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

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Comparison of and characteristics of educational multi-media

Jacques Hugo - Usability Sciences

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VR in Africa – for Africa – by Africa

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1 PREFACE

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

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

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

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

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

Appreciation is also due to the two Local Coordination Committees:

Local Coordination - Uganda

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

To date, VR initiatives in Africa have resulted in:

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

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

Local Coordination - South Africa

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

2 Comparison of and characteristics of educational multi-media

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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

2.1 Principles of Adult Learning

2.1.1 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 1: 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

2.2 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

2.2.1 Totality Principle

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

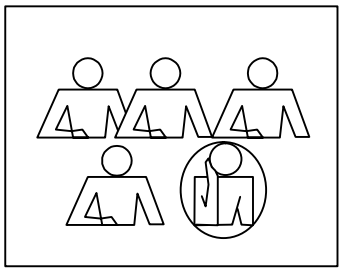
Application

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

2.2.2 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

2.2.3 Motivation Principle

Application

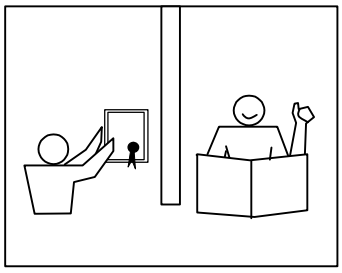
Motivation can arise from four possible sources:

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.



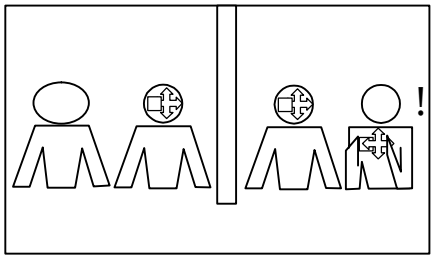
4. **Manner of motivation**:

   (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

2.2.4 Visualisation principle

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

Application

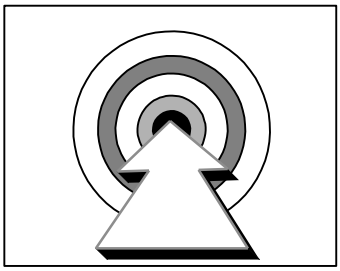


1. This principle is implicit in perception of the external environment by means of the senses and subsequently the internal processing of information gained in the process.
2. Direct observation by means of audiovisual aids
3. Promotion of realism in training

2.2.5 Goal-directed Principle

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

Application

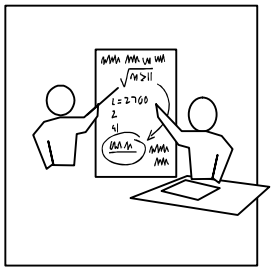


1. Clear objectives are essential and must be defined in an unambiguous manner. The instructor must indicate the required standards and circumstances for achievement of goals. (*If you don't know where are going, you are bound to end up somewhere else*).
2. Must provide direction for the trainee.
3.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

2.2.6 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

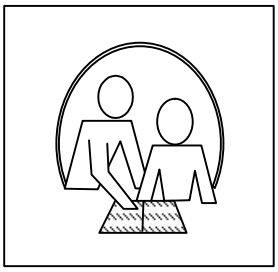
mental activity:

- 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

2.2.7 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.

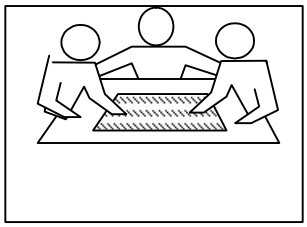


Application

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.

2.2.8 Socialisation Principle

This principle deals with social acceptance and conformance.

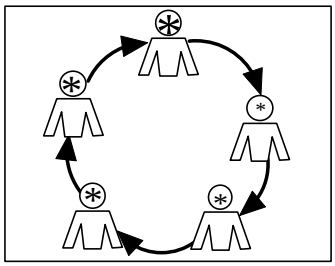


Application

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).

2.2.9 Development Principle

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

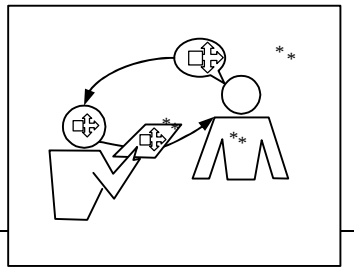


Application

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.

2.2.10 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**.

2.3 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.

2.4 Visual Communication and Visual Literacy

2.4.1 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).

2.4.2 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.

2.4.3 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.

2.5 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:

2.5.1 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.

2.5.2 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.

2.5.3 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.

2.6 Educational Method Overview

2.6.1 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 2: 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.			

2.7 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 3: 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

2.8 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:

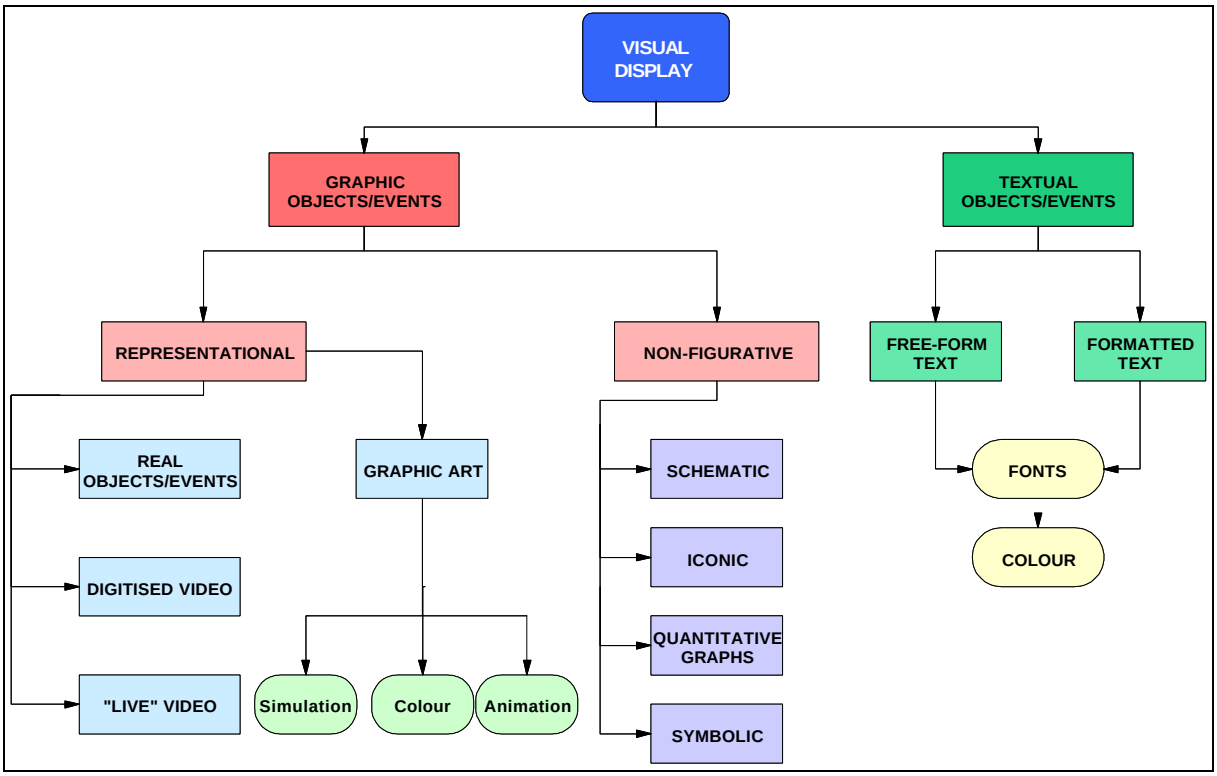


Figure 1: Taxonomy of visual communication

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.

2.8.1 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

2.8.2 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

2.8.3 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.

2.9 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[1] 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:

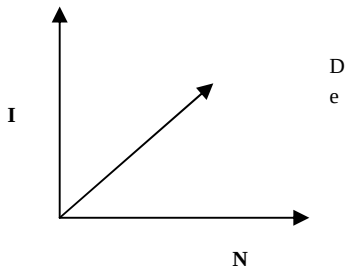


Figure 2: The VR Dimensions

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

2.9.1 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.

2.9.2 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.

2.9.3 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 6)

   "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

2.10 Selection of Educational Methods and Media

2.10.1 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:

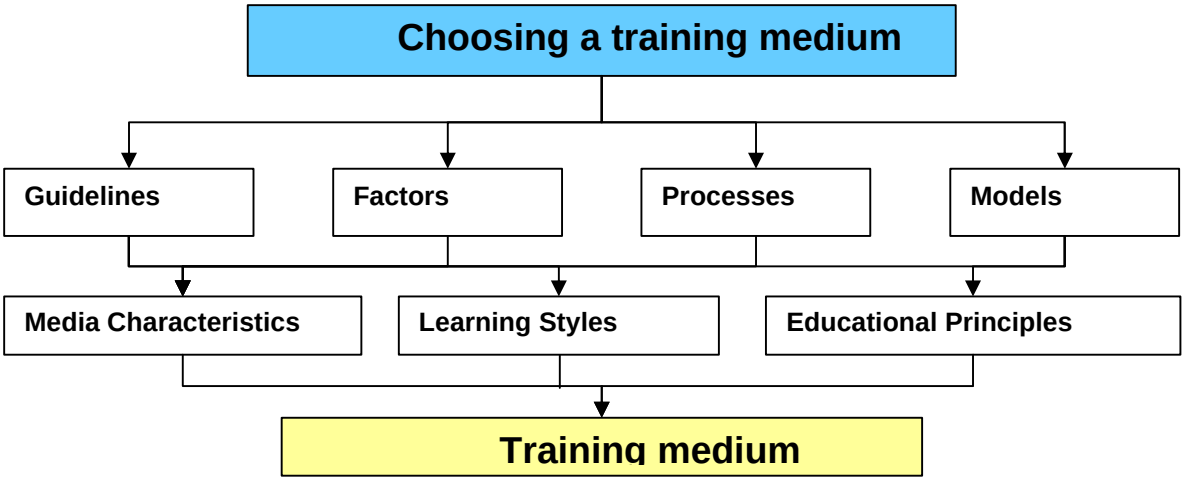

Figure 3: Strategy for choosing training medium

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

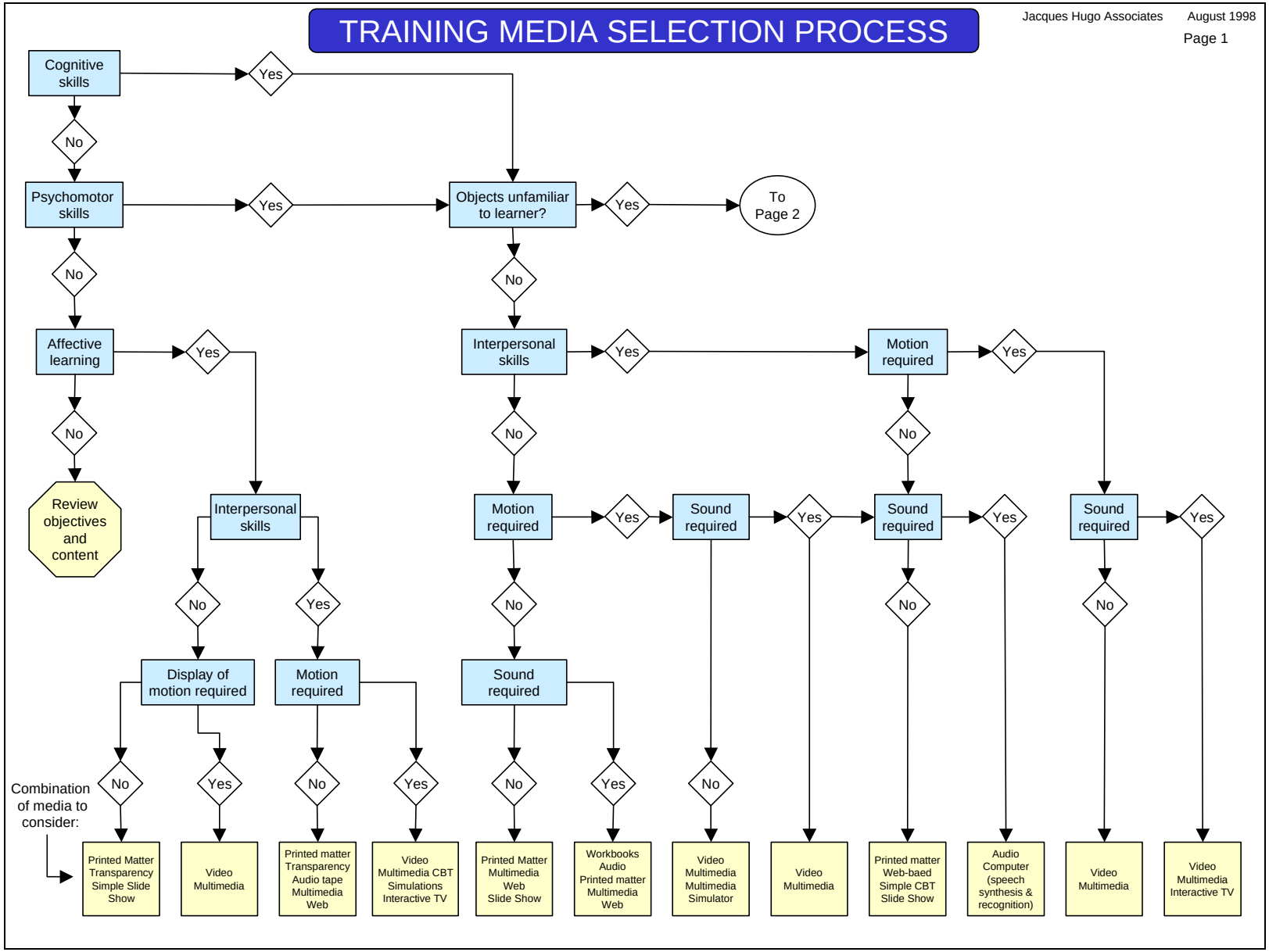

Figure 4: Media Selection method (1)

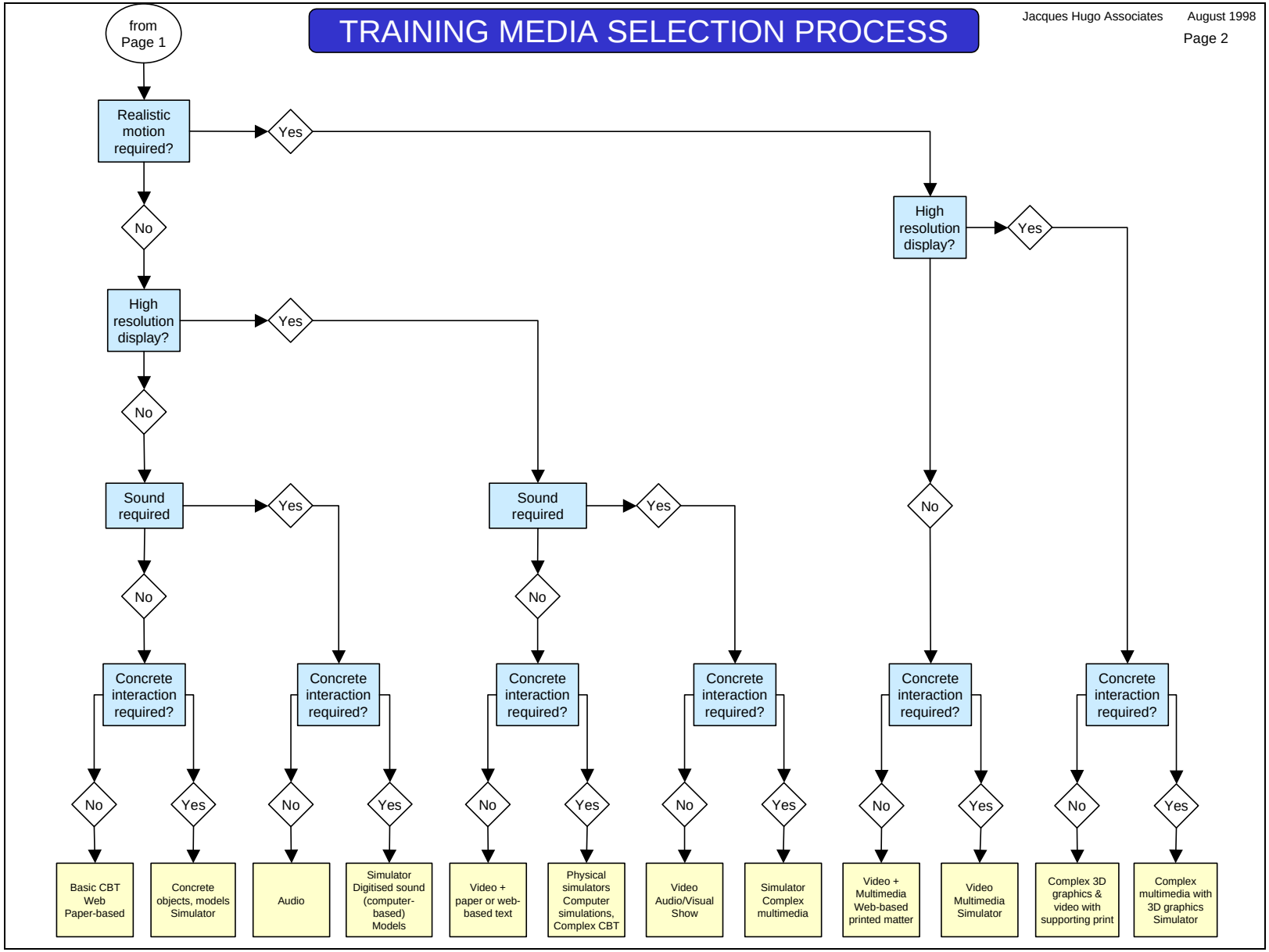

Figure 5: Media Selection method (2)

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

Table 4: Media Characteristics

Communication code	Interaction category	Books	Models	Video	Computer	Multimedia	Simulations & Simulators[2]
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

[2] This includes various forms of Virtual Reality

2.11 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.