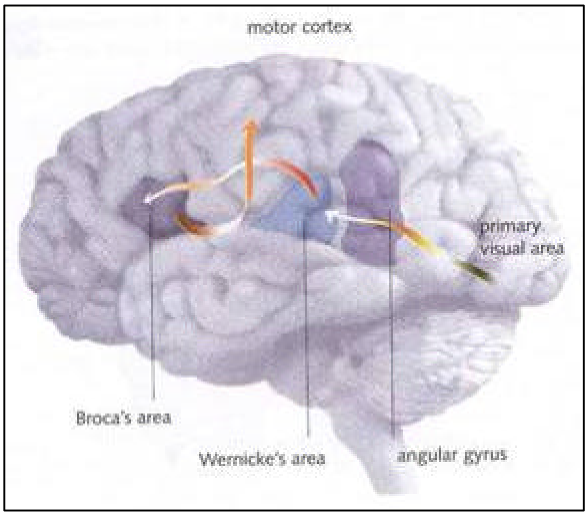

Figure 15: The language cortex

3.7.2 Speech processing

Analysing a stream of spoken words is highly complex. First, the brain has to recognise that what is coming in is, in fact, language. Speech is then shunted to the language areas to be processed, while environmental noises, music, and non-verbal messages (grunts, screams, laughs, sighs, etc.) go elsewhere. Once speech has been identified, as many words as possible are assigned some sort of meaning, whilst simultaneously the complex ribbon of sound is broken down into its elements - separate words or phrases. The two things are necessarily done together because without meaning it is almost impossible to make out language construction.

- Analysis of word **meaning** is carried out either in or very close *to Wernicke's area*.
- The cortical area that finds **structure** in incoming speech has yet to be identified. The eminent linguist Noam Chomsky has produced an elegant hypothesis for some kind of 'language organ' in the brain, but what form it might take and where it might be located are not known. Steven Pinker has built on this theory, suggesting that the language organ may not be a neat module at all[40].

- *Broca's area* governs **speech production** - a different part of the brain which is further forward in the side of the left frontal lobe. It abuts the motor cortex that controls the jaw, larynx, tongue and lips, and appears to instruct these neighbouring parts of the motor cortex to articulate speech. People with damage to Broca's area can understand what is said to them perfectly well, and they know what they want to say. They just cannot say it!

3.7.3 Reading[41]

Babies are tuned to hearing speech from birth, or even perhaps in *utero*. Speaking also comes naturally to infants - provided they are exposed to *spoken* language during infancy. Therefore, even though language seems to be such a comparatively recent acquisition, the basics of hearing and speech

[40]Pinker, S.; 'The Language Instinct'. New York: Harper Collins, 1994.

[41]Carter, R.; "Mapping the mind". Phoenix, Pp251-4, 1998.

previously must have been 'hard wired' into the brain to carry out procedurally similar cognitive functions, and as an essential precursor to the emergence of complex language[42][43].

Whilst infants do not need to be taught the basics of hearing and speaking language, by contrast, reading and writing are far from being natural acquisitions and can only be learned by children after speech has been established. Printed text has only been widely available for a few hundred years, and therefore, on the evolutionary time scale, reading has had no time at all to even begin to become an innate ability. The only reasonable explanation is that we learn to read and produce written language by pressing into use the language system as evolved for speech, together with relevant parts of the visual and touch systems, e.g. object identification and gesturing systems (to use fine hand movements to manipulate a writing instrument).[44]

It is not surprising, then, that the areas dedicated to processing the written word are situated around the junctions between the areas given over to these different skills. Just behind Wernicke's area lies a bulge called the angular gyrus, which seems to act as a bridge between the visual word recognition system and the rest of the language process. It is a region of the brain where vision, spatial skills and language appear to overlap on the margins of the occipital, parietal and temporal lobes[45] (see Figure 16).

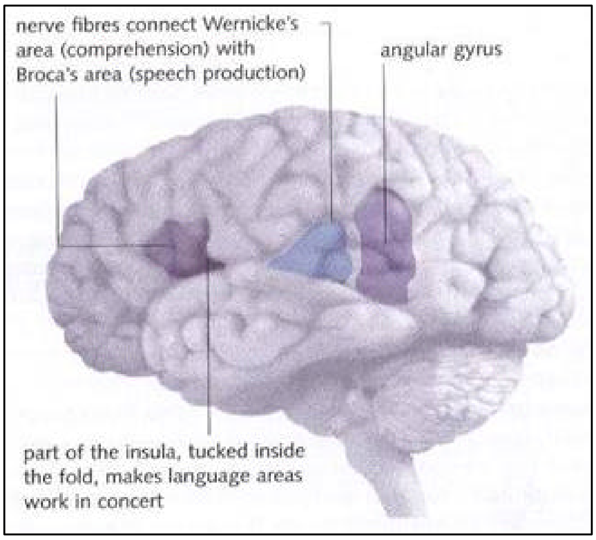

Figure16: Processing the written word

It is important to emphasise that the unnatural nature of reading and writing have serious implications in their use both to receive information (reading) and to express ourselves (writing). We do not write as we speak (especially in text books and academic journals). Therefore, how accurately does what we have (unnaturally) written represent what we would (naturally) have said? And what about the reader? Assuming the text being read *does* accurately represent what the writer intended, the reader has to, via a learned process (likely to be slow and inaccurate) convert that text into abstract mental models (either directly, if a speed reader, or using an additional sub-vocalisation step), and hope that those models accurately represent the writers intentions. Text has advantages, especially representing abstract concepts and details. But the cognitive scientific reasons why it is prone to slow information transfer, serious inaccuracies and poor retrieval need to be fully appreciated. Even for the literate people on this planet, in cognitive terms, text is the least efficient and effective of all the available communications media.

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[42]Cotterill, R.; "Enchanted Looms: Conscious Networks in Brains and Computers". Cambridge University Press, p 388, 1998.

[43]Pinker, S.; 'The Language Instinct'. New York: Harper Collins, 1994.

[44]Kosslyn, SM, & Koenig, O; "Wet Mind: the new cognitive neuroscience" (New York, Free Press, 1992)

[45]Carter, R.; "Mapping the mind". Phoenix, Pp254-8, 1998.

3.8 Memory

The only way that the brain can take in the data it needs to construct knowledge and behaviours is through the sensory perceptions that enter through the windows of the body's five senses. Anything that a person does, perceives, thinks, or feels while acting in the world gets processed through complex systems of storage pathways[46] and creates memory.

The brain has 100 trillion connections joining billions of neurons and each junction has the potential to be part of a memory. So the memory capacity of a human brain is effectively infinite, providing it is stored in the right way[47]. The human memory is different from a computer's in that it is selective. Items of interest - those that ultimately have some bearing on survival - are retained better than those that are not. So personal and meaningful memories can be held in their billions while learnt 'dry facts' (usually text-based) often quickly fade.

3.8.1 What is memory?

Although researchers are still not 100% sure how memory works, neuroscientists are making important discoveries in this area. Several models of memory exist, including the popular concept that our brains somehow record or 'videotape' life. This theory has its origins in reports that during surgery, electrical stimulation of the temporal lobe produced episodes of recall, almost like 'seeing movie clips'. It persists even though such findings could not be replicated and have been dismissed by most experts!

Researchers generally agree that memory is not a fixed thing or singular skill, but rather is a process where a transient stimulus creates a persistent change in the brain. Our memories are not stored in a single location. Instead many distinct locations are implicated with certain memories (e.g. sound in the auditory cortex, learned skills in the basal ganglia, associative memory formulation in the cerebellum, etc.). Hence, a complex set of multiple memory locations and systems are responsible for our best learning and recall[48] (see Figure 17).

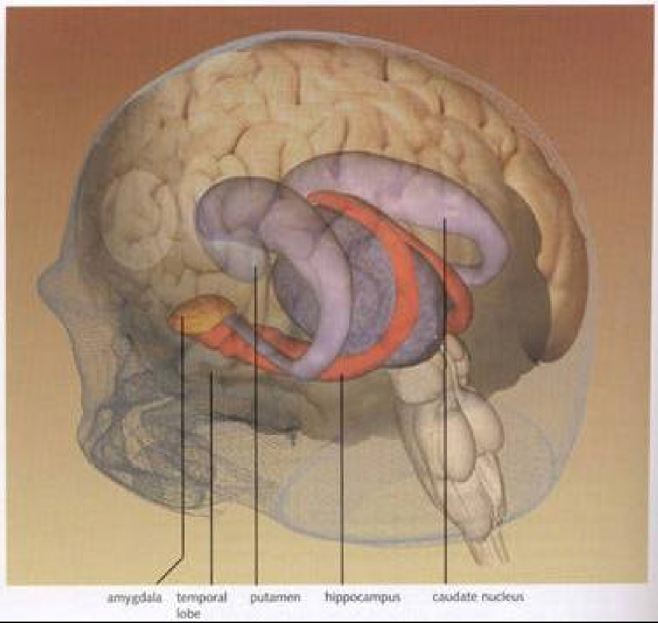

Figure 17: Memory involves many locations in the brain

The process for *retrieval* is proving to be much more consistent than is the location the memory was elicited from, and hence this is providing a much better platform for understanding memory.

3.8.2 Retrieval

There is no firm distinction between how well a person thinks and how well he or she remembers.[49] We can retrieve most of what we have paid attention to originally, but the success of that retrieval is highly

[46]Restak, RM.; 'The brain: The last frontier'. New York: Warner, 1980.

[47]Carter, R.; "Mapping the mind". Phoenix, pp288-9, 1998.

[48]Schacter, DL.; 'Understanding Implicit Memory'. American Psychologist 47, 4: 559-569, 1992.

[49]Turkington, C.; 'The Brain Encyclopedia'. New York: Facts on File, 1996.

dependant upon multiple factors, including state, time and content. For example, remarkable levels of recall have been demonstrated for Spanish,[50] mathematics,[51] city streets, locations, names, and faces when careful attention was paid to context and state. The variety of ways in which information is stored and retrieved indicates that our focus should move on from simple 'memory' to 'which kind of memory and how it can be retrieved'[52].

Explicit/Declarative Memory. This is formed in the hippocampus and stored in the medial temporal lobes. It comes in several forms, including the more word-based semantic memory and the event-type episodic memory:

- *Semantic Pathways:* Semantic memory is also known as explicit, factual, taxon, or linguistic memory, and includes names, facts, figures, and textbook information. It is word-based and is activated by association, similarities, or contrasts. The capacity limitations are more strongly influenced by the strength of associations made than the sheer quantity of items. We remember best in 'chunks', which are single thoughts, ideas, or groups of related ideas. A 3-year-old can handle 1 chunk, which increases to 7 (+ or - 2) in people of 15 years and older. The brain does not appear to be well equipped to routinely retrieve this type of information, since humans have had little need for semantic recall until recent history when books and literacy became common. *Given the newness of this need, it is not surprising that this is by far the weakest of our retrieval systems.*

- *Episodic Pathways:* This system is also known as the loci, spatial, event, or contextual recall process - a thematic map of daily experiences. The visual system has both 'what' (content) and 'where' (location) pathways[53] (see Vision section), and it *is believed that this information is processed visually by the hippocampus.* Learning and memory are prompted by contextual cues, such as location and circumstances. The formation of this natural memory is motivated by curiosity, novelty, and expectations, and is enhanced by intensified sensory input, such as sights, sounds, smells, taste, touch and emotions. Episodic memory has *unlimited capacity*, forms quickly, is easily updated, requires no practice, is effortless, and is used naturally by everyone.

Implicit memory: Our minds are full of information, but 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. Two distinct pathways are discussed here: procedural and reflexive.

- *Procedural Pathway:* This is often known as motor memory, body learning, or habit memory and involves both the basal ganglia and the cerebellum. Body and brain are not separate but are parts of the same contiguous organism, and what happens to the body happens to the brain. This dual stimulus creates a more detailed 'map' for the brain to use for storage and retrieval[54]. Such 'hands-on learning' creates a wider, more complex, and over-all greater source of sensory input to the brain than mere cognitive activity. It appears to have unlimited storage, requires minimal review,

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[50] Bahrick, HP.; 'Semantic memory Content in Permastore: Fifty Years of memory for Spanish Learned in School'. Journal of Experimental Psychology, 113: 1-29, 1984.

[51] Bahrick, HP, & Hall, LK.; 'Lifetime Maintenance of High School Mathematics Content'. Journal of Experimental Psychology, 120: 20-33, 1991.

[52] Jensen, E.; "Teaching with the brain in mind". Association for Supervision and Curriculum Development (ASCD) Publications, pp99-109, 1998.

[53] Kosslyn, S. 'Wet Mind'. New York: Simon and Shuster, 1992.

[54] Squire, L.; 'Memory and the Hippocampus: A Synthesis from Findings with rats, Monkeys, and Humans'. Psychological Review 99, 2: 195-231, 1992.

and needs little intrinsic motivation. At school, this type of learning diminishes each year until it is virtually absent (as in most tertiary courses). Yet a summary of the research tells us that this learning is easier to master, is fairly well remembered, and creates lasting positive memories.

- *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.

3.8.3 Working memory

A new term has recently emerged to describe how we juggle perceptions, memories and concepts: *working memory*.

Memory used to be regarded as a simple library with a long-term store (childhood memories and so on) and a short-term store (a temporary holder in which information is retained for as long as it is needed, then discarded). As experimental techniques became refined, however, it has become clear that there is no rigid dividing line between a memory and a thought[55]. A range of related findings has led to the abandonment of the idea that a single short-term memory serves as the working memory. It has been replaced by a tripartite scheme which, according to the model of working memory developed by Alan Baddeley and his colleagues[56], comprises a *central executive* and two subsidiary *slave systems*, as indicated in their highly schematic diagram (see fig 19 overleaf):

The Central Executive: is an attention-controlling system, probably located in the prefrontal cortex. It co-ordinates information from a number of sources, directs the ability to focus and switch attention, organises incoming material and the retrieval of old memories. It marshals cyclic processes in the two slave temporary storage systems, namely the visuo-spatial sketchpad, and the phonological loop. These might each be a series of successively linked cortical clusters, their interactions being mediated by the forward and reverse projections that are common features of the cortex. Recent brain imaging studies at the Wellcome Department of Cognitive Neurology have found that the three parts are echoed precisely in the activity seen when people carry out cognitive tasks, and have confirmed the separate nature of visuo-spatial imagery and verbal repetition:[57]

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[55]Baddeley, AD. & Hitch, GJ.; 'Working Memory.' In GH Bower ed. 'The Psychology of Learning and Motivation', Vol. 8, New York, Academic Press, 1974.

[56]Baddeley, AD.; 'Working Memory'. Science, 255, 556-9, 1992.

[57]Cotterill, R.; "Enchanted Looms: Conscious Networks in Brains and Computers". Cambridge University Press, pp283-5, 1998.

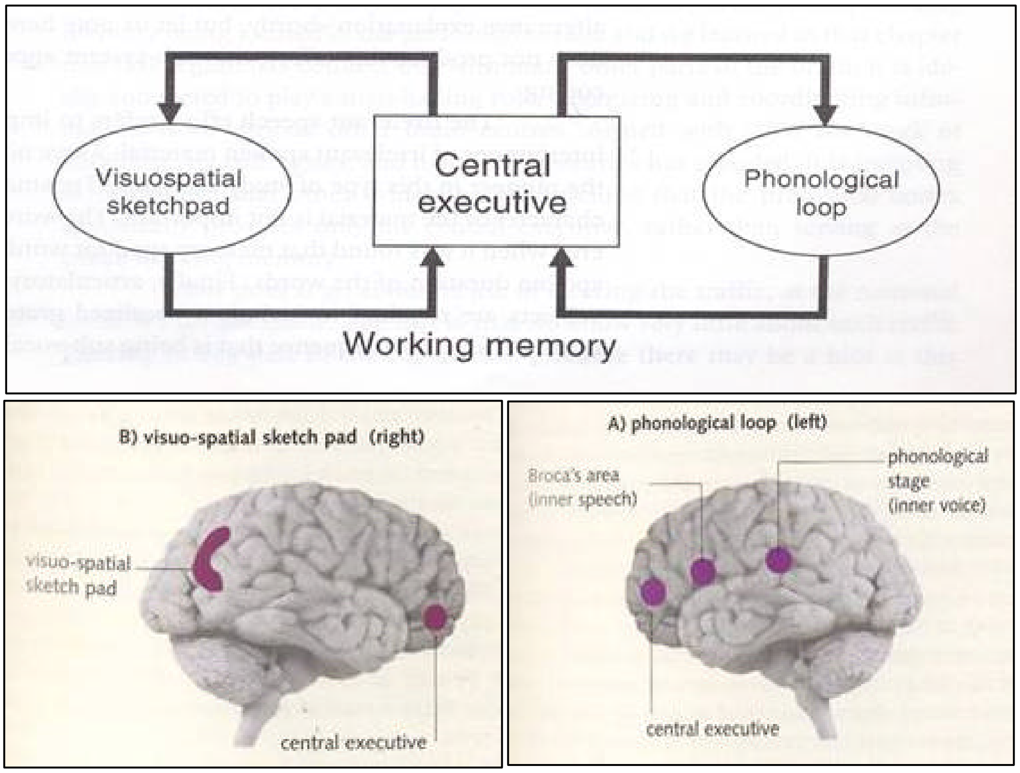

Figure 18: Components of working memory

- *s*
  patial sketch pad is responsible for setting up and manipulating visuo-spatial imagery, with further separation between *positional* (occipital lobe) and *pattern* (parietal lobe) processing in the visual domain. It is complex and remains poorly understood, although the four active regions so far identified by functional imaging are thought to represent 'what', where', executive control, and possibly image rehearsal.

- *The Phonological loop* maintains acoustic and speech-based information, and can be split into two components: a *phonological store* that holds a fast decaying (1 - 2 seconds) speech-based trace, and an *articulatory control mechanism* which plays a mediatory role, and which permits us to register visual information in the phonological store via sub-vocalisation. This store is thought to serve as a backup system for speech comprehension.

Working memory is best regarded as a mechanism that permits performance of complex cognitive tasks through its ability to temporarily store information related to the various sensory modalities, particularly those of vision and audition. It enables us to use our memory systems flexibly; to hold onto information by rehearsing it in our minds; to relate that information to older knowledge; and to plan our future actions. In Alan Baddeley's view, working memory stands at the crossroads between memory, attention and perception, and as such, its role in human cognition and learning could hardly be more important.

3.9 Natural Learning

3.9.1 Brain development and early learning

For the first year or two of life outside the womb, our brains are in the most pliable, impressionable, and receptive state they will ever be in'[58]. We begin to be shaped as our immensely receptive brain/mind interacts with our early environment and interpersonal relationships. In part, there are predetermined sequences of development in childhood, including windows of opportunity for laying down the basic hardware necessary for later learning. Such opportunities are why new languages, as well as the arts, ought to be introduced to children very early in life.

Babies are tuned to speech from birth (perhaps even before). "Proper" language starts in the second year with the activation of Wernicke's area and Broca's area[59] (see Sound section). Language comes naturally to children - provided they are exposed to it during infancy. But if they are deprived of the sound of speech, their brains may be physically disordered. All babies are born with the potential to speak any language and many languages, but if they are only exposed to a single tongue their options soon narrow because the neurological wiring needed to distinguish sounds atrophies if it is not stimulated in the first two years of life. Therefore, people who learn foreign languages as adults rarely speak them without an accent.[60] Indeed, second languages (learned later in life with much greater difficulty and poorer results) are processed in a different section of the language area than the mother tongue[61].

Whether you want to call it a bioprogramme or a Universal Grammar, learning the hardest aspects of language seems to be made easier by a childhood acquisitiveness that has a biological basis (like learning to walk upright). Perhaps this acquisitiveness looks for intricate patterns in sound and sight and learns to mimic them. In many ways, this pattern-seeking bioprogramme looks like an important underpinning for human levels of intelligence[62].

This is supported by the fact that all people, from birth, also engage in a kind of scientific thinking. Natural selection shaped man to be intuitive physicists, biologists, engineers, psychologists, and mathematicians so that he could master his local environment[63]. However, it is important to distinguish these intuitive abilities from the modern, academic disciplines that most people find so hard to understand and learn.

For example, formal mathematics is an extension of the mathematical intuitions expresses by one week-old babies, who are aware when a scene changes from two to three items, or vice versa. Arithmetic grew out of our sense of number, and geometry out of our sense of shape and space. But, to assert that academic mathematics follows from our intuitive mathematics does not say that it follows easily.

According to psychologist George Miller, 'The crowning intellectual accomplishment of the brain is the real world.... All the fundamental aspects of the real world of our experience are adaptive interpretations of the really real world of physics'. Many cognitive scientists agree that the mind is

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[58]Darling, DJ.; 'Zen Physics: The Sense of Death, the Logic of Reincarnation'. New York: Harper Collins, p 18, 1996.

[59]Carter, R.; "Mapping the mind". Phoenix, Pp254-8, 1998.

[60]Oliver Sacks; 'Seeing Voices'

[61]Kim, KHS, et al; "Distinct cortical areas associated with native and second languages", letter to nature, 388: 6538 (1997), 171.

[62]Calvin, WH.; "How brains think". Basic Books, p74, 1996.

[63]Pinker, S.; "How the Mind Works". Penguin, p299-360, 1997.

equipped with innate intuitive modules which represent major ways of understanding the world. There are modules for objects and forces, for animate beings, for artefacts, for minds, and for natural kinds like animals, plants, and minerals. Although these different ways of knowing are innate, this does NOT mean that knowledge is innate. The concepts of innate modules help explain learning, they cannot minimise it. Beyond simply capturing experiences, learning requires a system for recording our experiences so that they generalise in useful ways.

3.9.2 How do we learn

Learning is what the human brain does best. Scientists are unsure precisely *how* this happens, but they have some ideas of *what* happens[64].

To our brain, we are either doing something we already know how to do or we are doing something new (i.e. learning). Doing what we already know how to do is merely exercise, whilst doing something new is *stimulation*. As long as it is coherent, this novel mental or motor stimulation produces greater beneficial electrical energy than repetitive exercise. This input is converted to nervous impulses which travel to extraction and sorting stations like the thalamus, located in the middle of the brain. In intentional behaviour, a multisensory convergence takes place and a ‘map’ is quickly formed in the hippocampus[65]. From there, signals are distributed to specific areas of the brain (see Memory section).

Once this input is received, each neuron transmits an electro-chemical impulse (powered by the difference in concentration of sodium and potassium ions across the cell membrane), and resultant voltage changes stimulate the demand for dendritic growth. The process is repeated, via the synapse, to the next neuron, and so on. Eventually, the repeated electrical stimulation fosters neuron growth by way of dendritic branching. These branches lead to even more connections until, in some cases, whole, dedicated ‘neural forests’ help us understand better and, maybe someday, make us an expert in that topic. Hence, new dendrites and synapses usually appear in the effected parts of the cortex after quality learning.

Learning and memory are two sides of a coin to neuroscientists - i.e. the only evidence of learning is memory. Lasting learning, or long-term potentiation (LTP), has long been accepted as essential to the actual physical process of learning. Since its discovery in 1973 by Bliss and Lomo, countless experiments have defined its intricacies. Neurons change their receptivity to messages based on previous stimulation, i.e. the neurons have ‘learned’ and changed their behaviour. In short, our learning is achieved through the development of new dendrites and synapses, and the alteration of synaptic efficacy.

The daily chemistry of our brain adds great complexity to the question, ‘how does our brain learn?’. Neurotransmitters (e.g. glutamate, GABA,..) act as ‘cellular phones’ offering specific communications between synapses, whereas the other chemicals (e.g. serotonin, dopamine, noradrenaline, ..) act more like ‘loud speakers’ that can broadcast to wide areas of the brain. The latter produce observable behaviours such as attention, stress, or drowsiness. In short, learning happens on many complex levels simultaneously.

3.9.3 Improving learning and intelligence

The end result of learning for humans is intelligence. The key to getting smarter is not having a bigger brain or more brain cells per cc., but is growing more dendrites and synaptic connections between

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[64]Jensen, E.; “Teaching with the brain in mind”. Association for Supervision and Curriculum Development (ASCD) Publications, pp13-16, 1998.

[65]Freeman, W; ‘Societies of Brains’. Hillsdale, NJ.: Lawrence Erlbaum and Associates, 1995.

neurons as well as not losing existing connections. It is these connections that enable us to solve problems and figure things out (i.e. act intelligently and learn).

The brain is 'plastic', which means that much of its hard wiring can be changed by an individual's experiences. Research shows that complex learning is enhanced by challenge and inhibited by threat. The mind learns optimally when it is appropriately challenged in an environment that encourages taking risks. Under these circumstances, rat brains make maximum connections in the areas where learning is taking place by their neurons growing large numbers of new dendrites and synapses within a few hours (see Figure 19). Conversely, the mind appears to 'down-shifts' under perceived threat. Under threat, rat brains reduce connections by their neurons losing significant numbers of dendrites and synapses within a few days. The mind then becomes less flexible and reverts to primitive attitudes and procedures. Low threat, however, is NOT synonymous with simply 'feeling good'. The essential element of perceived threat is a feeling of helplessness or fatigue. Occasional stress and anxiety are inevitable and are to be expected in genuine learning. The reason is that genuine learning involves changes that lead to a reorganisation of the self. Such learning can be intrinsically stressful, irrespective of the skill of, and support offered by, a teacher.

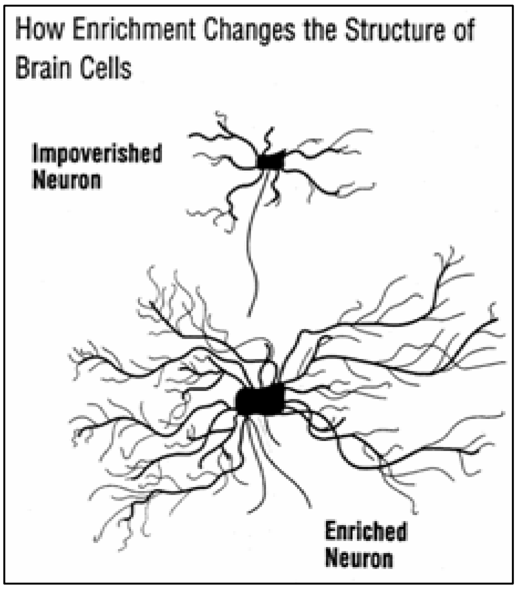

Figure 19: Enrichment grows dendrites and increases connections

Although each of our 100 billion neurons ordinarily connects with between 1,000 and 10,000 other neurons, theoretically, they could connect with far more. Hobson has calculated that a normal brain could be capable of processing as much as 10^{27} bits of data per second[66]. Some estimate that we use much less than 1% of our brain's projected processing capacity. Whatever the case, the brain's architecture has the inherent capacity for every individual to significantly increase their intelligence!

3.9.4 Individuals, society and the learning process

Learning is significantly influenced by the nature of the society within which people are existing. Vygotsky emphasised the social construction of knowledge[67], and it is now generally accepted that throughout our lives, our minds change in response to engagement with others. Hence, individuals, their identities and their learning, should be seen to be integral parts of larger social systems.

But every individual's mind inherits the lifelong drive to 'search for meaning' (i.e. the passion to learn). This search for meaning tries to make sense of our experiences, is survival oriented, and at its core, is driven by the individual's purposes and values. The range of human purposes and values, and their strong relationship to differing social systems was discussed by Maslow[68]. Thus, the search for meaning ranges from the need to eat and find safety, through the development of relationships and a sense of identity, to an exploration of our potential and the quest for transcendence[69].

[66]Hobson, JA.; 'Chemistry of Conscious States'. Boston, Mass.: Little, Brown and Co.. 1994.

[67]Vygotsky, LS.; 'Mind in Society'. Cambridge, Mass: Harvard University Press, 1978.

[68]Maslow, AH.; 'Toward a Psychology of Being'. 2nd ed. New York: D Van Nostrand Company, 1968.

[69]Caine, RN. & Caine, G.; "Education on the Edge of possibility". ASCD Publications, pp104-8, 1997.

Most societies place a high value on learning. Yet their emphasis is on ‘measurable’ results, whilst the crucial, but more complex processes of learning tend to be down-played. What ensures our survival is using our highly effective and adaptive minds to adapt and create options. Humans have survived for thousands of years by trying out new things, usually in small groups, NOT by always getting the ‘right’, tried-and-true answer - that’s not healthy for growing a smart, adaptive mind.

This raises important questions regarding the appropriateness of a variety of combinations of individual or group learning in independent or interactive modes:

- When is independent learning most effective (just the learner and the learning material)?
- When is individual tutoring most effective (just the learner, the tutor, and the learning material)?
- When is group learning most effective (small groups (2 - 5) of learners actively interacting with each other, the learning material, and perhaps a tutor/facilitator)?
- When is classroom/lecture theatre instruction most effective (large groups (15 - 400) of learners passively being instructed by a single teacher/lecturer)?

4 The Global Approach to Teaching and Learning

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4.1 Summary

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

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

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

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

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

in the developed world, are even more needed in Africa. These materials must not be imported, but must be locally produced to address the wide range of learning needs of Africa's excluded majority taking full account of the local literacy, language and cultural issues.

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

4.2 The Need for Fundamental Change

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

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

However, the recent emergence of neuroscience, an exciting interdisciplinary approach to non-invasive brain research, is providing an ever growing wealth of major insights which are challenging many conventional educational beliefs, most of which have been entrenched in the current 'factory model'. Brain scanning devices like functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) enable us to analyse the living human brain whilst its owner was carrying out a wide variety of cognitive activities, including learning. During the '90s, (the decade of the brain), interdisciplinary brain research involved a growing number of sub-disciplines, e.g.: genetics, physics, and pharmacology[70].

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

4.2.1 Improving teaching and learning

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

In a rapidly changing society, we cannot teach people all the facts they will need to know in their lifetime. But we can teach them how to assess their knowledge state, how to find out things for

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

themselves, and how to evaluate conflicting sources of information. The emphasis in modern learning must move from the memorisation of facts to the acquisition of cognitive skills - thinking, learning, and reasoning. Once the focus shifts, the learner's understanding (or theory) of mind becomes important[71]. Modern pedagogy is adopting the view that learners should be aware of their own thought processes, and that it is crucial for the pedagogical theorist and teacher alike to help them become more metacognitive - to be as aware of how they learn and think as they are about the study material[72]. Researchers have made strong claims regarding the importance of 'theory of mind' development for learning.

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

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

- Learners construct understanding for themselves.
- To understand is to know relationships.
- Knowing relationships depends on having prior knowledge [73].

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

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

Enriched learning environments need to be created that involve learners in a variety of inquiries within *rich content contexts*, thus increasing the likelihood that knowledge and thinking capabilities will be improved. Whenever bits of information are isolated from these rich contexts, they are usually forgotten and become inaccessible to memory[74]. Because the mind resists having meaninglessness imposed on it, effective education must give learners an opportunity to formulate their own contextualised patterns of understanding.

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

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

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

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

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

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

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

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

Complex learning is enhanced by challenge and inhibited by threat.

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

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

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

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

We need to know a great deal more about the innate component of each human ability, and the most appropriate stage in the development of the brain for it to be built upon and mastered. And we need to *take notice of what is already known*. For example, the dominant technique in American reading instruction, called 'whole language', is based on the erroneous deduction that since spoken language is a naturally developing human instinct, so is *reading*. As explained in section 1, reading is NOT innate, and must be taught via the 'old fashioned' method of practice at connecting letters to sounds. Instead, children are immersed in a text-rich social environment to encourage the innate ability of reading to manifest itself. But the children simply don't learn to read![75] Understanding how the mind learns does not eliminate hard work and practice, but should ensure that they are used only when appropriate (and they can still be fun).

4.2.2 Improving memory and retrieval

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

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

experience better recall. Therefore, educators have an obligation to share with learners a better understanding of memory, and the related retrieval strategies[76].

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

4.2.3 Explicit/Declarative memory strategies:

Semantic memory

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

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

- Novelty is known to improve recall dramatically.
- Semantic memory particularly needs time for quiet processing and reflection, otherwise little is transferred to long-term memory. Keeping 'chunks' to a minimum helps the working memory.
- Mind-maps and other graphic organisers have established significant value by drawing, organising, or symbolising key points.
- More visually effective contexts have high impact, e.g. illustrations featuring strong colours; cartoon-like story-boards of key ideas.
- Studies show that analysis of semantic material, particularly in group discussions, aids its recall[77].
- Recall improves when material is repeatedly reorganised and reviewed from various points of view.

Episodic memory

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

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

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

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

4.2.4 Implicit memory strategies

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

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

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

4.2.5 Improving working memory

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

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

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

4.3 The Role of Text

We have seen how complex a challenge it is for the human mind to detect and interpret language, and that it is still in the process of evolving to best cope with this valuable emerging unique human ability. Reading is very more recent, and much more of a processing challenge. However, seeing, and identifying the code (letters and words) that make up written language are far from being a challenge to our visual perception (we have shown how the further interpretation and processing of the visually detected code happens in the language centres, not the visual cortex). Employing the amazing power of our primary sense organ (almost 50% of the cerebral cortex) for hours to detect this small selection of stationary, repetitive, symbols is not like using a Rolls Royce to fetch food from the corner store. Worse, it is like repeatedly using an articulated lorry to fetch food from the corner store, bringing back just a few items at a time (due to the sequential nature of text). Some claim that 'speed-reading' utilises more of our visual power, but many who attempt to acquire this skill fail, whilst there is little sign of it being taught in primary schools.

So how and why did text acquire this dominant role in our lives? Cultural critic Marshall McLuhan points to Gutenberg's invention of movable type as the force behind a vast array of cultural effects. His major message was that societies and cultures are more shaped by the nature of their communication media, than by the content. According to John Culkin, one of Marshal McLuhan's major interpreters[78],

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

Certainly, the alphabet, text, and Gutenberg's movable type must rank amongst man's most impressive and important achievements. But a wonderful tool appears to have become a tyrannical master for the majority of the people on the planet. Is the problem with text, or with the ways society has grown to use it? Horn argues that the current split and imbalance between using words and using images (exemplified in the education system) parallels a historical split[79]. Just after the invention of the Phoenician alphabet, words and images (artistic pictures, sculptures, and drawings) began to take separate routes, becoming separate forms of communication. Each had its own vocabulary and syntax, each its own tools and concepts. Each had its own master craftsmen and teachers, each its own department in the university. Even in the elementary grades, teachers specialised in one subject or the other, seldom both. In school, everybody knew that you were either a word person or a picture person. It was all part of the great either/or division that our societies have relied upon for millennia.

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

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

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

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

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

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

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

How serious a problem is 'text-o-phobia' in the developed world, where almost everyone is taught to read early in life, and has the opportunity to access a wide range of material in their natural language(s)? We can't answer this question with unequivocal statistics, since 'text-o-phobia' is not a recognised condition, but there are some strong pointers. Why does *Functional Illiteracy* remain a major problem in the developed world? As the World's most affluent society, the USA has been pumping $ billions into its education system for decades. Yet, according to Manuel Castells, over 40 million adults in the USA in 1997 (>25% of the adult population) had 'blatantly insufficient levels of reading and writing in English, as well as of elementary arithmetic'[80].

The importance of literacy and higher levels of language skills in modern society can hardly be exaggerated. People are judged on how they write and speak and, as we have seen, nearly all academic teaching is dominated by language ('text-and-tell'). Therefore, since it has become such a fundamental, cross-cutting tool, anyone who is not 100% proficient in reading and writing is likely to be seen as deficient across a whole range of skills[81].

How many people in modern developed societies are "100% proficient in reading and writing"? At the other extreme are people with dyslexia, who have a history of being severely discriminated against, and treated as if having little intelligence. Dyslexia takes many different forms and probably has many different causes. However, PET brain scans of dyslexic people doing word tasks have shown that, unlike in non-dyslexic people, their language processing areas fail to work in concert, so the incoming words get jumbled up and disjointed. The insula (the deep infold that lies between the language areas, and which appears to orchestrate their activity in non-dyslexic people) did not fire and each language area was activated singly.[82] It must be stressed that this dysfunction of a small area of the brain is NOT an inherited flaw, but a failure to fully develop an unnatural skill.

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

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

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

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

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

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

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

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

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

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

4.4 The Role of Technology

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

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

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

4.4.1 Using technology in existing learning environments

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

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

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

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

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

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

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

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

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

4.4.2 Using technology to create new learning material

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.5 Teaching and Learning in the Developing World

This article has not yet differentiated between education in the developed and developing worlds. The intention has been to emphasise that there is a *global* crisis in education, what the fundamental causes of that crisis are, and where the solutions lie. We educationalists have been doing the wrong things for too long. The good news is that, at least in the developed world, we have all the resources and capabilities to implement the solutions. If the USA could mobilise itself between 1962 and '69 to reach the moon, surely the world can mobilise itself along the above lines to achieve UNESCO's 'Education for All'[83] within a decade or two. Who will argue that EFA is less important than reaching the moon?

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

4.5.1 Status of 'formal education' in the developing world

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

The essence of UNESCO's "Education for All" challenge is to work towards the eradication of abject poverty throughout the world. The global tertiary sector, combined with their traditional values concerning the well-being of society, should be ideally positioned to address this. However, today's universities are faced with the perplexing task of balancing the tensions of Sir John Daniel's eternal triangle, i.e. to improve quality, cut their costs and to serve more and more students[84].

Global access to tertiary education has grown from 6.5 million enrolments in 1950 to 88.2 million in 1997, growth of more than 1200%. Although this growth appears remarkable, the global education crisis has deepened. In 1995 a little more than half of the world's tertiary students (47 million) lived in the developing world, with a gross enrolment ratio mostly below 15%. However, the average for Sub-Saharan Africa remains less than 4%. Saint[85] points out that at least 16 countries in Sub-Saharan Africa will need to double current tertiary enrolment in the coming decade just to maintain the existing and unacceptably low gross enrolment ratio.

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

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

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

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

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

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

The distinguishing pedagogical feature of higher education (HE) massification (e.g. the mega-universities) is that, instead of giving individual faculty the responsibility for teaching, sophisticated learning systems have been developed based on innovative divisions of labour where the responsibility for teaching is carried collectively by the organization. The differentiating feature of mass provision via open learning systems is that the institution teaches, not the individual teacher. By replacing the traditional lecturer model with a total teaching system where the functions of teaching are divided into a range of specializations, HE massification is able to scale up the delivery of quality teaching to levels that simply are not possible in conventional campus-based or dual-mode models.[86]"

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

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

4.5.2 New learning materials for Africa

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

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

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

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

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

Can importing and customising do anything other than increase the developed world dependency of the African elites whilst leaving the poor and remote majority even further behind? Manuel Castells argues that this process has stimulated the emergence of the ‘Fourth World’ made up of multiple ‘black holes’ of social exclusion, and including most of Sub-Saharan Africa. He warns that *“The rise of the Fourth World is inseparable from the rise of informational, global capitalism”*, and identifies illiteracy as a primary global cause of unemployability, poverty and social exclusion[87].

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

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

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

[87]Castells, M.; ‘The Information Age: Economy, Society, and Culture’; vol. 3, “End of Millennium”, Blackwell, pp70-165, 1998.

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

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

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

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

5 Comparison of and characteristics of educational multi-media

Jacques Hugo. Usability Sciences. Pretoria. South Africa. . Usability and design expert.

This report forms part of an evaluation of the comparative advantages of applying multimedia and three-dimensional (3D) visualisation tools to interactive training applications for learning and community development in Africa. The purpose of this section is to summarise the key characteristics of learners and mediated learning scenarios, with special reference to the potential role of Interactive 3D Visualisation and Virtual Reality. These technologies are compared to:

- Traditional methods such as classroom training and self-study using media like text, broadcast video and audio, and so on
- A range of other computer-based approaches

The document also identifies the learning areas in which visually interactive applications could have a comparative advantage over other learning methods

5.1 Principles of Adult Learning

5.1.1 Andragogy versus Pedagogy

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 parent, educator, citizen or worker. There are important inherent differences in the way adults learn and this requires that they be treated differently from children.

The differences are best described by comparing Andragogy with Pedagogy (see table below).
The adult is more than just a grown-up child. As shown in the table, the adult learner has certain unique characteristics that require teaching principles and techniques that will exploit these characteristics.

Table 4: Pedagogy versus Andragogy

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 a next level)	Experiences a need to handle an actual life situation more effectively
Learning orientation	Subject-centred orientation to learning Must learns 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

5.2 Didactic principles

An understanding of the basic didactic principles can serve as a guideline for instructors in preparation as well as teaching a course. The emphasis is on what the trainee assimilates, and not on what the instructor conveys to the trainee.

This also indicates that in adult learning the emphasis is on LEARNING and not TEACHING. This means that as a Facilitator the primary job of the instructor is to create the conditions necessary to enable the trainee to LEARN.

The following section will explain the ten basic didactic principles:

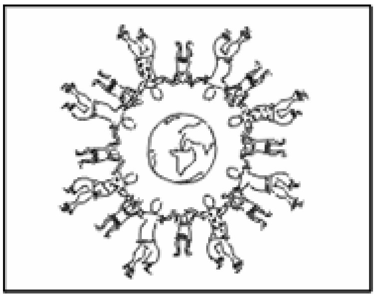
1. Totality principle
2. Individualisation principle
3. Motivation principle
4. Visualisation principle
5. Goal-directed principle
6. Activity principle
7. Psychological principle
8. Socialisation principle
9. Development principle
10. Communication principle

5.2.1 Totality Principle

This relates to the familiar Gestalt principle in Psychology - an emphasis on studying the human being as a whole.

Application

1. The human as a unit placed in the total surrounding
2. The instructor and trainee are involved in totality - i.e. whole personality
3. Learning process occurs as part of a bigger whole
4. Unitary learning occurs, as opposed to fragmentary or partial learning
5. This is the foundation of systematic education

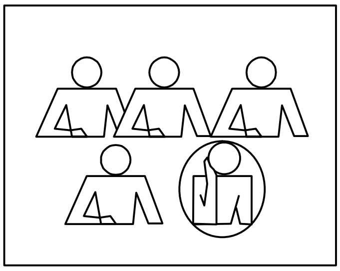


5.2.2 Individualisation Principle

For example, in one-to-one learning situations, the trainee is treated as an individual.

Application

1. Every trainee learns at his or her own tempo
2. Where appropriate, the training style and content must make provision for principle
3. Typical scenarios:
   (a) Individualised training, for example computer-based training
   (b) Enrichment for gifted trainees
   (c) Project work
   (d) Grouping according to ability



5.2.3 Motivation Principle

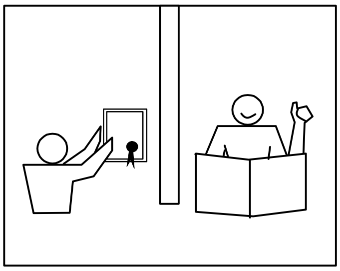
Application

Motivation can arise from four possible sources:

1. **Extrinsic motivation**: this is what the learner receives (or expects to receive) from outside, for example a certificate or trophy.

2. **Intrinsic motivation**: the way the learning material or learning situation motivates the trainee. This usually leads to spontaneous interest in learning which reinforces learning.

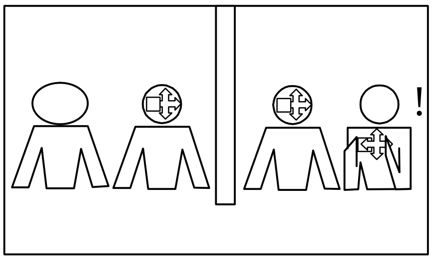
3. **The instructor**:
   (a) Must stimulate a desire to learn.
   (b) Instructor must be aware of learner's values and needs.
   (c) Must enable trainees to **apply** the material.
   (d) Must ensure that the trainee **understands**.
   (e) Must show interest in the trainee.



4. **Manner of motivation**:
   (a) Create a need for something.
   (b) Link new goals to previous learning.
   (c) Learning **causes** learning.
   (d) The trainee must experience progress.
   (e) Variety cultivates interest ("variety is the spice of life…").
   (f) Employ higher order learning processes - challenges, problems

5.2.4 Visualisation principle

All education should have visualisation (and therefore visibility of concepts) as a basic point of departure.



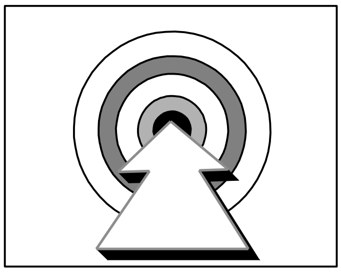
Application

1. This principle is implicit in perception of the external environment by means of the senses and subsequently the internal processing of information gained in the process.
2. Direct observation by means of audiovisual aids
3. Promotion of realism in training

5.2.5 Goal-directed Principle

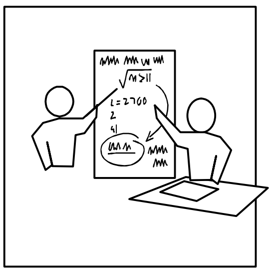
This principle means that every learning activity should have an immediate and ultimate purpose.

Application



1. Clear objectives are essential and must be defined in an unambiguous manner. The instructor must indicate the required standards and circumstances for achievement of goals. (*If you don't know where are going, you are bound to end up somewhere else*).
2. Must provide direction for the trainee.
3. Must provide direction for the instructor.
4. Must provide a measure for evaluation.

5.2.6 Activity Principle



This means active participation and involvement in the learning process.

Application

1. It is essential for motivation and achievement of objectives.
2. It entails active participation.
3. Issues in learning activity:
   (a) Learning activities promote retention, which is influenced by

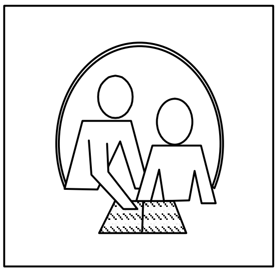
mental activity:
- You remember 10% of what you read,
- 20% of what you hear,
- 30% of what you see,
- 50% of what you hear and see,
- 70% of what you say,
- 90% of what you see and say, while doing it.

(b) Trainee activity must be part of the lesson!
(c) Group discussions and demonstrations stimulate the trainee
(d) Activity means self-activity

5.2.7 Psychological Principle

This principle refers to the psychological climate between the instructor and trainee that results from, for example, the trainee's need for psychological support.

Application

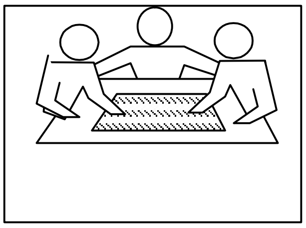


1. This usually manifests in the mutual understanding and respect between trainee and instructor.
2. It should also be evident in the instructor's respect for the learning material.
3. The instructor must be sensitive to the changing climate, for example when trainees stop thinking for themselves and become overly dependent on the instructor for direction.

5.2.8 Socialisation Principle

This principle deals with social acceptance and conformance.

Application

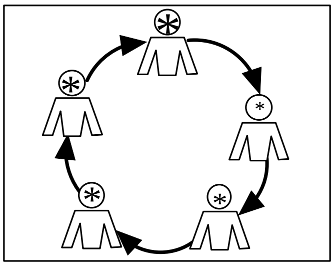


1. Trainees want to be socially accepted in the group.
2. The instructor must recognise the influence of the group on individuals.
3. This is obviously a potential problem with distance tuition, especially for trainees who are dependent on group support).

5.2.9 Development Principle

Everything in life is a process, and especially learning and the assimilation of information.

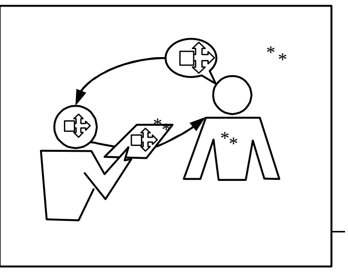
Application



1. Learning material must be **deployed** for trainees.
2. Learning material must be structured:
3. From the simple to the complex,
4. From the known to the unknown,
5. From concrete to abstract
6. This principle is directly applicable in systematic methods of training like computer-based training.

5.2.10 Communication Principle

This principle deals with the process of communication between a communicator (for example an instructor) and an intended receiver (for example a trainee). It is the universal and constant process of attempting to acquire meaning and understanding from messages perceived by the senses - auditory (hearing), visual (sight), haptic (touch), olfactory (smell) or gustatory (taste). This principle is the basis of all organised training and one might even say that training is nothing but good communication.



Application

1. The **needs** of the receiver must be clearly identified.
2. The message must be **concise** and **unambiguous**.
3. The goal is to satisfy a communication requirement - both instructor and trainee must know what they **want to achieve**.
4. The communication must be aimed at a **specific** target.
5. The communicator must have the **skills** required to successfully construct and deliver the message.
6. The **circumstances** and **timing** must be chosen with care.
7. All communication must be **structured**.
8. Provision must be made for the necessary **variety** to ensure that the receiver's interest is stimulated.
9. The most appropriate communication **medium** must be chosen.
10. The communicator must arrange for **feedback**.
11. The success of delivery of the communication must be **evaluated**.

5.3 Characteristics of adult learners

In addition to the andragogic principles described above, the instructor should also be aware of the general characteristics of the adult, especially those characteristics that relate to the constant pressure to obey social and cultural demands, conventions, expectations and norms:

1. **Know their duties and responsibilities and obey them**. The adult has certain rights (for example remuneration, fair trial, etc.), but must also play their part by accepting their responsibilities and keep their promises.
2. **Not only Inquiring, but also Accountable**. The questions asked and the demands made, must occur with fairness. They must also be able to take responsibility without being pedantic.
3. **Accept themselves fully and are prepared to make something from what was given to them**. They may not have any say in matters like their birth or physique, but they accept their shortcomings and try to develop their talents.
4. **Have self respect and also regard for the mystery of others**. Self respect (e.g. with regard to language, sobriety, integrity and chastity) are their must valuable possessions, but they also respect the dignity of others as unique human beings.
5. **Can make a moral judgement of themselves and others**. They must be able to apply criteria and norms impartially and to subjugate their interests to those of the group.
6. **Conquer the freedom that they desire so that they can live in service of it**. Real freedom is also the highest and most sublime bondage. A human being is free only when he is bound to the highest norms.
7. **Are aware of their fallibility and incompleteness**. The pre-adult is inclined to assert that everybody but he is guilty. The mature adult is humble and grateful and realises that everybody bears the guilt for something.
8. **Provide proof of their ability to handle crisis and marginal situations**. For example, they are prepared to accept the death of a beloved or a terminal illness and integrate it meaningfully into their lives.
9. **Demonstrate a consistency of value preferences, choice and direction**. They know what they want to achieve and set their own standards for what is "good enough".
10. **They are independent in their dependency**. Although they have achieved a large measure of independence, they still remain dependent on others. They like an adult to support them, but are prepared to provide support to others, like a child or other dependents.

5.4 Visual Communication and Visual Literacy

5.4.1 The power of visual communication

Visual communication is the product of a complex human intelligence that is very poorly understood. It is generally accepted that a human being is dependent on vision for most of his information. It is thus a paradox that so little is known about visual communication. In a society that is overwhelmed by technology and the mass of complex visual messages that it generates daily, it is so much more important to understand the nature and characteristics of visual communication.

Visual communication has the ability, through symbolism, to enable a person to interpret meanings hidden deep in visual images (paintings, photographs, film or television). Only visual media have the ability to give form to abstract ideas.

Vision and visual communication are more than just one-way processes where one absorbs messages like a sponge. Visual communication is a dialogical process where the way a person perceives his environment is influenced by his knowledge and experience. Vision is really the source of human language and may thus be said to be more important than verbal language - in fact, in antiquity images were first made to conjure up the appearance of something that was absent (like rock paintings of animals).

5.4.2 The origin of technology-mediated visual communication

As man developed into a more complex being, his communication activities also became more complex. With it, the mechanisms, signs, symbols and language that he uses 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 affective as possible, the communicator first has to ensure that his receiver is familiar with the visual codes used.

5.4.3 The need for visual literacy

If the receiver (whether television viewer, computer user or student) is not visually literate, he or she has to receive some form of orientation or training. Furthermore, the more complex and technologically advanced the medium is, the more complex the visual codes are likely to be and the more attention must be paid to ensuring a common knowledge of visual codes and conventions.

Probably the most important motivation for the improvement of visual literacy, is that it should promote understanding and offer a means to share information among people in such a way that the probability is increased of everybody getting the same meaning from messages.

To achieve this goal, a person should use more than just his or her natural, inborn or intuitive visual talents. It requires exposure to, and knowledge of the elements of visual communication of a particular medium, as well as the structuring and functioning of these elements in effective communication.

Only persons who have achieved a reasonable level of visual literacy, can rise above the mediocrity and artificiality of popular media messages. Only then can they take their own decisions about what is applicable, effective and aesthetically pleasing in images. Given the necessary resources and skills, a visually literate person can produce visual messages that will contribute significantly to effectiveness and understanding. Visual literacy is thus an absolute prerequisite for the fine artist, media communicator, interface designer and instructional designer.

In modern interactive, visually-intensive applications like games, computer-based training, interactive encyclopaedias and so on, instructional designers pay a lot of attention to **communicating an educational message effectively** to a learner. Clearly those designers consciously or unconsciously do the right thing - they **design for communication**. However, it is not enough to adopt a user-centred design methodology. Instructional designers should also understand that the computer is a **visual communication medium** and it is therefore imperative that they add an understanding of visual communication to their instructional armoury. Clearly instructional designers need a methodology that takes into consideration the dialogical nature of computer applications. Such a methodology would consist of a systematic analysis of users, their tasks and skills, performance criteria, information structures, coding of software, implementation and maintenance.

When the computer is used interactively, a very complex communication and learning process is set in motion. Because the design of the interface design represents the convergence of several disciplines, of which information technology is just one aspect, it is totally unlike any other communication activity. The computer is a medium that requires special skills for development of messages, whether the nature of that message is instruction, business process or entertainment. Also from the user's point of view, different perceptual skills are required to reap the full benefit of the medium.

In multicultural environments this is particularly challenging, because designers need to accommodate not just language differences, but also several cultural variables. At an individual or psychological level, culture is complex and fragmented and is an integral part of a person's psyche. People also experience culture differently and on various levels. This influences their perception, understanding, behaviour and performance in work or play. Acknowledging the influence of cultural variables will ensure optimal structuring of the interactive component of the computing system that the user is confronted with - the visual interface.

5.5 Modes of Visual Representation

There are various modes of visual representation – that is, ways to represent the object as it is perceived visually in the real world (objective reality), the abstract attributes of an object, idea or event, and the symbolic attributes of an object. A person’s visual literacy is therefore influenced by three possible attributes or levels of stimuli:

1. the object as it is perceived visually, that is, the objective reality;
2. the abstract attributes of an object, idea or event;
3. the symbolic attributes of an object;

A person's visual literacy is consequently determined by his or her knowledge and understanding of these three levels:

5.5.1 Realism

Six factors contribute to the perception of an image as realistic:

1. Recognisable scale

2. Recognisable forms, especially in terms of their brightness and clarity
3. Recognisable detail
4. Colours depicted as in the real world
5. Recognisable movement depicted, either real or suggested (that is, real-time movement, stop-frame movement or animation)
6. Perspective depicted as perceived in reality.

Note that this list is based on common “first world” behaviours and perceptions and it is important to remember that it might be valid only from a Western, or even only a Eurocentric perspective. This is why it is vital to keep the audience's frame of reference and "visual language" in mind when designing a visual message, regardless of the particular medium employed.

Is should also be pointed out that these levels of realism have a direct relationship with the characteristics and capability of certain technologies, as shown in the tables that follow.

5.5.2 Abstraction

Abstraction in visual communication manifests in the simplification or contraction of an idea into a visual representation that has little or no relationship with the objective reality. The more realistic the image, the less uncertainty there is about its meaning. Conversely, the more abstract an image, the more generic its meaning becomes. Any marginal alteration of the original, realistic image, will stylise it, such as the reduction of a picture to a basic outline.

Although the latest computer technology is sophisticated enough to allow a very high degree of visual realism, the majority of business applications are characterised by a high degree of abstraction. This is partly a historical fact because of earlier limitations of the technology. But it is also due to the fact that, as a communication medium, the computer is normally used to capture, process and distribute quantitative data. Thus it is logical that information and concepts will more often be represented in abstract images.

5.5.3 Symbolism

The development of photography has also played an important part in the development of non-figurative and non-realistic styles in art. This was the beginning of a process of abstraction where, as seen in the previous paragraph, superfluous information in images is omitted and only outstanding characteristics are emphasised. When abstraction is taken to extremes, the image or a part of it acquires symbolic meaning. Unlike icons and realistic images, with symbols there is no relationship between the appearance of a symbol and its meaning, that is, reality is no longer recognisable. A symbol now acts as a substitute for the object, event or idea symbolised. The important fact is that accurate interpretation of symbols relies on the receiver's knowledge of the sign conventions that apply in a particular community or culture. This implies that, in order to be effective, a symbol must be recognised by the majority of the community and must also be reproducible by them.

5.6 Educational Method Overview

5.6.1 Introduction

Section 5.6

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 tasks that must be performed (in others words, cognitive, affective or psychomotor) and several other factors These factors must be reconciled with the different training methods and -media with regard to their unique features and suitability for the particular topic or course. This approach is the opposite (and obviously the preferred) method of choosing a medium first and then finding a topic to use it for!

In addition, the characteristics of the subject matter expert, the training situation, the students and the performance aims of a particular system or device (that is, how the effectiveness and efficiency with which the task performed with the system or device can be measured) must also be analysed. The organisation's operational aims must therefore relate to the tasks to be performed as well as the skills needed for the task. From this the training objectives can be derived.

The following is a brief summary of the key features of the most important training methods with an indication of their advantages and disadvantages and their typical application.

Table 5: Training Methods

Training Method	Description	Advantages	Disadvantages	Suitability
Full-time Courses (Academic classroom training)	Full-time courses take place in the form of formal or academic education where, for the duration of the course, a student is in the education environment the whole time (the classroom or study centre)	The student is involved full-time in formal instructional surroundings and his progress can thus be monitored continually. The student has a continual interaction with the trainer. On account of the formal nature of the instruction, training standards are easier to maintain.	Formal and fixed instruction facilities are required. The student is removed of his working environment. Training can be expensive due to travel-and accommodation costs Low availability of expert trainers It is difficult to maintain standards between different trainers or ever a period. Trainers find it difficult to give individual attention to students. Students may not perform optimally due to the pressure	Classroom course are suitable for all types of formal training. It is also suitable for long courses that exceed 30 hours attendance.
Seminars	Seminars have a short instructional duration. Normally it is not longer than 1 day during which a comprehensive topic is presented. The advantages and disadvantages can briefly be described as follows:	Seminars are mobile and are only dependent on the availability of some of lecture room or auditorium. Because of the mobility a large audience can be reached. Because of the short duration, the time way from work is limited to a minimum. Travel time can also be reduced because of the mobility.	Due to the time limitation, the topic and interaction with students are limited, with a resultant reduction in learning and retention. It is difficult to achieve the learning objectives. No or little evaluation can be conducted	Seminars are suitable for general orientation, especially for senior staff, or presentations of particular topics or systems. The training value of a seminar is minimal and should not be employed where particular learning goals must be achieved.
Part-time courses	Part-time training is programme during which a student attends formal lectures on a part-time -basis. Lectures are presented on an ad hoc-basis after hours or within a given period in working hours. Formal lectures take place inside a classroom, although some self-study may be expected of the student. The various types of part-time courses are as follows: **After hours**	Lost working hours are reduced to a minimum. Course material can be enhanced with knowledge acquired in the working environment. Formal instruction and student evaluation is possible. Because the trainer can distribute lecture time, a large number of students can be trained.	The student must sacrifice much of his free time. No credit is normally given for such time. The training period is normally 3 times longer than a full-time course.	Part-time courses are suitable when a person cannot stay away from work for long periods to attend classes.

	This is the most common type of part-time study - lectures are presented after hours, in the evening or over weekends. The course structure is planned and compiled in the same way as a full-time course. **Part-time instruction** Part-time instruction is structured so that it enables the student to remain in his working environment. Although lectures are presented during working hours, the duration is restricted due to the intervals needed to accommodate the student's normal working day. This type course can only be successful if the training facility is close to the student's work place.			
Correspondence courses (managed self-study)	Correspondence Courses are self-contained and are presented away from the classroom. The student's progress is monitored via correspondence and any problems are solved via indirect communication with the trainer.	Loss of working hours reduced to a minimum. Course material is enhanced amplified by knowledge acquired in the work situation. Individual student progress is not dependent on progress of the class as a whole.	Because instruction happens remotely, courses are difficult to develop and demand a high degree of specialised knowledge. The student must sacrifice a lot of her free time. Normally no credit is given for such time. Distribution of learning material to and marking of students' assignments place an additional administrative burden on trainers.	On account of the high and unusual administrative burden of this method of training, it is less suitable for system training. It is also not suitable for group-oriented training (for example Management training).
On-the-job-training	On-the-job training happens inside work context. It can be formal or informal and normally focuses on an employee's ability to perform particular tasks. The training is usually structured modularly according to specific learning outcomes and performance requirements. The training responsibility is delegated to the learner's direct supervisor who is also responsible for the training standard, based on the learner's capabilities. This category is found typically in system or application training where the employee acquires expertise on the job.	Minimal working hours are lost. Learning experience is maximised by practical knowledge. Feedback is immediate, which promotes retention. Students can work at their own tempo. Learners are supported by mentors that are subject matter experts.	Training standards are difficult to maintain. The quality of work and productivity of a department can drop because of the student's inexperience. Supervisors often not held directly responsible for training. Mentors are often not trained to lead	Informal (or formal) on-the-job training, especially where it is complemented by some form of computer-based training (CBT), or is built into the system (like Task Support Systems), should be one of the most suitable methods for system- or application training.
Self-study	Self -study means a learning situation	Flexibility - Students receive	Long development times - especially	Self-study in all forms of

	where a student is personally responsible for his or her own training. There are several approaches to self-study, including programmed instruction, correspondence courses and computer-based training. This category of training is suitably for on-the-job training.	training when they are ready for it. They can study in their own time until the goal is reached. Stability - Presentation of information to different audiences stays the same. Mobility - Training takes place where classrooms are not available. Effectiveness - When it is designed properly, self-study may be just as good or better than other methods. This implies that it must be compatible with the learner's learning style. Cost Saving - Self-study methods like CBT reduce costs associated with training period, travel and accommodation and other resources. It is compatible with adult learning principles. The focus is on the learner, not up the trainer, the method or the medium.	for CBT. More difficult to maintain, revise or update, especially if the training is built-into the system. Lack of interaction with other student s and trainers. Elaborate planning required. Specialized expertise required for design and development of self-study courses. Unavailability or scarcity of specialized training facilities and equipment.	training, with particular reference to functional principles, should be must be encouraged. It especially applies to system training where computer-based facilities are available. (for CBT or Web-based courses).
Workshops	A workshop is a group of people with a special interest or problem who meet for a particular period in order to improve their individual skills, abilities and/or understanding by means of study, research and discussion.	Theory and practice are dealt with simultaneously. The learner is encouraged to grow by means of interaction with others	The learning situation is inclined to develop around the needs and interests of individuals, instead of clearly defined aims that must be verified by specialists. Learning transfer cannot be guaranteed. Evaluation is difficult.	Workshops can be very effective when it is incorporated into formal system training where learners can benefit from each other's experience and can acquire knowledge of the relationships between systems.
Games and Simulations	A game can be defined as a structured activity in which two or more participants compete within certain rules in order to achieve particular aims. Games and simulations are used in a wide range of training situations. It can be used for introductory modules or for	A simulation game can be an effective substitution for the reality, especially where the use of actual, operational equipment is very expensive and dangerous. Games motivate the learner and offer	The competing nature of a game can dominate the learning process. Development of a game or simulation can be very expensive and time-consuming. It is difficult to evaluate the learning effectiveness of instructional	Where CBT or Interactive 3D Visualisation are used as training media, simulation of parts of the application becomes mandatory. To ensure learning and practical application,

	advanced training of specialists. Such modules last from a few minutes to a few days. A simulation is an operational model where select components are used, or an actual or hypothetical process, situation, procedure, mechanism or system. The most common application is found in strategic simulations, in business simulations, or war games.	effective learning experiences without the pressure of conventional training. Games and simulations are ideal for individual training. Simulation employs models in the context from which can be learnt. Trust is consequently transferred from the simulation to the reality that it tries to model.	games.	simulations must be faithfully reproduced.
Task Support	Task Support Systems (also called “Performance-centred systems “ or "Electronic Performance Support Systems", or "EPSS") are usually found in the form of a system with integrated hypertext, hypermedia and knowledge-based systems. (Note that a task support system may be both a training method and a training medium and can therefore be included in the next section Training Media). A Task Support System may be comprised of a large number of components, e.g.: o Application software, the main component of the user system o Traditional databases, numeric data, graphics and other data. o Text database -"on-line" documentation. o Visual databases - libraries of images, diagrams, graphics, maps and video that can serve as examples and models, etc. o Audio databases of sound, verbal sequences and music. o Information services (Internet, chatrooms, web sites etc.) o Productivity software - spreadsheets, word processor, etc. o Knowledge-based systems and	The need for training is reduced or changed dramatically. General productivity increases. The focus of training responsibility shifts from the training administrator to the individual. The availability of a task support system increases the alternatives for task-oriented programs: the system can be used for training simulation, practical exercises, etc. To the extent that the facilities of such a system represent the complete scope and complexity of the task, task competence can therefore be achieved within an informal training programme on the job. Especially inexperienced employees can thus tackle more complex tasks.	Current organisation structures, policy and skills are not in line with the use of advanced task aids. Current skills and knowledge with regard to management, training, computer science and system operation are fragmented and distributed across organisation boundaries. The multi-disciplinary nature of task support systems makes their implementation so much more difficult. It is difficult to determine development cost and time in advance. Development methodologies for computer systems do not normally include integration of training facilities and experience with such systems is still lacking among instructional designers.	The integrated nature of modern programs indicate that task support systems may be the ideal solution for the information and training needs of system users. This assumption is supported by three conditions: The availability of technology - each user has immediate access to a workstation with the ability to supply the necessary information, training and support. The technology has the potential to raise productivity. There is enough proof that current conventional training methods and media are not adequate and do not sufficiently leverage the user's performance to satisfy the changing operational needs.

	intelligent task aids. o Help facilities that are initiated by the system, context-sensitively, and query-based. It included explanations, demonstrations and alternatives. o Interactive tutorials - CBT or multimedia. o Evaluation systems - evaluation of knowledge and skills both before task performance and evaluation of competence. o Feedback and monitoring systems that inform users about the suitability of their actions (error messages and instructions) o Consistent user interfaces that offer user-defined access to all the above-mentioned components.			

5.7 Compatibility of training methods and media

When the methods shown above are mapped to the various compatible educational media, the following matrix is produced:

Table 6: Training Methods versus Media Types

Training methods	Computer-based training	Books	Models	Video	Multimedia	Low-fidelity simulations§	High-fidelity simulations¥
Classroom courses	O	X	X	X	/	O	O
Seminars	/	X	/	X	/	/	/
Part-time courses	X	X	O	X	/	/	/
Correspondence	/	X	/	X	/	/	/
On-the-job training	X	X	X	X	X	X	X
Self-study	X	X	O	X	/	/	/
On-line (e-Learning)	X	X	O	X	X	X	/
Workshops	O	X	O	X	/	O	O
Simulations/Games	X	/	X	O	O	X	X
Task Support Systems	X	/	/	O	X	/	O

KEY – Compatibility with training method:

X = fully compatible

/ = partly compatible

O = not compatible

§ Includes low-fidelity 3D visualisation

¥ Includes high fidelity 3D visualisation

5.8 Educational Media Overview

An education or training medium is understood to mean the device or system used to encode the content and the message and to present it to the learner by means of auditory or visual representations. The auditory component may consist of spoken content or of sounds representing the characteristics of the subject matter (for example sound effects). The visual component may consist of textual or graphic representations. The latter category can be depicted in taxonomy as follows:

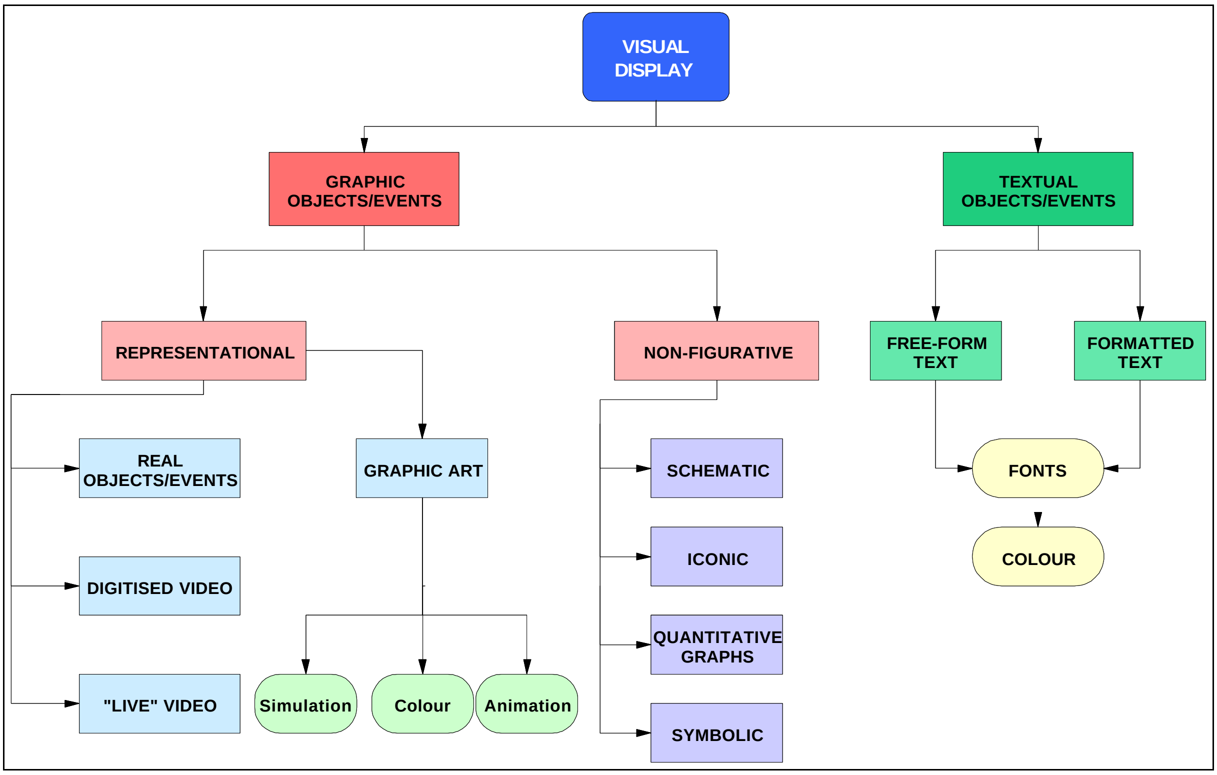


Figure 3: Taxonomy of visual communication

A large variety of educational media can be grouped into "Conventional" media and "Computer-based" media. This is an oversimplification of course, but should suffice for the purpose of this document.

5.8.1 Media characteristics

The key characteristics of the media can be summarised as follows:

Animations

- highlight specific details
- show action
- demonstrate processes
- gain and focus attention on particular images

Charts

- show relationships
- show percentages of the whole
- compare data

Images

- present information that cannot be described adequately with words and that does not involve motion
- highlight specific details

- provide navigation
- create a consistent look
- gain or focus attention
- show realism
- provide historical or cultural context
- show relationship between ideas and concepts that do not require a linear model for learning

Sounds

- information that needs to be heard to give it more credibility or because the audience must know the sound itself
- provide historical context (e.g., recorded speeches)
- supplement or reinforce information
- present text to reading and visually impaired students
- present information to auditory learners
- hear other foreign language speakers' accents
- create a mood
- place other information in context (e.g., music from a time period being studied)

Text

- present information that is verbal and has no visual component
- detail specific steps
- reinforce concepts
- present abstract arguments

Videos

- present visual information that involves movement
- suggest realism
- show gestures
- generate excitement
- trigger group discussions
- provide lectures for student review

5.8.2 Conventional media

Conventional educational media include the following:

- Classroom training/learning media – in this traditional setting one or more conventional media might be employed:
  (a) Text – handwritten, textbooks, posters, etc.
  (b) Video – taped subject matter, live educational broadcasts, or interactive television
  (c) Audio –lessons and subject matter on audio tape, CD-ROM

5.8.3 Computer-based media

- **Computer-based training** (CBT) – this usually employs multimedia or hypermedia (audio, graphics, animation) in an interactive system that allows structured or unstructured criterion-based learning.
- **Simulations/Games** – this can range from simple educational games to complex business, industrial or environmental simulations. This method is often dependent with advanced technology and is usually associated with visually-intensive subject matter.
- **Task Support Systems** – this is usually found in task environments characterised by complex decision-making or where there is a need to optimise productivity and minimise human error.
- **On-line (e-Learning)** – this is web-based learning and can be either self-study, or a component of classroom learning, part-time training or on-the-job training.
- **Interactive Three-Dimensional Visualisation (I3DV**) – this can generally be described as the generation and manipulation of 3D graphics by user interaction. The key term is *interactive* which is used to describe a system where the user can display data and perform some manipulations like

rotation, zooming, changing colours and light properties, etc. These manipulations however are all on the visualisation, not on the data itself.

- **Virtual Reality (VR)** – This medium can be defined as a high-end user interface that involves real time simulation and interactions through multiple sensory channels. The design and development of a VR system attempts to put the human in the centre of the system, so that the machine adapts to the human, and not the human to the machine. The characteristics and role of VR are discussed under a separate heading below.

5.9 Virtual Reality and Interactive Three-Dimensional Visualisation

For the purpose of this overview it is necessary to make a distinction between VR and I3DV. This distinction is based on the level of fidelity (realism) and the level of immersion, as described below, coupled with the level of interactivity offered by a specific technology or program. When the user or learner can interact with the virtual environment on the computer screen only without the need for head-mounted displays and other more or less sophisticated hardware, it can be described as I3DV. When effective visualisation and interaction requires the user to become ”immersed” in the virtual environment to such an extent that multidimensional manipulation requires the use of head-mounted displays, data gloves, body suits and other position-tracking devices, the system can be called Virtual Reality. Note however that the basic techniques and technology are essentially the same in both types.

Definition

The simple definition of Virtual Reality is an effect that exists but is not real. In practice, virtual reality has been implemented with varying degrees of success using advanced computing hardware and software. The most frequently used examples of computer-mediated virtual reality include flight simulators used by the military, simulation of complex real-world environments, and for entertainment purposes on home computers. The effect is one of moving inside the simulated environment, and manipulating the simulated controls, even though they do not really exist. Technologies that create the VR effect include audio and video transmitters, head-mounted displays, computer drivers, and various other peripherals such as gloves, body suits with sensors, position trackers, etc

.

The effect of virtual reality can be defined by two dimensions. The first dimension involves how good the overall system is at creating the virtual environment. Crandall and Wallace[88] call this the *Immersion* dimension. The second dimension involves how easy it is for a user to interact and move around within the virtual system. Crandall and Wallace call this the *Navigation* dimension. How virtual a system is, is a function of the combination of the *Immersion* and *Navigation* dimensions, as shown in the following figure:

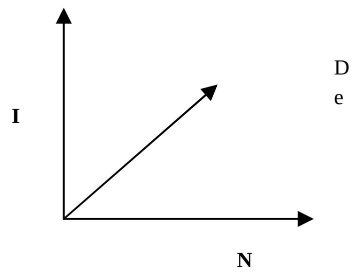


Figure 4: The VR Dimensions

Adapted from Crandall and Wallace

The potential role of VR in education is indicated from the above aspects, assuming that human machine interaction design implemented especially with VR, is transferred from cognitive to sensory ergonomics. In principle interactive computer environments do not function as cognitive tools, but as perceptual enhancers or sensory artefacts. It cannot help students to think better, but it can allow them to experience more and in various ways, for example by introducing synaesthesia.

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

5.9.1 Advantages

1. Cost Savings—Avoid damage of expensive equipment due to lack of adequate training, or even more serious, injury or loss of life. Increases in production through decreased training times and cross-training by using VR.
2. Prototyping – Engineers can model a new machine or structure completely in 3D before committing it to manufacturing. Users can interact with the device in virtual reality, thereby enabling engineers to change design parameters and values with no cost.
3. Proof of Concept ("try before you buy") - Using Virtual Reality a business manager can set up any production, or distribution scenario prior to investing money in a new system or machinery. This is particularly important for smaller companies with limited resources.
4. Human Resources - By mapping out where and how certain demands for workers will be met in a virtual setting, companies are able to avoid or optimise workforce restructuring.
5. Sales - Sales personal are able to communicate with each other and clients through virtual meetings on servers. The need to come together in order to coordinate marketing plans is diminished. Clients can become a part of the process involved with the product they are buying through virtual reality. Clients are able to conduct virtual tours of a production facility without ever visiting.

5.9.2 Disadvantages and Limitations

The loss of human contact that inevitably results when using VR in training, business meeting, and manufacturing settings may be a serious limitation in more traditional environments. There is no substitute for practice and training on the real thing, and virtual scenario testing in business should not be trusted to a VR computer program. In addition there is an ethical concern with regards to what is allowable in the virtual versus the real world. Research has also revealed some serious psychophysical problems with certain types of virtual reality.

5.9.3 Some theoretical principles underlying VR

There can be little doubt that virtual reality has the potential to stimulate powerful experiences in the user. These experiences have a basis in human psychophysical characteristics, the most important being the ability to learn and experience the world through visual perception. In the normal sighted person, visual perception has the potential to dominate all other learning experiences. The following comments may help to explain why VR has such enormous potential in education and training:

1. **Visualisation builds knowledge**

   Our experience of the world and ourselves is enhanced when we can SEE the source of our experience. In this way experience is translated into information and knowledge almost simultaneously.

2. **Humans have two visual systems**

   Two visual systems relate to the way we try to match what we observe and experience with what we already know.

   - Egocentric ("looking in")
   - Exocentric ("looking at")

3. **Humans have a dual cognitive system**

   - The part that excels at logic and abstract processing ("left brain")
   - The part that excels at concrete and intuitive processing ("right brain")

Our power of creative and rational analysis and problems solving is unleashed when our experiences and the perception and assimilation of information help us to integrate these processes.

Unfortunately our modern education system does not properly encourage integration of these processes. Humans work and live in three dimensions, but we have been brainwashed through learning (and by the media) to think in 2 dimensions!

4. **The educational perspective**

All education should have visualisation (and therefore visibility of concepts) as a basic point of departure:

- Perception of the external environment through the senses and subsequent internal processing of information
- Direct observation by means of visual aids
- Promotion of realism in training
- Learning activities promote retention, which is influenced by mental activity (refer Activity Principle on page 19)

"Interactive 3D visualisation" is obviously the ideal way to exploit this.

5. **Technology-mediated experiences**

Conventional visual displays (user interfaces) interfere with our natural ability to transform data into information into knowledge, mainly because it removes most of the direct experience.

Virtual reality, and most of its derivatives, 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

5.10 Selection of Educational Methods and Media

5.10.1 Selecting the training medium

Based on what the instructional designer knows about training methods and learning styles, he or she can now choose the most appropriate training medium according to the following two levels:

- **Level 1**

  Effective communication
  Reasonable cost
  Practical limitations
  Human factors

- **Level 2**

  Training goals
  Course Content
  Learner perceptions, attitudes and learning style
  Instructor availability and skills
  Facilities required
  Availability

The key principles upon which the selection of education and training media are based, can now be summarised as follows (not necessarily in order of importance):

- Do the learning objectives suggest particular media?

- How should each of the preferred media be used, and how much should each be used (for example, for what share of the student's time)?
- Is the technology needed to carry these media available?
- What would it cost designers, instructors, and learners-in money, time, and flexibility-to use these media?
- Would less expensive media be sufficiently effective?
- Do the chosen media offer variety of stimulus and activity?
- How can the media be combined for maximum effect?
- Which media are likely to appeal to the learners?

The strategy for choosing the most appropriate medium for a particular educational method can be depicted as follows:

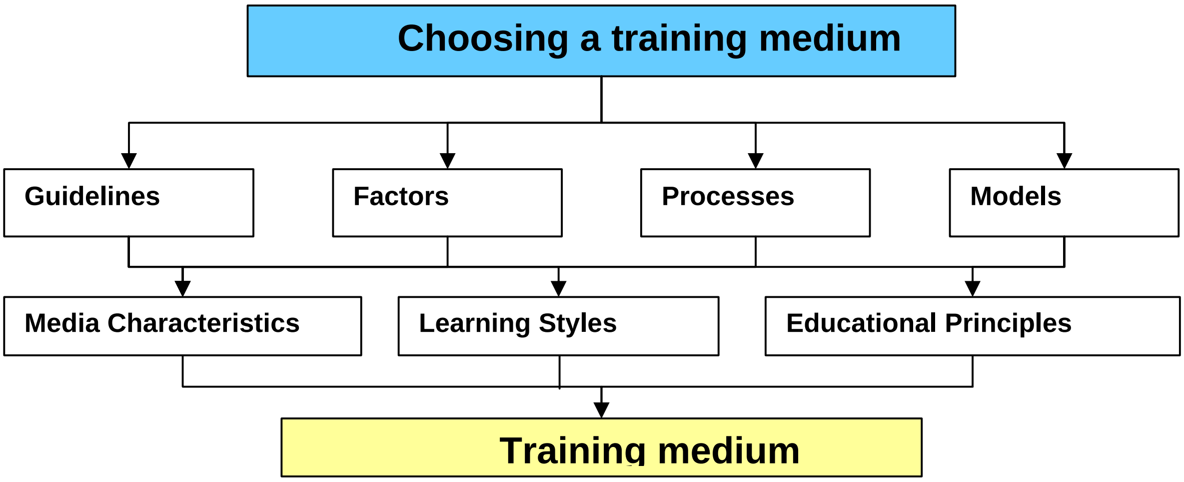

Figure 5: Strategy for choosing training medium

A simple decision tree (figures 24 and 25 below) depicts the key decisions to be made (NOTE: in the diagram where "Simulator" is indicated as the chosen medium, this will generally include either I3DV or VR at various levels of fidelity

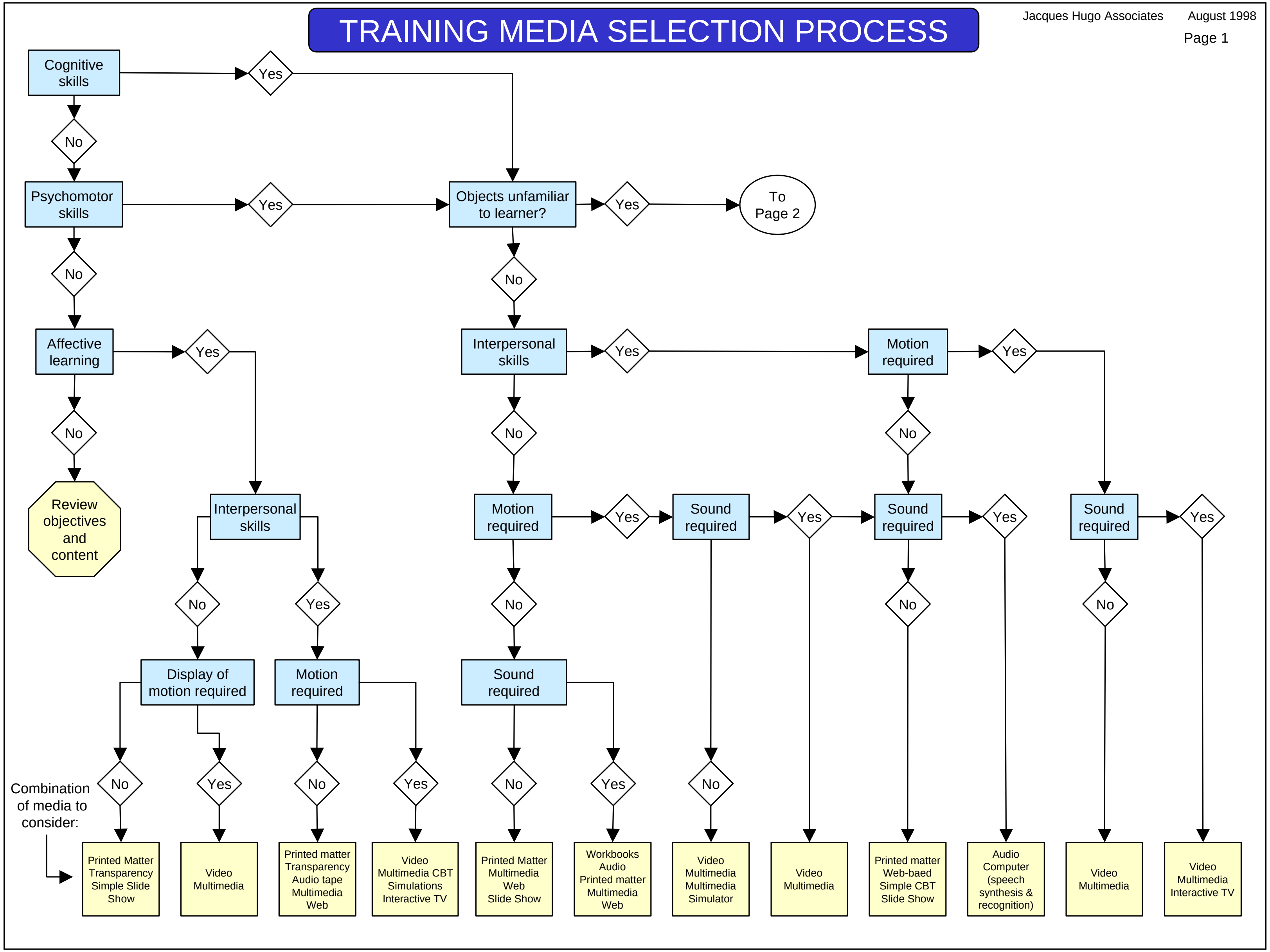

Figure 6: Media Selection method (1)

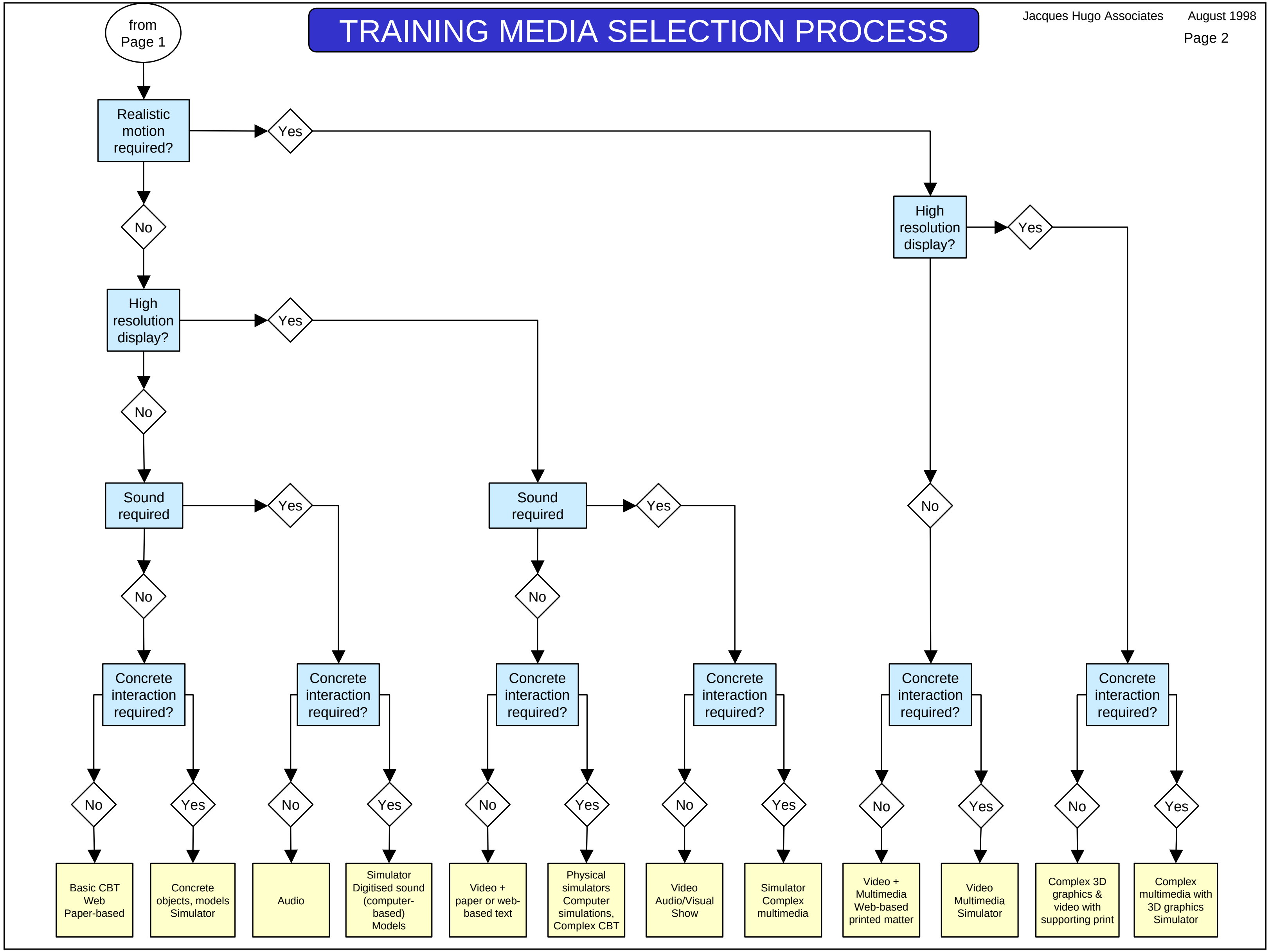

Figure 7: Media Selection method (2)

When this strategy is mapped to the characteristics of the various educational media, the following matrix is produced:

Table 7: Media Characteristics

Communication code	Interaction category	Books	Models	Video	Computer	Multimedia	Simulations & Simulators[89]
Symbolic codes	Text	X		X	X	X	X
	Icons	X	X	X	X	X	X
	Analogue codes		/	X	/	X	/
Senses involved	Vision	X	X	X	X	X	X
	Hearing		/	X	X	X	X
	Touch		X		/O	/O	X
	Motion		X	X	/O	/O	X
	More than one		X	X	X	X	X
Realism	Amount of detail		X	X	O	X	X
	Colour	X	X	X	X	X	X
	Movement		X	X	X	X	X
	Size/Dimension	X	X	X	X	X	X
	Sound effects		/	X	O	X	X
	Music			X	O	X	X
	Speech intonation			X	O	X	X
Interaction	Feedback			/	X	X	X
	Questions	X		/	X	X	X
	Tempo control		X	X	X	X	X

KEY:

X = Communication code is fully supported

/ = Communication code is partly supported

O = Dependent on specific technologies

Blank = not compatible

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[89] This includes various forms of Virtual Reality

5.11 Summary

This section has summarised the characteristics of a range of educational methods and media. It was shown clearly that there is no single best medium for training and education. However, it is possible to systematically determine the best method and medium for a given situation and subject, based on the learning requirements, learner characteristics and the characteristics and capabilities of various media. It is not within the scope of this document to determine the best methods and media for any given situation or subject.

It must be emphasised that, Virtual Reality and Interactive 3D Visualisation are very powerful and flexible training media, but it should be chosen with due consideration of all relevant factors. The issues briefly mentioned in this section can be used to achieve this.