Towards A General Model for the Design of Virtual Reality Learning Environments

A thesis
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by

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Dedication

I would like to dedicate this thesis to two of my cats Fluffy and Pebbles, who had to be constantly told to get off the keyboard, during the many hours that they wanted to play and I wanted to type, and to my third cat William who recently got killed.

In Loving Memory

of

William

who died 5. 6. 2002

You were always there when I woke each morning; your body snuggled against mine.
You always ran to greet me when I came home tired and needing a friend.
You were always there to give me a warm cuddle when things were not going well.
Your strange voice was always heard when you returned home from your travels.

Burying your stiff little body was the hardest thing I have ever had to do.
It is so painful knowing you will never put your head on my knee as I type my thesis.
No more walks around the garden and meditations together on the bridge.
William, I loved you so much, and I miss you every day.

Please Lord; it is your turn to look after him now. I did my best.

Acknowledgements

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Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in this thesis are those of the author and in no way represent those of the University.

Signed Date 30/9/2003

Abstract

Virtual reality (VR) has been described as a new and unique type of learning media primarily because it encourages active participation. However, a large number of VR worlds are barely more than passive 3D graphic visualisations. This might be due to the lack of guidelines for the design of interactive worlds, or to the learning preferences of the designers themselves. The literature indicates a number of principles, especially in the area of VR design and learning theory that could form the basis of appropriate design guidelines and this thesis presents these as a set of guidelines for VR designers. There is a lack of information about the learning preferences of VR designers or the design of appropriate help systems for VR learning media so four additional fieldwork studies were carried out to investigate the learning styles, communication styles, attitudes towards the use of VR in learning and training situations, and preferences for the design and use of VR help systems using a sample of VR designers and VR design students. The results indicated that the learning style and communication profiles of VR designers may not be suitable for the design of active learning material. It was also found that VR designers had positive attitudes towards the development of VR in general but less so for learning situations. VR designers tended to provide mainly text-based (visual) instruction in their designs, which may be linked to their predominantly visual learning modalities. However, the results suggested that visual-dominant VR design students were equally likely to prefer voiced (auditory) instructions when used naturally within a VR world. The findings from these four studies were incorporated into a broad set of top-level guidelines that form the first step towards a general model for the design of active, participatory VR learning environments.

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1.0 NATURE OF THIS STUDY

1.1 Introduction

1.1.1 Background

The motivation for this thesis arose from the author's own work in designing virtual reality (VR) learning environments for the Royal Air Force in the mid 1990s (Mason, 1994; 1996). As a psychologist, the author was intrigued by the different ways that people learned using these environments and at the different attitudes towards using virtual reality as a learning environment. The author was also disappointed in the lack of interaction and natural forms of help that were offered in the VR worlds during her work in the field. Many of the worlds seemed to concentrate upon trying to create realistic graphics rather than realistic behaviours.

VR is more than the visualisation of 3D graphics (see Chapter 2); it is about interaction, participation and experience (Bricken, 1992; Helsel, 1992). Thus realistic world behaviours should be more important to VR designers than consideration of higher resolution textures and more sophisticated objects. User interaction should be given equal if not more importance than the use of realistic textures. The term 'interaction' is often defined as a two-way communication process or transfer of information between the user and the computer (Westland, 1994) and 'interactive' is the adjective relating to this process. This implies that there is activity and participation by the user. VR offers the potential for this interaction to be more active and participatory than other forms of multimedia (Bricken, 1992). It enables the user to become part of the virtual world taking on the role of an object within the world in a realistic manner, e.g. a person, an animal, a tree, etc. The user is given the ability to participate in the world by moving around the world and interacting with objects as they would in the real world, all in real-time. The user is thus an active participant rather than just a passive observer in the world (Helsel, 1992). These interactions should be as natural or intuitive as possible, e.g. users can open and close doors by touching the door handle, users can bump into walls and climb up and down stairs, user can watch dogs moving around and hear them bark etc. Thus designers need to be aware that providing such realistic behaviours is the essence of VR and a vital component of a VR learning environment, perhaps more so than realistic textures (as discussed in Chapter 2).

1.1.2 Overview of the Problem

This thesis investigates why designers are not designing active, participatory worlds as proposed by several researchers (Bricken, 1992; Helsel, 1992; Mason, 1994). There may be a number of reasons for why this is not happening and it is beyond the scope of this thesis to address all the possible reasons. Two are considered worthy of investigation here: the lack of guidelines to help designers to provide more active, participatory worlds and the lack of active learning styles in the designers (and knowledge of this issue) that may be reflected in their designs.

Lack of Guidelines

In the United States, educational researchers, such as Helsel (1992) and Pantelidis (1993), have suggested that VR provides opportunities for active learning experiences as users participate in the learning environments. However, this is not always apparent in some worlds presented as VR that are really 3D graphics environments that are viewed by 'flying' around the objects. Such worlds offer little opportunity for active participation for the user. The literature has indicated a lack of design guidelines (see Chapter 2) that can assist the designer in creating VR media offering active, participatory learning environments. Producing such interactive learning environments needs input from other domain experts, which tends to increase the overall costs of a project as well as the time deadlines (Kaur, 1998). Designers of active learning environments could benefit from practical guidelines that would emphasise a need for design characteristics to enhance the interaction of the world. There is also a need for more research to highlight the advantages of providing such interaction.

In order to investigate the literature for possible guidelines for VR learning environments both design of VR and design of learning environments were examined.

VR Design Characteristics

A number of sources discuss the need for particular characteristics for VR systems or worlds (see Chapter 2). Several researchers have proposed different ideas of what the main characteristics of VR are but many (e.g. Rose, 1995; Vince, 1998) emphasise the overall need for a sense of presence and natural interaction. Unfortunately, there does not seem to be any guidelines on the importance of designing for active, participatory worlds *per se*; however, several general characteristics would be suitable for ensuring that there is interactivity in VR worlds and could serve as the basis of appropriate guidelines.

Theoretical Learning Principles

It has been emphasised in the literature that instructional design should be based on guidelines and principles developed from suitable learning theories (Pont, 1991; Schneider, 1994; Wilson, 1996) although some argue that designers are often too creative to be constrained by such rules (Gros et al, 1997; Schiffman, 1995). Many different theories of learning and of instructional design have been proposed over the past century relating to a variety of learning situations, but there is no one theory of learning that seems to relate to VR (see Chapter 3).

Winn (1997b) suggests that any learning media design should be based on appropriate theoretical learning principles; however, there are no principles to be found in the literature specific for the design of active learning environments. Other VR researchers suggest that VR cannot be designed by traditional learning principles because it is a new type of learning medium and as such it needs a new learning paradigm (Osberg, 1997a; Rose, 1995; Roussos 1997). A constructivist paradigm has been proposed because it advocates the use of active learning principles (Byrne 1996; Osberg 1993). Thus, users construct their own knowledge, in their own time, from their experiences in building the VR worlds. The constructivist idea of users building their own worlds has been shown to be useful in the teaching of children (Byrne 1996; Osberg 1993) but there has been little research of its effect with adults. Constructivism does not seem an appropriate framework for adult learning/training environments, where time and resources are often limited and need to be targeted towards specific learning/training goals (see Chapter 3).

The learning literature provides a number of principles for learning media and this thesis determines which of these might be suitable for the design of VR learning environments.

<u>Lack of Active Learning Styles</u>

It is suggested that the lack of interactivity in VR learning environments may be due to the personal learning biases of the designers that favour a more passive type of learning medium. The term learning style has been defined as "a description of attitudes and behaviours which determine an individual's preferred way of learning" (Honey and Mumford, 1992). The learning literature suggests that individual differences such as learning styles can be an important factor in the learning process (Duff, 2000). It has been strongly argued that learning occurs best when the learning style of the learner is matched by the learning style of the material being presented (Dixon, 1982; Poon Teng Fatt, 1993; Srisethanil and Baker, 1995). Further, it also seems that teachers automatically choose teaching methods that fit in with their own preferred learning style and therefore bias their effectiveness to those students with a similar style. In many cases computer software is designed to be used in place of a teacher, and thus the designer, to some extent, takes on the role of the teacher (Smith et al, 1996). It seems logical, therefore, that designers may be creating less interactive worlds because this suits their own way of learning or learning style.

It has been argued that VR offers a unique active type of learning experience, different from the more passive traditional classroom experiences (Bricken, 1992; Cronin, 1997; Pantelidis, 1993; Rose, 1996; Winn, 1997a). An active type of learning style has been identified by Honey and Mumford (1992) based on theoretical work carried out by Kolb (1984). This learning style has also been linked with the extraversion communication/learning style based on work by Myers and Briggs (Myers and McCaulley, 1985) and theoretical work of Jung (Myers and Myers, 1995). It is possible that designers with these styles may be more likely to create active, participatory worlds for users.

Certain learning styles are attracted to certain professions and particular types or patterns have been found for computer programmers and for designers (Honey and Mumford, 1992; Myers and McCaulley, 1985; Pimentel and Teixeira, 1992; Tognazinni, 1992). Data from these studies show that many programmers or designers tend to have certain preferences or biases in the way that they deal with information that might affect their designs. The literature shows that there are no such profiles for VR designers as this is still a relatively new profession. This thesis, therefore, attempts to investigate the learning style preferences of VR designers and discuss how these might affect their designs.

Other Issues in the Design of VR Active Learning Environments

This thesis addresses the issues of attitudes of VR designers and the design of appropriate help systems. It also proposes that VR designers need to have positive attitudes towards the use of VR in learning situations and must design appropriate natural 'within-context' help systems to ensure maximum interaction and sense of presence for the users.

Motivation and Attitudes

Self-motivation is an important aspect of active learning theories and research suggests that a positive attitude can help the learning process (see Chapter 4). Motivation has been considered as an important factor for learning, with positive motivation or attitudes being linked to better learning performance (Lieb, 1996). Positive attitudes of the teacher can also benefit the student (Cox, 1997). No studies have been found that looked at the attitudes of teachers or VR designers towards using VR as a learning tool within the classroom. As a new medium, it is likely that VR will not be introduced on any large scale in education unless designers and teacher attitudes towards its use are quite positive. Desktop VR systems can offer a cheaper, more flexible solution for VR learning but its use will need to be pioneered by positive attitudes from teachers and designers as well as proof of its effectiveness (Youngblut, 1998). This thesis will attempt to explore the motivation, attitudes, beliefs, and experiences of VR designers towards the design of VR environments especially in learning/training situations.

Design of Help Systems

An important aspect of successful learning is the requirement for adequate help and guidance and feedback (see Chapter 4). Within a classroom situation, this would normally come from the teacher (Gagné and Driscoll, 1998). Help is also needed when using computer-based-software programs, and if the teacher is not present during the session, it needs to come from the program. The literature indicates that the most popular form for computer-based software assistance is that of text-based online help where written information is divided into sections which can be searched via use of a keyword (Harrison, 1993; 1995). Indeed most software programs have implemented this type of help, but it has been criticised for being unusable and unhelpful for most novice users who are unable to choose relevant keywords (Sellen and Nicol, 1990), which may not be in the user's domain of knowledge. Use of interactive multimedia techniques in the software to enhance the help systems and artificial intelligence methods for creating adaptable systems that accommodate different users have all been suggested, but few have been incorporated in even the most sophisticated of programs.

If VR is to cater for active learning types, then it is necessary to incorporate a suitable help system that will not detract from the interactivity aspects of the VR learning media. Thus it needs to be natural and interactive and ensure that it enhances the user's sense of presence (Vince, 1998). There has been very little research on the type of help system deemed appropriate for VR learning. Research into VR and learning with school children (Bricken and Byrne, 1992; Byrne and Furness, 1994; Osberg, 1997a; Winn, 1995) suggests that researchers and teachers gave personal help if needed. The author's experience with desktop VR software has found that help has normally been provided either as a text file which can be accessed via a keyboard press or by on-screen text dialogue boxes. Both of these forms of help are not natural in a VR world (Mason, 1996; Roussos and Bizri, 1998) and can be distracting to the user. Less intrusive forms of help in a VR world are needed that resemble methods that would be available in the real world. Examples of such methods include talking to people directly, by telephone or e-mail, looking at books, leaflets and posters, using maps or signs, using the Internet etc. These methods need to be considered for inclusion in the design of VR environments. It is hypothesised that these methods would be enjoyable for different types of users.

The learning literature suggests that people learn with different types of modalities or senses (see Chapter 4). The most common sense is the visual sense (Pimentel and Teixeira, 1993) and this is catered for by text and images (Akamatsu et al, 1993); however, there may be a need to incorporate help systems for users with auditory and kinaesthetic learning modalities. Although visual types account for the majority of the population (Pimentel and Teixeira, 1993), no study to date that has been located has investigated the natural learning modalities of VR designers. Since VR is a visual medium, it may attract visual type learners as designers who may then prefer to '*look*' at text dialogue boxes rather than '*hear*' voiced instruction. However, this may not be the only reason, as it tends to be more technically difficult to incorporate speech recognition systems that would be the most natural form of communication and help in a VR learning environment. It is also more costly and time-consuming to provide these (Youngblut, 1998). This thesis investigates the design of help systems by clarifying the predominant modality preferences of VR designers with their choice of help systems.

1.2 Methodology

1.2.1 Aims and Objectives of the Study

This study has two aims:

(1) To provide a set of guidelines that would assist designers in producing more interactive VR learning environments. These guidelines will be presented as the basis of a possible design model that will focus upon the four areas so far discussed:

VR world design characteristics, learning theory principles, individual learning differences and use of natural help systems.

(2) To investigate the learning differences of VR designers (learning styles, communications styles, learning modalities and attitudes) in order to provide insight into the factors that might reflect in the designs produced and which might provide further data for the guidelines in Aim (1).

In order to fulfil the two aims outlined the following objectives were outlined:

(1) To review the literature in VR and learning with the purpose of providing a number of top-level broad sets of guidelines. (Aim 1)

(2) To select those guidelines that are appropriate for the design of active and participatory learning environments and present these in a first step towards a model that can assist designers to produce more interactive worlds. (Aim 1)

(3) To identify those parts of the model in (2) which lack guidelines for design. (Aim 1)

(4) To carry out fieldwork studies to produce recommendations for design (guidelines) of the areas identified in (3), particularly in the area of learning styles and the design of appropriate help systems. (Aim 2)

(5) To implement the fieldwork results into from (4) into the model of (2). (Aim 1)

(6) To identify limitations of this model and suggest areas for further research. (Aim 1)

This study intends to achieve these objectives in the following manner:

(1) By carrying out a literature review in order to assess the research concerning the characteristics of VR worlds, learning theories and principles for instructional design, individual learning differences and the design of help systems that might provide suitable guidelines for the design of active and participatory VR learning environments.

(2) To produce the first step towards a top-level model for such design covering the identified areas specifying appropriate guidelines where possible.

(3) To highlight areas of this model lacking research for guidelines.

(4) To produce and give a general questionnaire to assess the attitudes, motivation, experiences etc of the VR designer samples. To also give appropriate learning style tests in order to assess the predominant learning characteristics of the VR designers that might affect their final designs.

(5) To incorporate the results of the above into the original set of guidelines.

(6) To highlight the limitations of this model and suggest areas for future research.

The main contribution of this thesis will be the development of a broad set of top-level guidelines as part of a first step towards the production of a model for designing active and participatory VR learning environments.

1.2.2 Limitations of the Fieldwork of this Thesis

Full discussion of the limitations will take place at the end of this thesis but it should be noted that:

(1) The studies focus only upon VR designers and potential VR designers rather than users *per se*.

(2) During the duration of this thesis an apparent lack of suitable designers occurred in the UK for example, one of the main VR companies involved in the work moved its production to the US, thus preventing a more widespread sample being used.

(3) A sample of VR design students was used to supplement data given the premise (which might be proved false) that these students may represent the types of people who are attracted to the design of VR learning environments.

(4) Furthermore, the collapse of the VR market in the UK during the duration of this thesis prevented follow-up data collection from taking place, in particular for determining the help preferences of the VR designers.

1.3 Thesis Outline

This thesis addresses the problem of designing effective VR learning environments in the following nine chapters (Chapters 2 – 11). A brief outline of each chapter follows:

Chapter 2: Design Characteristics

Chapter 2 defines a virtual reality (VR) system and considers the problems of using a technological description rather than a conceptual one. Seven major characteristics of VR systems are proposed and their relevance for VR and implications for VR design are discussed. These characteristics are considered important aspects for a general design model of VR worlds. Evidence suggesting VR has the potential to be a new type of learning environment is presented and lack of guidelines for design of VR learning environments is highlighted. In order to exploit the potential of VR as a new form of learning, its special attribute's need to be identified. Ten special characteristics are identified in the literature and discussed with relevance to learning design issues. Both groups of characteristics provide some of the elements of the model outlined in Chapter 5.

Chapter 3: Theoretical Principles

Given that there is, to date, no theory of VR learning, this chapter presents the results of a review of 28 learning theories/frameworks that have influenced or provided principles of instructional design and discusses those principles that might have some relevance for the design of VR learning environments. The principles are presented into 4 possible groups of similar learning theory/frameworks for the purposes of this thesis. These principles provide the basis for several elements and guidelines in the design model outlined in Chapter 5.

Chapter 4: Individual Differences and Help

Many cognitive learning theories argue the need to take into account individual differences in the way that people learn. Chapter 4 highlights the importance of motivation and positive attitudes in learning and focuses upon three important learning differences: learning styles, communication styles, learning modalities. It presents learning style theories and models and shows how they have implications for learning. In addition it also highlights aspects of these differences that need to be taken into account when designing VR learning environments. Feedback, guidance and help are necessary for successful learning and on-line text systems are the most common type of help in computer-based software. These types of help may not be appropriate for VR and it is suggested that help systems be designed to be more 'natural', for example, using speech communication. These issues form the basis for several groups of elements within the model outlined in Chapter 5; however, the literature shows that specific research on learning differences and VR designers has not been carried out and thus it is not possible to derive guidelines for all the issues discussed without further investigation.

Chapter 5: Design Model

This chapter presents a general design model for VR learning environments. This model outlines the elements for nine groups within four areas considered to be the most important for the design of VR learning environments: VR design characteristics, learning principles, individual differences and appropriate VR help systems. The model presents a number of elements, from the literature presented in the previous three chapters, which are then extended into more practical guidelines. Elements that need further investigation are highlighted.

Chapter 6: Study 1 – Affective Survey

The literature advocates that positive attitudes and motivation affects learning performance but attitudes of VR designers have not yet been addressed. This chapter describes the results of a questionnaire study investigating the attitudes of designers and VR students to using VR as a learning medium and to the design of help systems. Subjective ratings of enjoyment using VR and other type of software are also presented.

Chapter 7: Study 2 – Learning Styles

Evidence suggests that VR is an active type of learning environment that might suit the Activist type of learning style as proposed by Honey and Mumford (1992). This chapter describes the results of a survey of the learning styles of VR designers and design students using the Learning Style Questionnaire that identifies the Activist learning style. An analysis was carried out to determine any particular bias in the learning styles and results were compared to each other and to available population data. The results are discussed and possible implications for VR design are examined.

Chapter 8: Communication/Learning Styles

Communication styles have been linked to learning styles, the Extroverted style being linked to the Activist learning style. Whilst there is a substantial volume of data on communication styles of many professions, there are no data for VR designers. This chapter investigates the communication style profiles for a group of VR designers and VR design students. The profiles are examined for particular patterns that might influence the design of VR worlds.

The results are compared to the three communication style models presented in Chapter 4.

Chapter 9: Learning Modalities and Help

VR worlds tend to present help instructions in the form of visual text boxes rather than auditory voiced instruction. VR is a visual type of medium that favours visually dominant learners and probably attracts visually dominant designers who may prefer visual instructions. However, not everyone is a visual learner and therefore the addition of speech communication facilities would, it is argued, benefit auditory dominant learners in the general population. This chapter presents the results of a survey of learning modality types within a group of VR designers and VR design students and attempts to correlate this with their choice of text or voiced instructions in a virtual learning environment. Results are analysed and discussed for relevance to the design of VR help facilities. Whilst speech is considered a natural form of communication for a VR world, research suggests that speech recognition systems are technically difficult to incorporate. An experiment was carried out to build a prototype speech recognition package with a desktop VR system. A world was created which enabled someone to be able to talk to characters in the world and to have some control over activities. The world acted as a prototype of the concept and limitations, and problems arising from this exploratory experiment are discussed further.

Chapter 10: Final Design Model, Limitations & Conclusions

This chapter discusses the results from the previous four fieldwork studies and shows how they can be incorporated into the design model, presented in Chapter 5, in the form of new guidelines. Implications for the design of VR learning environments are discussed. Limitations of the model are highlighted and possible areas for extension and further research are given. Conclusions from the literature review and fieldwork are presented.

In summary, this thesis will investigate the literature in learning and VR in order to derive possible guidelines for the design of VR worlds that are active and participatory in nature. It will also investigate if VR designers have appropriate learning styles for the design of such interactive learning environments with suitable help systems. The results of the literature review and fieldwork will be presented as a top-level model consisting of a set of broad guidelines that might serve as the first step towards the design of active, participatory VR learning environments.

CHAPTER 2: DESIGN CHARACTERISTICS

2.1 What is VR?

2.1.1 The Emergence of VR Technology

The words virtual reality or VR originated at the turn of the last decade when Jaron Lanier introduced 'VR' using technologies that were being developed for military simulations (Macpherson and Keppell, 1997). The system consisted of a networked computer system with a head-mounted display (HMD) or headset (see Figure 2.1) that displayed a 3D world.

Figure 2.1 User Wearing a Headset Device (source unknown)

The headset was based on earlier head-mounted display (HMD) designs introduced by Sutherland in the 1960s (Macpherson and Keppell, 1997), which showed that by combining head-positioning tracking and real-time graphics, a human could be placed inside a virtual world by wearing this device (Stone, 1993).

In order to interact with the virtual world, users wore input devices called DataGloves. DataGloves (see Figure 2.2) were worn that enabled users to interact with this 3D world by moving hands and fingers in order to manipulate and control objects within the world. The networked computers enabled several users to become part of, and interact with, the same world. Lanier put these technologies together in a way that had not been done before in order to present a unique type of system that could be used for social entertainment (Perkins and Perkins, 1993). He explained the significance of such a system in that his work had developed these tools from a form of interface to a form of communication.

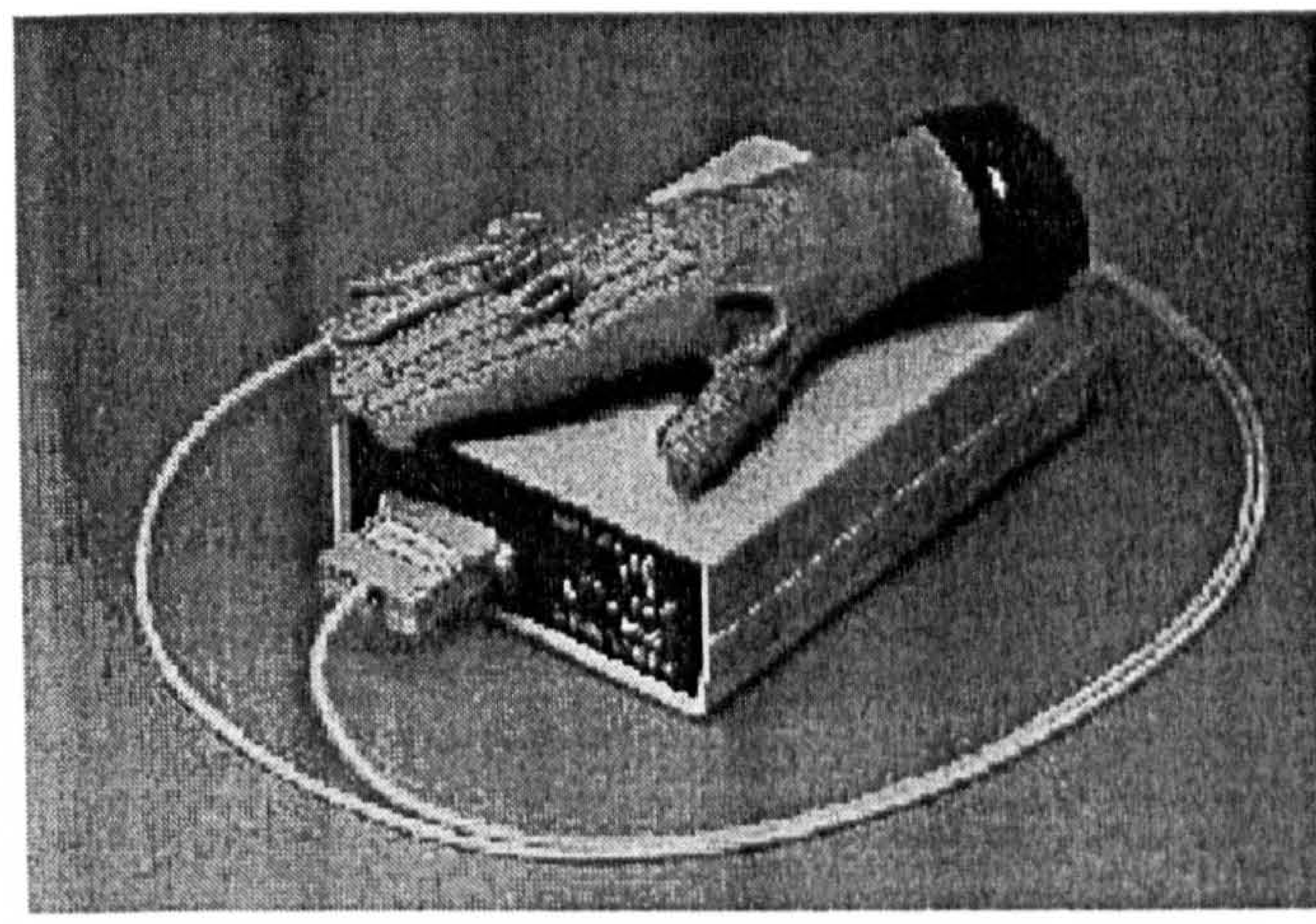

Figure 2.2 DataGlove Device and Control Box (source unknown)

Immersive Systems

In the early 1990s this type of VR system, which used a headset was called an immersive VR system (Kalawsky, 1993). It was argued that immersion (discussed later in this chapter) was an important aspect of VR so a headset was a necessary component of a VR system. Within the headset were small 2D displays showing the virtual world with focusing technology that enabled the eyes to focus at infinity and not at the end of their nose which would be quite tiring (Arthur, 1992). Wearing headsets, however, created many user problems (Powell, 1994), which still remain. The resolution of the display is usually poor, the field of view is often severely limited and there is always some kind of delay in the system that confuses the users (Arthur, 1992; Edgar and Bex, 1995; Kalawsky, 1993; Vince, 1998). Low frame rates mean that users world were seen as 'jerky' and poor resolution meant that details could not be seen clearly. Indeed users of these VR systems have been described as legally blind (Stone, 1994). There was also a problem with tailoring the VR peripherals to fit different users and a possible health hazard from the close proximity of high-voltage in the cathode ray tube displays (Angus and Stone, 1995). All these factors combined to make the VR experience less than optimum for the user who often became nauseous and disorientated within a short space of time (Regan and Price, 1993).

Because of the problems of using headsets, developers attempted to create an immersive effect using different technologies. Projection technologies were mainly used for this purpose. Researchers at the Electronic Visualisation Lab (EVL) in the US developed the *CAVE* system (see Figure 2.3). It is an example of a projection system where the virtual worlds are projected on to the walls of a room (typically about 10ft. x 10ft. x 9ft.) that surround the user and which enable an extreme wide field of view. The user wears stereoscopic glasses to enhance the 3D effect and navigates within and interacts with the world using a glove or wand device (see Figure 2.4).

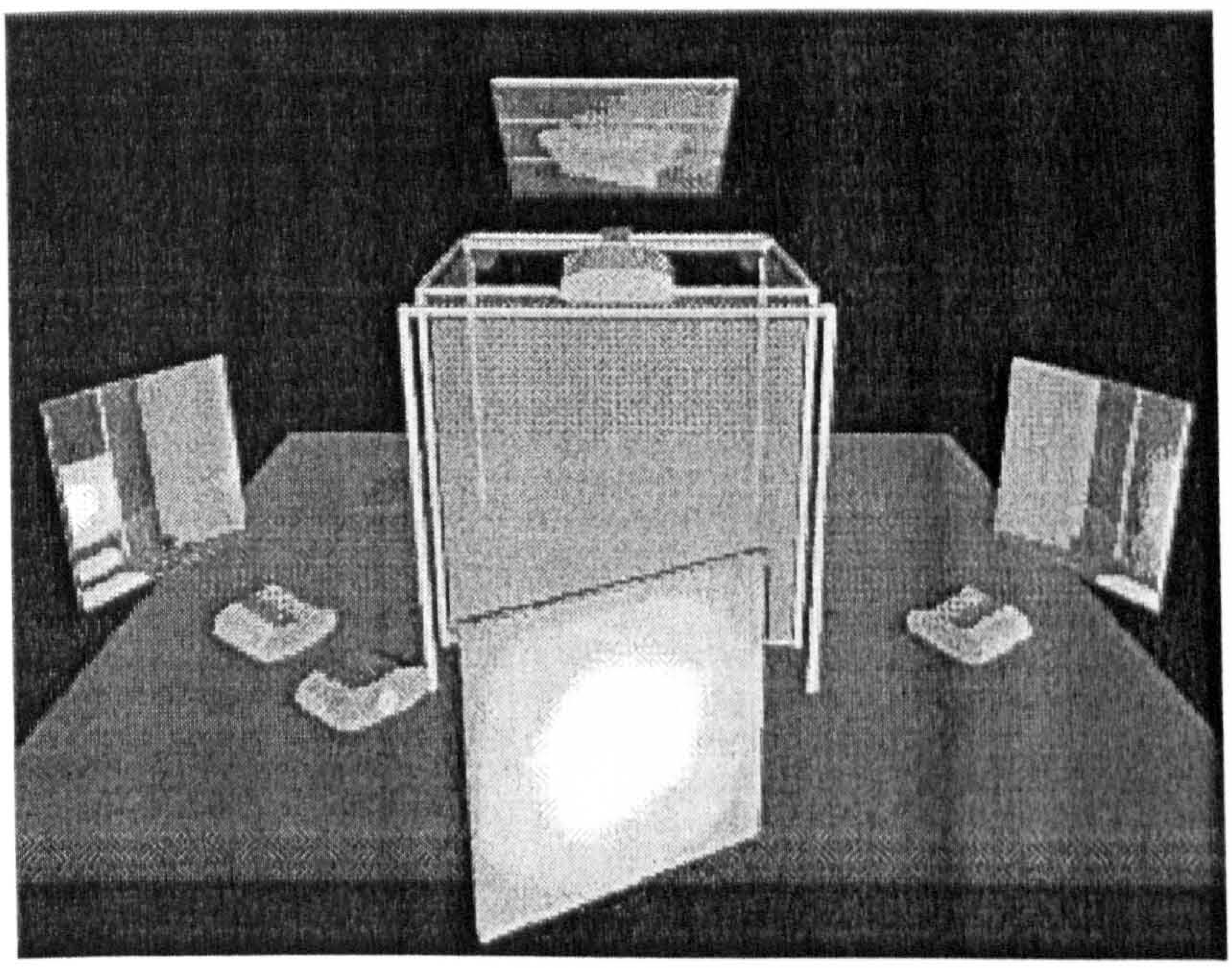

Figure 2.3 CAVE System with Projectors and Mirrors (Fakespace Systems)

Figure 2.4 Wand Tracking Device (Electronic Visualisation Laboratory)

The *CAVE* system seems to have been used more extensively in the United States than the United Kingdom (Youngblut, 1998). It is capable of allowing more than one user to be immersed within the world; however, only one of the users can be tracked i.e. only one can navigate and interact with the world (Czernuszenko et al, 1997). The others are able to view the world but not interact with it. The company that now markets the *CAVE* system also markets a semi-immersive VR system using similar technologies. This system is called the *ImmersaDesk* (Czernuszenko et al, 1997) (see Figure 2.5).

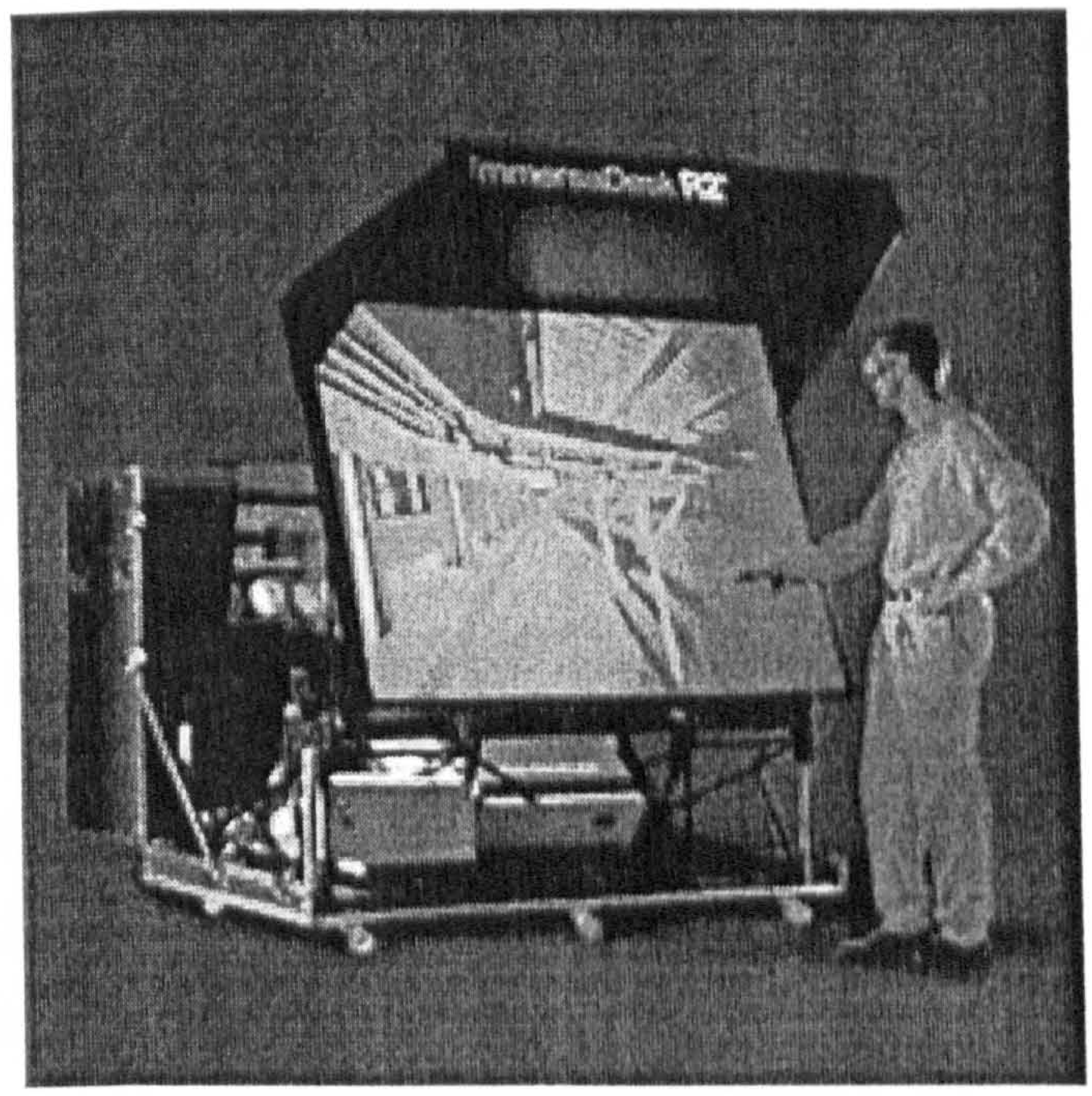

Figure 2.5 ImmersaDesk (Fakespace Systems)

The *ImmersaDesk* is a drafting table format VR display that features a 4ft. x 5ft. rear-projected screen positioned at a 45-degree angle in order to give a wide-angle view and to enable the user to look down as well as forward. The user wears stereo-glasses and sonic head and hand tracking devices that together give a semi-immersive effect.

A new concept for a fully immersive VR system that does not have the problems of headsets is that of the Cybersphere and which enables a more natural interaction with the virtual world (see Figure 2.6). This VR concept was invented in the UK but has not yet been marketed as a commercial product.

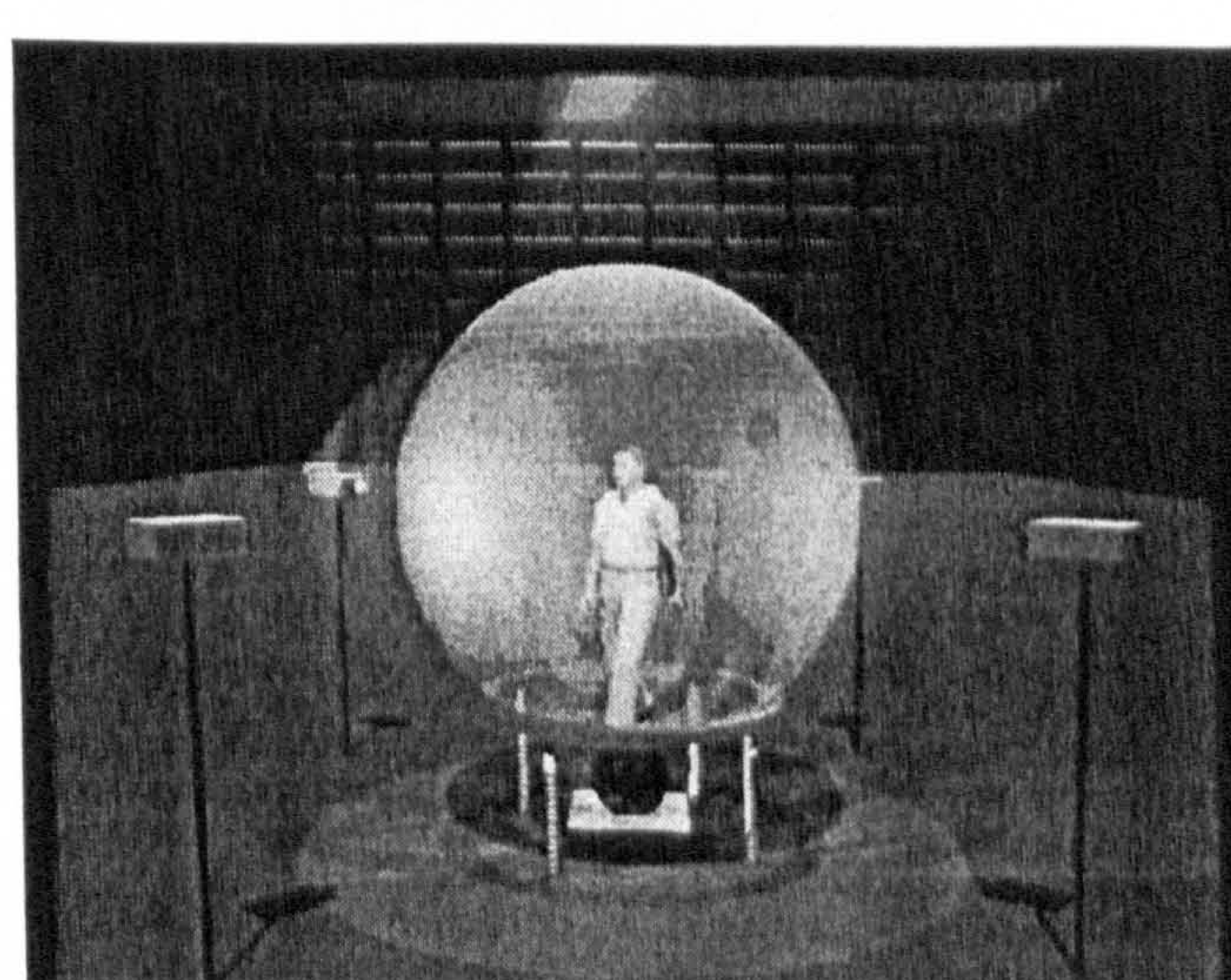

Figure 2.6 Cybersphere (http://www.ndirect.co.uk/~vr-systems/sphere1.htm)

The *Cybersphere* consists of a large, hollow, translucent sphere, 3.5 metres in diameter supported by a ring of bearings. An opening allows a user to get inside and the walking motion of the user causes the sphere to rotate. Computer-generated images, updated in response to the user's movements, are projected onto the outer surface of the sphere and can be seen from within the sphere. The observer is able to walk, run, jump or crawl in any direction, while at the same time being able to observe an all-encompassing virtual environment. It is not clear from the early prototype if there will be any interaction with the world but this could be considered for later versions.

Another type of semi-immersive system technology, called *DepthCube* is currently under development (www.3Dmedia.com). The high definition volumetric display uses projection systems to launch 3D objects into space that can be viewed without needing to wear any technology (see Figure 2.7).

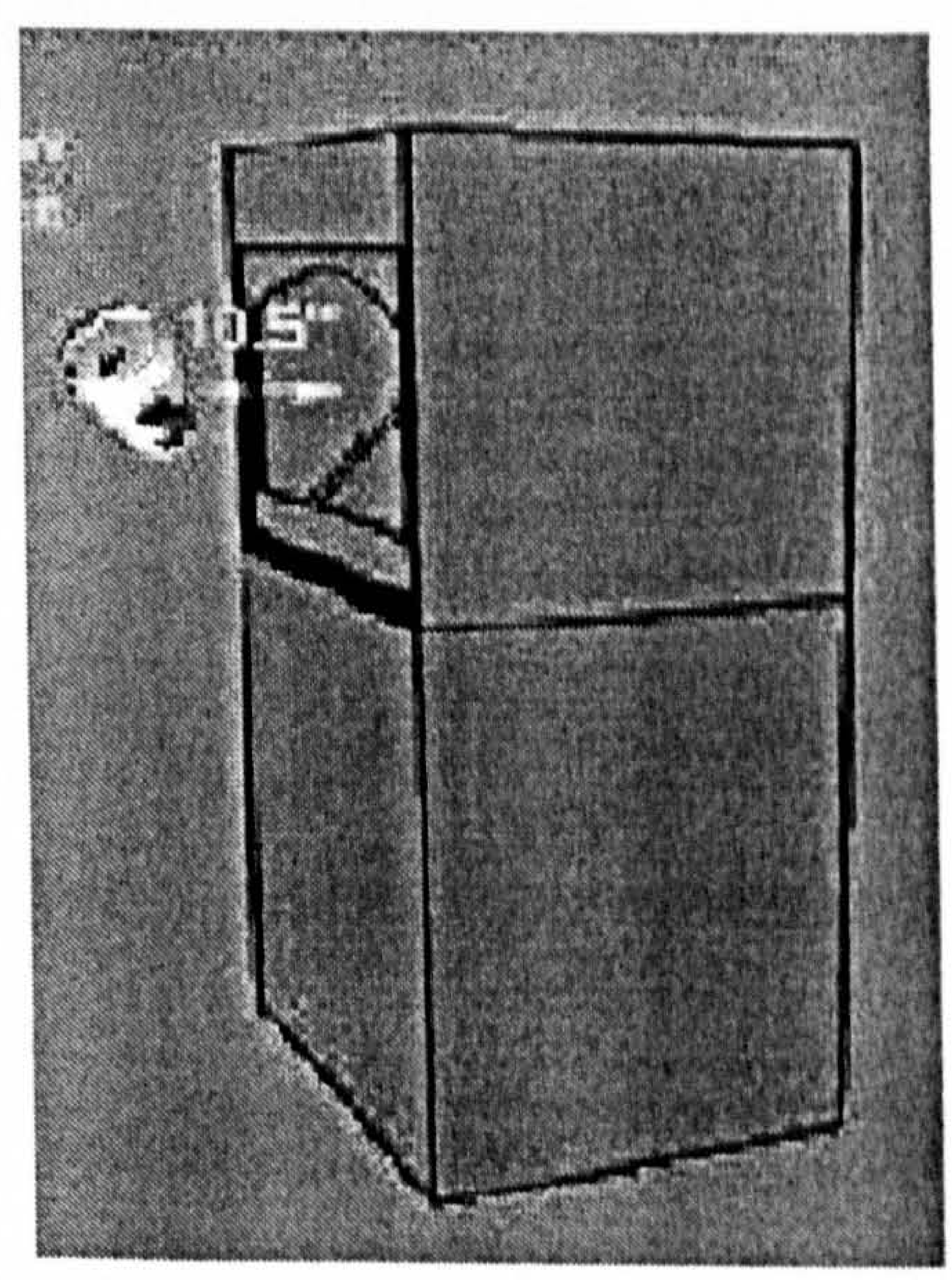

Figure 2.7 DepthCube Technology (3Dmedia.com)

At present users can control the objects using 3D buttons and the company is working on creating more sophisticated tactile feedback facilities. This system is currently being developed for a surgical simulator using an Army grant (VREfresh News, 2002).

Non-immersive VR systems

The above immersive and semi-immersive VR technologies have one thing in common; they are all expensive and this has hindered the selling of such devices on a large scale, especially for education and many training establishments. An alternative form of VR technology was developed that was relatively inexpensive and was considered to be more flexible (Austin, 1993; Schmitz, 1993). This type of VR system became known as 'desktop' VR because it operated on an ordinary PC system (although it needed to have high-end graphics and processing capabilities for best effect) (Regan, 1992). Desktop VR virtual worlds could be viewed on an ordinary computer monitor or projected to a large audience and some even enabled use of headsets or stereo-glasses (Schmitz, 1993). Users typically navigate through the world using a 6 degree-of-freedom (dof) space ball or space mouse (see Figure 2.8), although an ordinary mouse can be used instead.

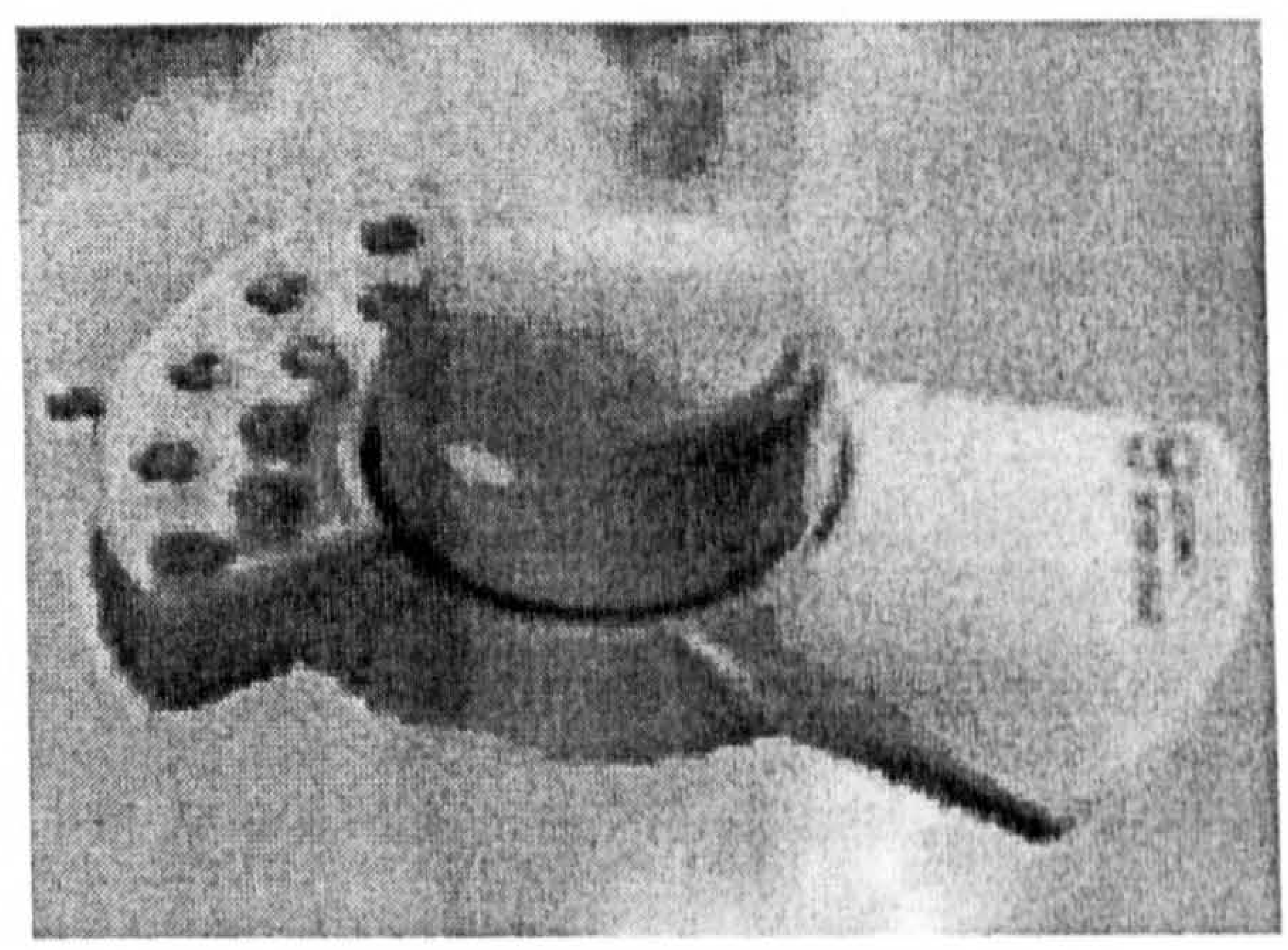

Figure 2.8 Space-mouse (Logitech)

Although some researchers have criticised desktop systems for not being 'true' VR because of a lack of immersion (Kalawsky, 1993; Winn, 1997a), such systems have proved very popular in the UK (Youngblut, 1998). Reviewing the literature and the media in the mid 1990s suggested that desktop systems had produced more practical applications of VR than immersive systems (Woodhouse, 1995). Byrne (1996) found that interactivity was more important than immersion in learning situations and some researchers found that desktop systems could produce a sense of immersion or presence if designed well (Mason, 1994).

2.1.2 Defining VR

At the start of the 1990s, the concept of what VR was, or should be, became enmeshed in terms of the technology (Helsel, 1992). Several definitions of VR as a technology were given. The most comprehensive was given by (Chiou, 1995, p. 328):

> "*VR technology is an integrated technology of computer hardware and software that requires the user to be fully immersed into the computer-generated, real-time and three dimensional virtual environment as an inside participant to look, listen,*

manipulate or interact, feel, speak, and even smell if it is possible; it may be a networked or a stand-alone technology".

A more recent technology definition was given by Ruzik and O'Connell (2001):

"Virtual reality is a special technology---usually a special computer system---that allows students to explore an artificial environment through computer-created sensory stimuli."

Many definitions in the early 1990s reflected the emphasis of research and development of VR hardware; however, several researchers argued that VR did not really exist because the technology could not match users' expectations of this term (Heim, 1993). They contended that VR was therefore a misnomer and proposed more suitable terms such as artificial reality, virtual environments, synthetic environments or cyberspace which were more suited to the offerings of the technology (Patel and Cardinali, 1994). Other researchers rejected this technological bias and argued that a conceptual definition was more appropriate for the advancement of VR, especially in learning situations (Helsel, 1992; Bauer et al, 1995). Definitions of VR as a concept do not specify any particular technology but define it as a process (Helsel and Roth, 1991, p. 38):

VR "enables users to become participants in abstract spaces where the physical machine and physical viewer do not exist."

or a state of mind (Macpherson and Keppell, 1997, p. 2):

"VR is a state produced in a person's mind that can, to varying degrees, occupy the person's awareness in a way similar to that of real environments."

In regarding VR as a concept, Latta and Oberg (1994) advocated the use of a wider definition of VR ranging from a flight simulator to a synthetic or virtual environment to telepresence. They suggested that any definition and conceptual model of VR must be robust enough to encompass all current forms as well as any others that might develop as the technology evolves. Helsel (1992) believed that debating over the meaning of VR wais not very useful and it would be better for VR designers to focus upon the processes of cognitive, social, emotional, spiritual issues of the user and think of the computer merely as a tool (Helsel, 1992). This idea was echoed by Carr (1995) when she highlighted the limitations of considering VR as a tool rather than a concept. As a concept VR is able to provide a framework in which various solutions can be implemented, whilst as a tool it can only be implemented and tested.

Investigation of the literature shows that most researchers have not defined VR with much reference to the social concept that Lanier talked about when he first introduced his VR system. And more than 10 years later, there have still been few social (or networked) applications in VR projects, especially in learning situations (Youngblut, 1998). Interaction with other virtual characters or with other people is an important part of VR as it adds to the realism and sense of presence for the user (see p. 27 and p. 35). Recently 3D social chat rooms, sometimes referred to as virtual reality or cyberspace, have started to be developed on the Internet (e.g. www.activeworlds.com; www.cybertown.com; www.thepalace.com; www.virtualiran.com). These enable users to communicate with each other in a 3D world via text messages. Emphasis is placed on the incorporation of 3D avatars that can be personalised and animated in order to make emotional gestures. Creation of such worlds as a means of communication and the development of emotions in avatars are becoming the focus of a new area of research (Olveres et al, 1998; Nijholt and Evers, 2001). This may become the virtual reality of the future. It certainly is a way for VR to be accessed by many people without large expense, and seems a likely way forward for incorporating VR into long-distance educational programs. However, the author's experience of accessing such 3D worlds shows that the capabilities of telephone modems (the most common way to access the Internet for most people at home) are too limited and downloading and interacting in these worlds is too slow even for a high-end graphics machine. The introduction of larger bandwidth communication links are necessary for most people to enjoy using such facilities unless the there is a significant advance in the programming of the software running these worlds.

A definition of VR would ideally combine the elements of the technology and the concept and the following definition is proposed by the author as suitable for this study and which takes in a number of the characteristics discussed in this chapter and emphasises the importance of an active and participatory learning environment.

> *VR is a feeling that the user is a participant inside a 3D computer world of objects and people, that can be understood, controlled and manipulated by the user, that will change and react to the user's behaviours and actions in real-time, that enable users to communicate with each other or with virtual characters in the world and allows for*

interaction with virtual objects in a natural and realistic manner.

2.2 VR as a New Type of Learning Environment

Although VR was first highlighted by the games industry as a tool for entertainment, and had been seriously regarded as an effective training and marketing tool, its potential has, more recently, been considered for educational purposes (Latta and Oberg, 1994; Winn et al, 1997; Youngblut 1998). One of the main reasons for this is the decreasing costs of the VR technology and in particular the low-cost and flexibility of desktop virtual reality systems (Kalawsky, 1996; Youngblut, 1998). The high costs of immersive VR systems have always been a barrier to research and development of VR environments, but desktop solutions, which can run alongside other types of multimedia software on classroom equipment, have provided an entry-level step into the world of VR (Macpherson and Keppell, 1998; Winn, 1997a; Youngblut, 1998). However, unless these desktop worlds are designed to make use of its special characteristics it may be just be seen as an extension to multimedia in the form of 3D graphics as proclaimed by Dede (1992). Several characteristics have been suggested as being exclusive to VR as opposed to other forms of multimedia; first-person perspective with high level of presence, interaction with virtual objects and characters, realistic movement with gravity and collision detection, realistic sounds, communication (avatars can move and speak even if only in a simple manner) with other avatars, fully participatory experiences, a wide range of non-linear, exploratory and experiential scenarios and within-the-world help systems. These will be discussed in more detail below. Although some suggested that, because VR could emulate everything in the real world, it could become the ultimate form of learning and training medium (Kelly, 1996; Wright, 1990), others have proposed that, more practically, it should used alongside, and complement, other more traditional forms of learning media (Dede et al, 1994).

Several authors have put forward lists of reasons for using VR in learning situations. Bricken (1992) suggested that VR provided experiential learning, intuitive interaction, shared experiences, unique new experiences, and could be tailored to individuals. Kalawsky (1996) listed opportunities for exploration (both spatially and semantically), sense of scale, simulation, repeatability, and abstract representation. Auld and Pantelidis (1994) writing about the application of VR with school-going children, claimed that VR offered self-paced acquisition of new information, opportunity for new types of insights, experience with new technologies and encouraged active participation rather than passive observation especially amongst the youngest of children. Pimentel and Teixeira (1992) emphasised VR's characteristics as the ability to fly, to occupy any object as a virtual body, to observe the world from multiple perspectives, to be in places too small or far away for humans in the real world and to be part of a powerful situation in which the time, scale, and physics can be controlled.

Several researchers in the 1990s recognised the importance and possible uniqueness of the interactive nature of VR (Barker, 1993; Pantelidis, 1993; Clark, 1993). Auld and Pantelidis (1994) advocated the use of VR for schools as it had the potential to change the way that students learned in a school setting. Rose (1995) suggested that the interactive and immersive qualities of VR provided the basis of a new form of experiential learning. VR also offers the opportunity for people to engage in learning activities and behaviours within a safe environment (Sϕby, 1993). It could also transform the way that teaching occurs. Rather than teaching facts or even concepts, virtual reality could present a rich variety of casual laws, communicating that there are many ways that objects, actions, and events might be related, and that there are many possible ways of looking at them (Sϕby, 1993). VR may provide a new type of symbol system that would enable students to use facets of the mind not encouraged by those of ordinary PC systems (Mikropoulos et al, 1997). Users of computer-based software usually have to provide cognitive effort to convert the screen's representations into the user's meanings just like the readers of books (Bricken and Coco, 1994). Traditional teaching materials usually teach the abstract symbol systems first; however, VR can bypass such a system by enabling a student to directly interact with concrete objects, a form of natural semantics thus reducing cognitive effort (Bricken, 1992, Bricken and Coco, 1994; Brown et al, 1997).

Barker (1993) contended that VR systems offered an opportunity for experiential learning and 'what-if' scenarios. Joyce (1989) claimed that an extremely effective training device is the 'what if' scenario. Knowing and understanding a key new concept involves not only grasping the meaning of the concept in the context in which it is introduced, but also seeing how that concept works in an awful context. Such scenarios can encourage trainees to think about new ideas into ways. First, the system can set up hypothetical scenarios and ask students what might happen under certain circumstances. Second, trainees can asked the system what might happen under certain circumstances. 'What if' scenarios are by no means easy to build into a system, but they are a refinement that can add immense training value. Larijani (1993) also highlighted the fact that using VR for 'what if' choices could encourage curiosity and creative thought in the learner.

Before any technology can enhance learning it must be designed to facilitate the human learning process. Learning tools need to be designed by people who understand how humans learn and solve problems, and VR is just another learning tool in this respect (Durlach and Mavor, 1995). The problem is that the learning process is still quite difficult to understand, there is no unifying theory of VR learning and there are no guidelines for designing virtual learning environments. Progress will be made when the unique attributes or characteristics of VR are identified and become independent variables in formal, science-based, evaluative experiments (Winn, 1997a). This thesis attempts to highlight some of these characteristics that will become part of an overall model of design for VR learning worlds.

2.3 Characteristics of VR

In designing a virtual world that will support the above definition, several characteristics need to be considered. Some of these characteristics are related to the technology or the VR system and others can be related to the VR software or content.

2.3.1 Characteristics of a General VR System

Several authors have discussed the essentials for a VR system that assist in providing a VR experience for the user. Avis (1994) proposed that the 3 main requirements for a VR system were immersion, natural interaction and multi-user capabilities. Vince (1998) contended that VR systems needed to have 3D navigation and interaction with a sense of immersion and presence. Zeltzer (1992) presented a framework for VR systems that consisted of three dimensions; autonomy, presence and interaction. Hedberg and Alexander (1994) suggested that VR could be measured along three dimensions: degree of immersion (sensory, conceptual and motivational), fidelity of representation of information, and degree of active learner participation. From a review of the literature and from the author's personal experience, a list of seven main characteristics has been proposed. These are important features or aspects of VR that support its nature and in some cases distinguish it as a new type of medium. It is important for designers to recognise these qualities and ensure that their designs take them into account.

3D Representation

One of the basic requirements for a VR world is that of a 3D computer-generated world (McLellan, 1991, Vince, 1998). Enabling a user to become part of a 3D world is one of the unique characteristics of VR. Interacting with virtual 3D objects is part of the fun of VR. Most humans have stereoscopic vision, which enable them to see the real world in 3D and this feature is what makes the virtual world seem realistic (Christou and Parker, 1995). Creators of 2D pictures have tried to induce a 3D effect by the use of various depth cues such as linear perspective, light and shadow and texture gradients (Goldstein, 2002). Sophisticated graphics programming enables a user of VR to get a perspective view, but in most VR programs all objects in the world, near and far, are all equally in focus. This is not really realistic. Ray tracing techniques can induce a depth of field effect in VR, but unfortunately this is not possible in real-time (Vince, 1998). Use of distancing techniques can give similar effects. Distancing techniques in software enable details of objects to disappear when the viewpoint of the user, relative to the object, is further away. Although the low resolution of VR displays has been criticised, details are only necessary when standing still and looking at an object. It is envisaged that users will be moving around in a virtual world and therefore designers may not need to provide high levels of detail for all objects. The field of perception indicates that when humans are moving around in the real world, or viewing an animation, the human perceptual system cannot take in details and therefore can accept a lower resolution image which the brain still interprets as normal (Goldstein, 2002).

Real-time

A second important aspect of a VR world is that it is designed to run in real-time. This feature distinguishes VR from other realistic interactive animations, videos and films that have been already created and are then played to the user. Real-time rendering in an interactive VR world means that the user can control what happens next; it is not pre-programmed. Not many authors refer to this aspect but it is central to creation of a VR experience. High-end graphics engines and cards are needed to process and display the vast array of 3D information in real-time, changing the display to take into account any changes, several times a second. This is called the frame rate and it has been suggested by psychologists that a frame rate of 60 per second is needed (Goldstein, 2002). Television uses a frame rate of about 30 and movies of about 60. Vince (1998) suggests a frame rate of at least 50 times a second. Achieving such frame rates for large, realistic VR worlds can be difficult for the programmer, but are necessary for producing a smooth motion effect.

Appropriate use of textures and distancing techniques help to increase the frame rate. Frame rates lower than 10 can cause a serious 'jerking' effect that can make it very difficult for the user to navigate and interact with the world (Draper, 1996; Pimentel and Teixiera, 1992; Winn, 1998). Another aspect of VR that is related to real-time rendering is that of latency or lag (Draper, 1996; So and Griffin, 1995). Users expect the world to react to their actions immediately as in the real world and a delay in the display updating to take account of the actions can if more than 0.25 seconds becomes a problem for the user (Vince, 1998). Displaying a virtual world on a desktop computer monitor does not entail any real lag but it can be a problem in immersive systems. Transmission lag can occur in translating head movements in a headset back to the computer in order to be sent back to the headset display. Lags of 40 ms or more can cause head-tracking errors that seriously disturb the user and such lags and errors have been the cause of the reported effects of malaise, dizziness and simulator sickness (So and Griffin, 1995). Vince (1998) suggests that a latency of no more than 50 ms is acceptable for VR.

Realism

One of the main criticisms of VR was that it did not look realistic enough, especially when using low-resolution headsets (Arthur, 1992; Stone, 1993). VR developments in rendering and in simulation were aimed at achieving photo-realism (Stappers, 1998) and use of textures and lighting was considered necessary. Photo-realism is not always desirable and there are plenty of examples where non-photo-realistic images are preferred in order to assess the relevant information (Lansdown and Schofield, 1995). Of course such efforts took a long time to design and contributed to a lower frame rate and great lag problems as highlighted previously. Realism is useful but only to a point. There are plenty of computer games that are not very realistic but are more engaging than some VR worlds because the games designers are better at using graphical tricks to improve the overall experience (Stappers, 1998). Realism of graphics is one issue but a more important issue is that of realism of behaviour and realism of scale. This seems to be more especially important in training and education situations where transfer of learning to the real world is vital. Programming realistic behaviour does take time and effort but can ensure that the world is taken more seriously for learning applications although constraints may mean that behaviour is simplified. For example in applications of fire safety, fires need to behave appropriately although it would be very challenging to create a truly realistic fire on low-end VR systems (Mason, 1994; 1996). However, the behaviour only needs to be 'convincing' (Stappers, 1998) rather than truly 'real'. Features such as collision detection and gravity can aid in making worlds more realistic. Realism of scale can be important for tasks such as workspace design and architecture. Incorporation of realistic scale is quite easy to do if the designer uses scale measurements during his design. One important point for learning, is that in some cases, realism is not needed. Some abstract concepts may be learnt more easily, by using simplified representations that may not be realistic at all, but none the less can transfer useful knowledge to the student (Dede et al, 1999).

Immersion

Immersion has been heralded as the major component of a VR system (Bicken, 1990; Hedberg and Alexander, 1994; Muscott and Gifford, 1994; Winn, 1997a); however, this has not really been proved (Robertson et al, 1997). Immersive systems are such described because the user is totally immersed in, or surrounded by, the virtual world and is not aware of the real world at all (Vince, 1998). The most common way to immerse a user in a VR world is to use an HMD or a *CAVE* system, which uses a tracking device that moves the world according to the user's head position (Robertson et al, 1997). Some researchers, however, have argued that an immersive effect can also be obtained by use of stereo displays and head-tracking (so called Fish-tank VR) (Ware, Arthur, and Booth, 1993). This is because a headset typically consists of two 2D displays, which are like smaller versions of desktop monitors and it is the ability to move the world with the head that seems to give the sense of immersion not the displays themselves. Durlach and Slater (2000) support this view when they say that immersion requires a match between the participant's proprioceptive feedback of body movements, and the information generated on the display. It has also been argued that immersive effects can be obtained in desktop VR conditions (Robertson et al, 1993) especially with the use of a new navigation aid called Peripheral Lenses (Robertson et al, 1997) or with a large window (Mason, 1994).

The type of immersion effect so far discussed can be described as physical immersion because it involves using devices to physically give the effect of being there (Hedberg and Alexander, 1994). However, there is also another type of immersion that is called psychological immersion (Hedberg and Alexander, 1994). This effect is related to the amount of 'immersion' that the user feels and is subjective. It has been suggested that it involves the same "mental shift of suspending your belief for a period of time as when you get wrapped up in a good novel or become absorbed in playing a computer game" (Pimentel and Teixeira, 1992, p. 15). This sense of immersion into the data space provided by the computer is determined by a complex set of elements related to the virtual world, the relationship which is as yet poorly understood (Psotka et al, 1993). Indeed, Psotka et al (1993) suggest that the ability to dream in colour can affect a user's sense of immersion. A third type of immersion is called motivational immersion, which is exploited by games designers (Hedberg and Alexander, 1994). Motivational immersion occurs when a user is enjoying interacting in the environment and is so absorbed that the degree of realism and fidelity of representation does not appear to influence this effect.

Whilst physical immersion is definitely seen as a unique aspect of VR, it is still not proven whether it is necessary for a learning environment. Studies comparing results of learning from use of immersive systems and non-immersive have given mixed results (Adams and Lang, 1995; Boyd, 1997; Slater et al, 1996). Within this study, it is assumed that designers concentrate upon the aspect of psychological immersion or presence and design worlds that encourage the user to feel a part of the world, whether or not they are physically immersed in the world.

Presence

Presence is seen as a state of consciousness or the psychological sense of being in the virtual world and is a subjective description of a user's mental state (Slater and Steed, 2000). Simply stated it is the sense of being in another place, the virtual place (Schuemie and van der Mast, 1999; Winn, 1998). Physical immersion with appropriate technology can give rise to presence (Slater and Steed, 2000). It seems to be more related to the concept of psychological immersion as it is subjective in nature (different users feel different amounts of presence with the same equipment) (Slater et al, 1994). Durlach and Slater (2000) suggest that factors such as field of view, display resolution, colour resolution and binocular disparity may affect presence. They also suggest that sound and realistic behaviours can enhance presence.

Winn (1998) suggested that presence was enhanced if there was a wide field-of-view, a match between the display and the users' movements, no noticeable lag or latency in the system and the system was multi-sensory, enabling natural interaction. Sheridan (1992) proposed four factors which might determine the amount of presence in a VR system; fidelity of information, match between users' actions and the system's responses, content, and user characteristics. Freeman et al (2001) added a fifth factor to this list; the social aspect of the

VR experience. The acknowledgement of a user's experience through the actions and reactions of other virtual characters (real or otherwise) can increase presence (Towell and Towell, 1997). However, although most studies seem to agree that presence is a multi-dimensional concept there is little evidence to confirm the existence of any relationships between these dimensions (Lombard et al, 2000).

Interactivity

Interactivity not only increases presence but also makes the VR experience more enjoyable (Winn, 1998). Interactivity, involving active participation, is one of the most important factors for VR learning and is a central theme in the concept of learner autonomy, which supports learning performance (Schwienhorst, 1998). Users need to believe that they are interacting with objects in the world, so they need to activate the door handle to open the door rather than have the door open when they approach. Natural interaction has been argued as one of the goals for which VR should be aiming (Winn, 1997a). Youngblut et al, (1996) carried out a comprehensive review of most of the VR technologies that were being used at that time and found that haptic devices, which would give a more natural form of interaction, were only being used for research purposes. Natural interaction is the key to immersion or feeling part of the virtual world (Winn, 1997a). When the body starts to move and interact with the world in a natural manner, then the brain can truly experience a sense of presence. For the brain to believe that the body is opening a door, the hand must actually reach out and twist just as it would in real life. For this to occur some sophisticated hand or body device would be required as part of the VR system which will enable the user to move their body as they would in the real-world in order to interact with the virtual world. It is, however, more common for less expensive navigation and interaction devices to be used such as the joystick or the ordinary PC mouse. These do not enable a natural six degrees-of-freedom movement, but can be translated by the use of software navigation devices such as provided with some VR browser software (see Figure 2.9). Users can navigate the virtual world by moving their mouse over the appropriate arrow in the navigation bar below the virtual world. Researchers have argued that whilst the mouse and keyboard can be used with VR, they are simply not sufficient for use with complex 3D virtual environments (Auld 1995; Cronin 1997; Kalawsky, 1996). However, other research has shown that navigation with immersions systems and wand or glove devices can also be problematic for users (Byrne, 1996; Dede et al, 1994; Mercurio and Erickson, 1990; Winn, 1997a).

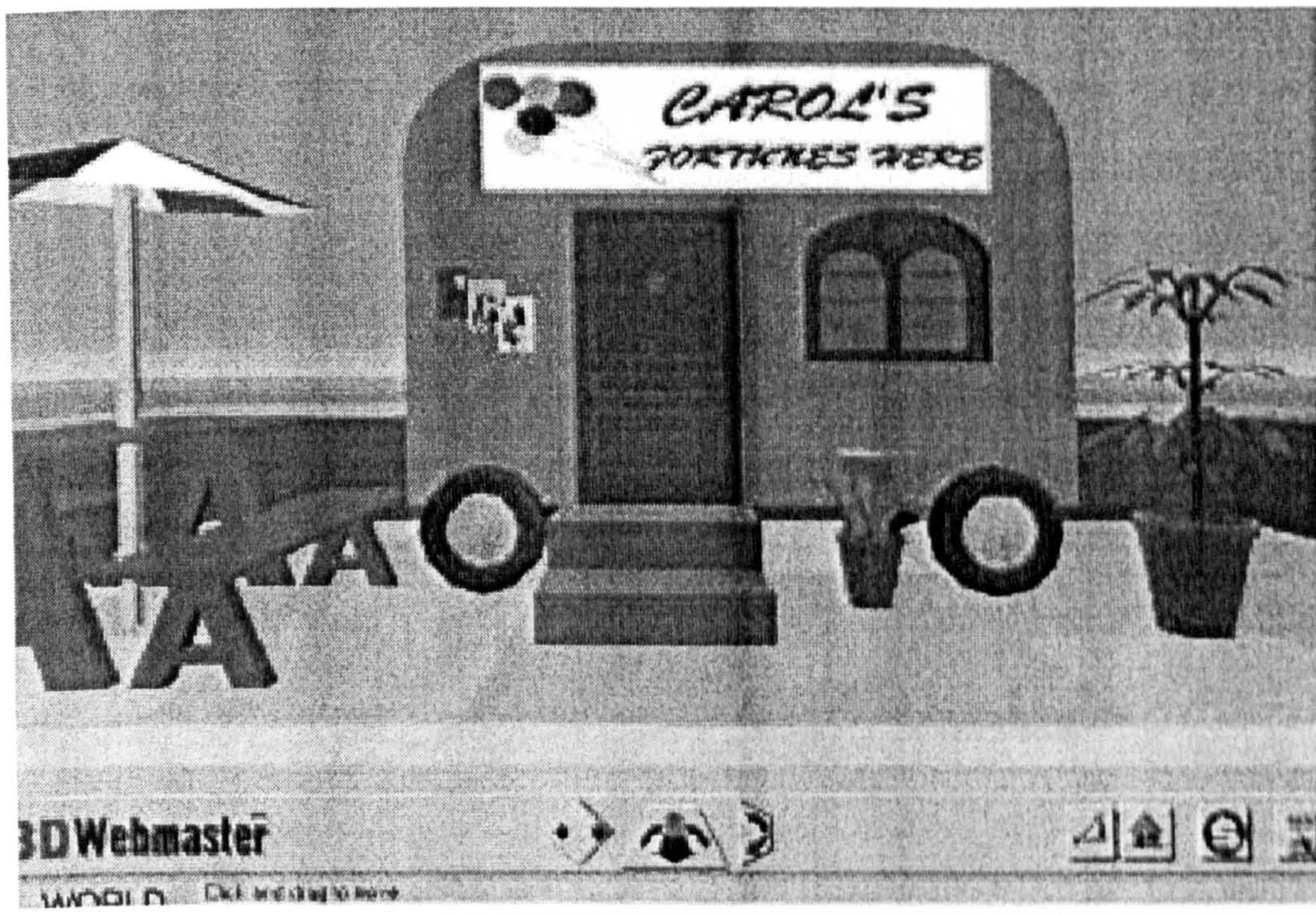

Figure 2.9 Navigation Bar at bottom of Superscape Virtual World

Although designing for natural interaction is challenging it should be seriously considered in all designs. The user interface is an important aspect to consider in the design of VR learning media as it directly affects the enjoyment and the effectiveness of the learning experience (Cronin, 1997). Some researchers have suggested that interactivity is more relevant to a high quality VR experience than realistically rendered images and objects (Amselem, 1995).

Communication

Whilst interaction with the application is a serious issue, interaction with other users is also important in providing an engaging and effective learning environment (Amselem, 1995). This last point does not seem to have been focused upon by many researchers until recently under the disguise of research into 3D avatars and chat rooms on the Internet. This seems strange given that the social aspects of multi-user systems were part of the original concepts of 'VR' as advocated by Lanier and also of 'Cyberspace' as advocated by Gibson (1984). Some desktop VR software packages do enable multi-user worlds to be designed quite easily and the author herself has had experience in developing multi-user prototype applications for the RAF. The *CAVE* system also had a multi-user aspect although this was very limited in that only one person could be actively tracked. Some of the VR games seen at conferences and in amusement centres include the ability for more than one player to be in the world at the same time.

Amselem (1995) argued that users could obtain a stronger sense of self by their interactions with other users. When actions are recognised and acted upon by other VR characters this can greatly increase the sense of presence (Towell and Towell, 1995). Multi-user VR worlds can also be useful for teamwork training situations (Amselem, 1995). For successful communication between users, a suitable multi-user communication system is needed. Typically the simplest method of communication is via the use of text messages that can be transmitted down the communication link using small file sizes that need little bandwidth requirements. A more natural form of communication would be provided if speech recognition and transmission systems were used (Karlgren et al, 1995). Use of speech in VR systems is covered in more detail in Chapter 6.

The Internet revolution of the past few years is encouraging researchers to focus upon the social communication aspects of VR. Research is now looking into the aspects of learning in multi-user or collaborative environments (Crook, 1994; Jackson et al, 1999; Roussos et al, 1997; Schwienhorst, 1998). Although multi-user worlds or distributed virtual reality can be developed over the Internet, their use is severely limited because of the low data bandwidth and high latency of most users' connections (Chen et al, 2000) and update rates can be frustratingly slow (Kalawsky, 1996). Although large files such as those of video and animations can be 'streamed' across the Internet (Song, 2001), this cannot happen for real time applications such as VR. The interest in providing multi-user environments over the Internet has also seen renewed interest in the development of avatars which can represent the users or act as autonomous intelligent agents within the world (Colburn et al, 2000; Johnson et al, 2000; Nass et al, 1995; Nijholt and Evers, 2001; Stansfield et al, 1995). Research is now looking at how realistically these need to be designed, e.g. improving their emotional and gestural capabilities.

The literature suggests that these seven characteristics are important aspects to be considered in design of any VR system. Thus the ideal system would enable the user to be immersed in a real-time 3D representation that elicited a considerable sense of presence in the user, perhaps by the realism of the graphics or the behaviours of the virtual objects within the world. It would also encourage natural interaction with the world, offering navigation and manipulation capabilities in all six degrees of freedom with facilities for sound, speech and possibly haptic feedback. The system should also be capable of providing communication with other virtual characters whether this is done with intelligent avatars or by multi-user participation. Thus the VR systems would be able to support the definition of VR proposed by this study and given earlier in this chapter. These features would enhance the sense of presence and provide a truly active, participatory world for users.

2.3.2 Characteristics of the VR Learning Environment

Many of the characteristics above are also important for a VR learning system, but designers need to ensure that the VR software or learning environment is designed to exploit its special attributes or qualities that will identify VR as a new and effective type of learning medium. This section proposes several characteristics that designers need to take into account in order to develop active, participatory learning environments.

In considering the design of VR worlds for learning purposes, there may be a need for a new metaphor and a new language (Winn, 1993). The design of the world can be related to the real-world in most situations, where objects and behaviours are designed to be as realistic as possible. However, in cases where this is very difficult or time-consuming, a trade-off can be made. Recognition is seen as more important than absolute realism (Heim, 1993). Many cartoons work on this principle. A useful metaphor for the user's role is that of the theatre (Laurel, 1993). Laurel associates VR with the role of the audience and immersing themselves in the play. However, this metaphor assumes a passive role for the user (audience) and does not support the active, participatory nature of VR as described in this study. Instead, the role of the actor is considered more appropriate. The actor takes on a role, with new clothes and props, and participates in the action within a simulated environment. Although the actor often has to keep to a script, thus limiting their activities, it still seems a more appropriate metaphor for VR. W. Bricken (1990) suggested that the user would shift from that of an external, passive observer with certain rights to that of an internal, active participant with certain responsibilities. Bricken also suggested that a new language be considered as shown in Table 2.1.

Table 2.1 New Language for VR (W. Bricken, 1990)

Computer-based Software	VR
Picture	Place
Observe	Experience
Use	Participate
Interface	Inhabit

In order to support this new metaphor and language, designers need to ensure that their software encourages the following qualities or characteristics that will encourage users to be active participants.

Active Participation

The idea of being an active participant (Mason, 1996), as an important, if not the most important, feature of VR, is supported by many researchers in the field of VR and learning (M. Bricken, 1990; W. Bricken, 1990; Brown et al, 1996; Helsel, 1992; Auld and Pantelidis, 1994 Winn, 1997a). Other traditional forms of learning media, such as television, film, video, lectures, tend to support passive observation (Stuart and Thomas, 1991). Even in so-called interactive multimedia software, the user is still relatively passive, in that the only actions that they can do is press buttons or mouse-click icons in order to select the next piece of information to view from a limited range of options (Hedberg and Alexander, 1994). In VR, the user is actually placed inside the information. Indeed the user, in many cases, can interact with the information, change the information, and in some cases become part of the information.

By engaging the user in an active participatory role, VR can promote learning (Pantelidis, 1993). If the VR world is designed with intuitive and interesting interactivity, then it seems unlikely that the user will want to remain a passive spectator, curiosity should engage the learner in becoming more active (Pantelidis, 1993). Active participation in a VR world may prove to be a powerful way of increasing understanding and in the transfer of concepts to new contexts (Hedberg and Alexander, 1994). Furthermore, it has been shown that passive learning, especially of declarative knowledge, has been widely criticised for producing fragmented and non-integrated learning (Rose, 1995). It has also been suggested that passive tasks such as reading and writing could be enriched by the addition of VR, which could bring the topics to life for the student and engage them in the learning process (Marcus, 1992).

The idea of participation in a VR environment is a much more sophisticated concept than interaction with a multimedia or CBT package (Hedberg and Alexander, 1994). One of the first examples of the use of VR in education was provided by Denton School in the UK (Clark, 1993). Children participated in the creation of 'Dangerous Workplace', a VR desktop world that taught health and safety issues to young children. The results of this pioneering study showed that this type of learning was enhanced using desktop VR and highlighted its potential as a powerful learning tool if used in an active, exploratory manner.

Non-Linear Nature

Another useful feature of VR learning environments is that they are non-linear in nature. Many CBT and multimedia packages are still designed with linear steps, although there may be some flexibility in the order with which they are taken. VR worlds are not designed with any form of linear framework, although actions may be a sequence of events and objects should be designed as stand-alone objects with a certain amount of intelligence (Larijani, 1993). Within the design of a virtual world, it is usual to let the participant decide where to go, what to do and what situations are to be set up. In fact, situations can be simulated which were not intended or even considered by the VR designer. This feature has been described as providing 'what-if' scenarios as students can set up certain situations that may never have been encountered in the real-world and 'see' what happens (Barker, 1993; W. Bricken, 1990). This encourages active participation, however, some structure or guidance may be needed, especially in training situations where certain procedures must be learnt. The author (Mason, 1994; 1996) created a fire-safety prevention world for the RAF, which enabled students to set up certain fire-safety features such as fire resistant doors and walls and fire exits. A fire could be started or maybe two and students could watch the results. Intelligent virtual characters were included which could try and escape given various pre-programmed rules. The use of random variables for features such as delay before escaping, speed of escape, ability to tolerate smoke, panic, etc enabled students to observe possible human behaviour in the fire situation. The students could also become participants in the world and learn what it was like to try to escape from the fire, could they hear the fire alarms, could they find the fire exits, were there enough exit signs, could they be seen in the smoke etc. Many different 'what-if' scenarios could be set up and the consequences observed; a powerful method for learning because it encourages curiosity and stimulates the thought processes necessary for creative work and encourages active participation (Larijani, 1993).

Sense of Presence

Immersion and presence have already been discussed and are considered to be a very important aspect of VR by some authors because of its potential to provide new and unique learning experiences for the student (Bricken, 1992; Osberg, 1993). The view is supported by evidence presented by Cronin (1997) who showed that immersion or presence is a subjective concept, because different users rated themselves as having differing experiences of immersion using the same VR equipment. It has also been found that an interface that allows natural interaction is an important factor for a high sense of presence (Furness et al, 1997). Psychological immersion can also be related to the motivation of the user or participant within the VR world (Hedberg and Alexander, 1994).

Attempts have been made to try and measure the amount of presence experienced by a person even though this is quite difficult (Schuemie and van der Mast, 1999). Such attempts have commonly used self-reporting questionnaires but these have been criticised as being unreliable (Freeman et, 2001). Measuring presence is complicated by the fact that it seems to be a transient state and is variable in the same person under the same conditions (Sheriden, 1992). Differences in the individual such as anxiety, depression, motivation etc are likely to increase or decrease presence (Huang and Alessi, 1998). Research has also found that presence may decrease with age (Winn, 1995).

First Person Perspective

One of the important aspects of VR for role-playing and for a sense of presence is that of the first-person perspective (Psotka, 1995; Winn, 1993). First-person perspectives have been called 'egocentric' viewpoints and can be compared to 'exocentric' or third-person viewpoints (Chee, 2001b; Furness et al, 1997; Slater et al, 1994). In a theatre or watching a video/film, the audience sees the action from a distance; this is called the third-person perspective. In some computer games it is more usual to have a third-person viewpoint that follows the character and the action and some users believe that this enables them to navigate the character more easily. In VR it is possible to create different viewpoints and some of these may follow the action from a third-person perspective. However the first-person perspective enables the user to become a character or object in the world and enhances the feeling of control and presence (Chee, 2001b; Winn, 1993). Designers need to incorporate the first-person perspective into their designs in order to encourage active participation, enabling the student to become part of the action instead of the observer; he or she becomes the actor and not the audience.

These first-person experiences are very private and are of the same quality as would be experienced in the real world (Winn 1993) and thus may be important when considering transfer of learning from the virtual world to the real world. In addition it has been argued (Psotka 1995) that using this first person mode can enhance learning because it reduces the individual's conceptual load. This is because the user, when faced with the third-person view, has to adopt a 'virtual self' and imagine what the first-person viewpoint would be, thus giving the brain more work to do. A well-designed VE could easily overcome such problems and increasing the quality of immersion/presence that the user experiences as well as freeing up cognitive resources.

Multi-user

VR has the capability of providing multi-user applications, although it seems that this has not properly been exploited. Networked PCs or *CAVE* systems enable more than one user to take part in the same world, each taking on a different avatar or role. In most *CAVE* applications there is only one active participant, the others are passive observers (Czernuszenko et al, 1997), but in networked desktop VR systems, all users can interact with the world. Unfortunately, either due to extra costs, or to extra complex programming, not many of the applications in the literature have been described as multi-user. In some intermediate cases, there is one 'real' user and they interact with other autonomous virtual characters in the world, thus seeming as though the application is multi-user. True multi-user VR offers the opportunity for collaborative learning and may well foster new forms of social interaction (Jackson et al, 1999; Stuart and Thomas, 1991). In particular it can enable remote collaboration on projects by people in different countries (Psotka, 1995). It also makes it possible for a teacher or instructor to observe the learning from within the world, perhaps without the students knowing, or to assist in the learning process from the confines of another virtual avatar. It is likely that there will be more multi-user applications in the future as the importance of multi-user virtual reality is starting to become a major factor in education (Schwienhorst, 1998).

Distance learning is not a new concept, but until recently it suffered from the lack of direct interaction between the instructor and the student. This meant that the students could not easily ask questions of the instructor and the instructor was not able to see any immediate problems to the presented information (Weiss and Jessel, 1998). Video conferencing facilities have been advocated as the solution to this problem, but unfortunately this has not proved to be as popular as expected (Weiss and Jessel, 1998). It has a drawback of needing a high bandwidth with steady transmission in order to produce the quality of video images needed for good communication especially when more than a few users are participating at the same time (Walker and Shepherd, 1997). It has also been found that with the small low-quality video images, students do feel that they have achieved any sense of presence within a shared meeting space (Walker and Shepherd, 1997). VR has the potential for bringing better quality images and a greater sense of presence and fun to long-distance meetings. Initial research (Towell and Towell, 1997) has already found that in a group of 53 participants, represented by avatars, some 74% reported a high sense of presence with the other participants in the meeting room. Research is now underway to look at the issue of avatar design, in order to make them more realistic, enabling them to have a range of expressions and gestures that can aid communication by portraying a sense of emotion (Colbourn et al, 2000; Johnson et al, 2000; Nass et al, 1995). Emotion in avatars was found to assist students in the communication process (Johnson et al, 2000).

Multisensory Environment

VR can provide the basis for a multi-sensory experience that can contribute to sense of presence and realism encountered by its users (Zeltzer, 1992) and can increase their learning (Furness et al, 1997; Psotka, 1995). It has been found that people have different learning modalities (see Chapters 4 and 9). Although VR tends to concentrate upon graphics, this can only offer learning in the visual modality and may not be optimum for those people who learn best with auditory or kinaesthetic learning modalities (Zeltzer, 1992). By including a full range of speech, 3D spatial sound, tactile, force-feedback and olfactory sensations, VR can provide for all types of learners.

Designers need to ensure that sound is incorporated into VR worlds. Sound is necessary to have conversations in the world, to hear things happening in the world; background noise is necessary to make the world appear more realistic. Some worlds do offer sound but it is often limited to a few noises such as door creaks or dogs barking. Conversations are a natural form of communication in the real world and ideally speech recognition systems need to be integrated into VR to enable users to speak to the virtual characters. This would be particularly important in a learning environment where help is needed. A virtual character or avatar could represent the helper or teacher and learners could 'talk' with this character. The character (whether this is an intelligent computerised agent or whether it is the virtual body being controlled by a 'real' person across a network) would be able to offer guidance, help and feedback to the learner via speech. Speech would enable users in a multi-user environment to understand what each other was thinking or doing. 3D sound may add to the realism of a world, but providing 3D auditory cues may not be reliable since each person's ear configuration is unique and some users have difficulty in localising 3D sounds (Pimentel and Teixeira, 1992; Wenzel et al, 1991).

Haptic or kinaesthetic capabilities are vital for increased realism and enhance interaction (Hoffman, 1998; Pimentel and Teixeira, 1992). Uses of haptic devices to give tactile and force feedback are necessary for a true sense of presence and for highly natural interaction to take place (Macpherson and Keppell, 1998). Incorporating haptic technology such as tactile and force feedback into a virtual world usually entails using more sophisticated clothing devices. Tactile feedback is where forces are acting upon the skin to give a feeling of texture whereas force-feedback is where forces are acting upon the muscles to give a feeling of weight and mass. Force-feedback would be useful to give extra realism to collision detections that can be programmed into the worlds. Users need force-feedback to gain an impression of what textures are like in the world, how heavy or stiff objects are when they try to move them etc. Stone (1993) discussed the need for tactile and force-feedback systems and described the potential of a new field of research called 'Biocontrol'. Biocontrol is a recording method that enables the control of virtual processes from bio-electric or electro-physiological signals from the human body. Although the concept of biocontrol has been of interest only to followers of science fiction, new technology developed initially for seriously handicapped individuals are now being considered as part of a VR (Stone, 1993).

Unfortunately, not only are such devices going to be expensive, they are still proving to be a challenge to design effectively. Interestingly, in the 1950s, Morton Heilig developed a type of multimedia kiosk (Macpherson and Keppell, 1997) called the '*Sensorama Game*' (see Figure 2.10).

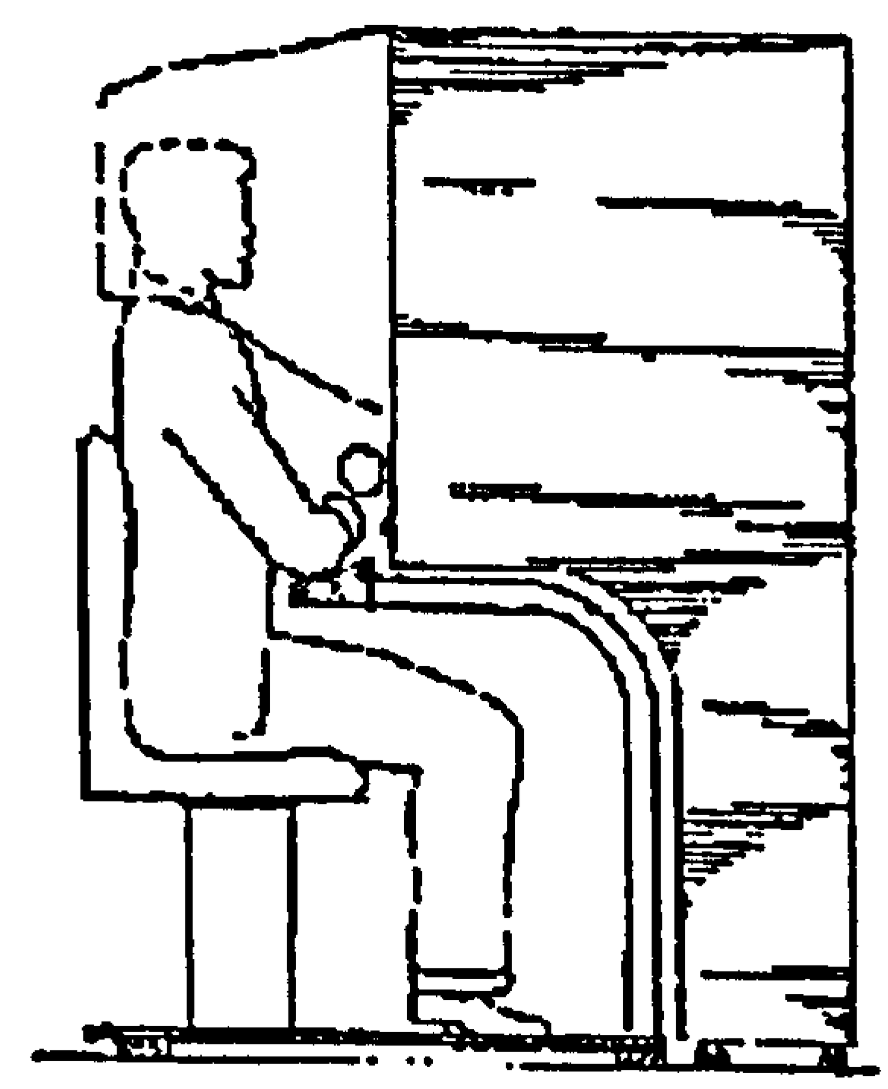

Figure 2.10 The Sensorama Game

This kiosk was basically a motorcycle simulator that enabled members of the public to experience a 'VR' ride through Brooklyn. Users could see a video sequence of a ride through the streets of Brooklyn, passing various shops. Heilig included realistic sounds and smells within his system and the motorcycle seat vibrated to enhance the experience for the user (Stone, 1993). Thus some kinaesthetic and olfactory sense devices could be considered without huge costs.

Research into providing tactile senses has lagged behind the development of visual auditory senses but the benefits of being able to feel collisions and textures in the world is enormous (Kahaner, 1994). One study in particular highlighted the advantages of using augmented tactile feedback (Hoffman, 1998). In this study, subjects were immersed in a virtual world and were asked to pick up a candy bar and imagine biting into it. This experience was compared to a group that used augmented tactile feedback where they actually picked up the bar and bit into it. This group rated the experience as more realistic and enjoyable than those in who just picked up the bar using a 3D wand device. This result seems obvious and a better experiment would have compared augmented tactile feedback with full tactile feedback. Volkov and Vance (2001) carried out an experiment to investigate the effects of how a haptic device might influence learning. The study found that haptic devices significantly improved the accuracy of users' estimations and significantly reduced the time taken to evaluate a parking brake design. A survey of the participants showed that they had a strong preference for having the haptic device.

Full multi-sensory participation is costly and challenging to create, but if it can fully engage the student, stimulating cognitive, affective and psychomotor skills, a powerful cocktail for successful experiential learning, (Ferrington and Loge, 1992; Osberg, 1993), then this needs to be encouraged.

Natural Interaction/Communication

One of the ultimate goals of a VR environment is to have such natural interaction between the user and the system that the interface becomes invisible and the users do not even realise that they are in a virtual world (Bauer et al, 1995; Hedberg and Alexander, 1994). An example of this can be seen in the example of the '*StarTrek Holodeck*'. However, such technology is a long way off this as yet. Currently, users have to use various input and output devices to navigate and to interact with the world. Typical interaction actions include clicking on or pointing at objects in the 3D world. This is not natural, and an even worse method of interacting is via the use of menus to obtain the action that is needed at that time (Hedberg and Alexander, 1994). Users need to be able to directly manipulate objects in the VR world.

It is also not very natural to have to interact with characters in the world by use of a mouse or wand. A more natural way of interacting would be the use of speech communication (Winn et al, 1999). These can be simple 'walkie-talkie' type systems for communication between users on a network system, or more complicated speech recognition systems that enable users to interact with intelligent avatars within the world. Current developments of speech systems are still limited in that they can only recognise known users, and the users need to ensure that everything they say is correct and they have problems recognising worlds in different environmental conditions (Noyes, 2001).

Another aspect about natural interaction is the way that the system responds to a user. In order to get help or instructions, it is common for a user to use on-screen text. This does not seem a natural form of communication for a VR world that is mimicking a real-world situation. It would be more appropriate to use objects in the world to give help and a natural form of such communication would be speech. Characters in the world need to be able to speak to the user (see Chapter 9). Natural interaction using 3D manipulators, speech, gestures and motion instead of programming keyboard and mouse, can enable VR to teach new types of learning such as causal laws rather than teaching facts and concepts (Mikropoulos et al, 1997).

Fun and Motivating

One of the problems with public education is that there are still too many children who are under-motivated, disengaged and under-achieving (Muir, 2002). As a direct result, many of these children get irritated and angry at the educational system and play truant or cause problems within the school. It has been suggested that these students tend to find the ways that subjects are taught at schools are too abstract and too complicated to understand (Muir, 2002). Also a mismatch of learning and communication styles between student and teacher can contribute to learning problems (Cilley and Watson, 1994; Poon Teng Fatt, 1993; Rushby, 1988; Srisethanil and Baker, 1995). Teachers are always finding new ways to try and motivate these students, and VR seems to have the potential to alleviate some of these problems by providing a new type of learning environment that can be very motivating (Muir, 2002; Winn, 1997a).

Research suggests that VR can be useful in education because it can be entertaining and fun (Brown et al, 1996; Osberg, 1993), certainly more so than traditional classroom learning (Ferrington and Loge, 1992). Studies have shown that even children who may not like computers enjoyed using VR (Bricken and Byrne, 1992; Byrne and Furness 1994; Osberg 1993). This enjoyment factor is not just limited to children; virtual worlds proved to be enjoyable and motivating to adults in the RAF (Mason, 1994; 1996; Schaefer and Wasserman, 1995).

It has been shown that VR can increase a student's motivation by its novelty factor and its disguise as some form of new game (Pimentel and Teixeira, 1992). Indeed there is considerable research to shown that learning can be enhanced by games (Malone, 1981; Pimentel and Teixeira, 1992). Malone (1981) presented a theoretical framework for intrinsic motivation in the context of designing computer games for instruction based on three qualities; challenge, fantasy, and curiosity. He further argued that intrinsically motivated activities provided learners with a broad range of challenges, concrete feedback, and clear-cut criteria for performance. Playing has also given importance in several learning theories such as those of Piaget, Vigotsky and Bruner (Brown et al, 1996). A term describing this form of entertainment and educational software is 'edutainment' (Psotka, 1995). Psotka argued that edutainment has enormous potential and consequences for education because it can liberate the imagination and it can provide interesting ways of exploring great quantities of information.

Role-Playing

One of the goals of public education is teaching people to work together as they would do in real-life in general and in a typical job situation in particular (Stuart and Thomas, 1991). VR can offer not only a way of communicating and collaborating with other people but enables the users/participants to take on roles of other people in the situation and see the world from their viewpoint. Role-playing is very useful in teaching empathy (Stuart and Thomas, 1991). This is identical to the way that people have taken part in role-playing games and training exercises for many years and support the metaphor of the actor as described earlier. However, VR takes this one step further, because in VR participants can become much smaller or much larger than they could in real-life. Children can become adults and adults can become children (Stuart and Thomas, 1991). Handicapped people can become able-bodied and vice versa (Inman, 1995). Users can become tiny atoms or they can become huge planets. They can view the world from many difference perspectives and take on the role of people, animals and inanimate objects without the other participants knowing. Actors pretending to be animals or trees etc. in real life would in most cases be easily identified as such by others. Although some of these role-playing capabilities may not be realistic for users in the real-world, they are important for learning in that they can enable learners to understand concepts or situations form new angles and perspectives and may need to become part of some learning software.

Visualising Special Situations

One of the more attractive features of VR is the ability of it to display objects and situations that are not normally visible in the real world. For example users can 'fly' into a fuel pipe in a car or touch the atoms of a complex molecule (Barker, 1993). VR can offer a safe place that can train people in situations that would be too dangerous or hazardous in real world (Brown et al, 1996; Kalawsky, 1996; Kelly, 1996; Weiss and Jessel, 1998). Such a facility is extremely valuable to the student if it enables them to learn skills and procedures by making observations and mistakes in a safe environment before trying out in the real-world. It is also necessary to point out that this powerful feature may also be a weakness if it creates a false sense of security to the learner, who does not then realise the true consequences of making errors in the real situation (Kalawsky, 1996). Such problems have been found in the training of airline pilots using simulators (Kalawsky, 1996).

VR also provides a means of visualising and learning about abstract concepts (Byrne, 1996). Science subjects such as chemistry, biology or physics requires visualisation of complex and abstract concepts e.g. what does an electron look like, how do neurons transmit energy etc. Through 3D visualisation and different perspective experiences, students can gain a better understanding of how such things work. This goes beyond what can be offered by 2D diagrams and 3D animations in multimedia software. VR can present the experience first and then try and explain the underlying symbol system (Bricken, 1990). Participating inside the conceptual information or data, in a VR world, can lead to a form of deeper learning (Chee, 2001b; Larijani, 1993).

2.3.3 Design Guidelines for VR Learning Worlds

There is a lack of information about the design of VR learning environments. Usability and health and safety factors in the design of VR devices have been considered in the literature, although not in any great depth (Kaur, 1998). Little has been written about the design of the software content, other than general comments such as design for interactivity and realism. There are no guidelines for new VR designers to follow and create effective software; often they follow guidelines given by the client and very rarely ever have access to users in order to evaluate their creations (Kaur, 1998). If VR is going to fulfil its potential as an effective learning medium, then practical guidelines and principles need to be determined.

This chapter has reviewed the literature and proposed a number of areas that need to be considered in the design of active, participatory VR learning environments. These areas need to be considered by designers and a number of guidelines can be drawn up from the literature that can be used in a general design model (see Chapter 5).

In the field of learning it has long been recognised that computer-based instructional software should be designed upon principles based on a sound theoretical basis (Saettler, 1990; Schiffman 1995). Such theoretical design principles are also necessary for the design of VR learning material (Winn, 1993; 1997b). In order to propose a suitable framework for VR design, the literature for learning theories and instructional design needs to be considered for relevance to VR design. These areas will be reviewed in the next chapter.

CHAPTER 3: THEORETICAL PRINCIPLES

3.1 Learning Theories

The literature suggests that a designer of learning environments should ground him/herself in some knowledge about models or theories of learning in order to design effective learning material (Pont, 1991; Schneider, 1994; Wilson, 1996). In particular knowledge about the nature of learning and the learning process is necessary if designing material to encourage this. Although considered a monumental task because of the vast range of information on learning theories, it is appropriate to have some grounding in theoretical approaches because instructional design procedures do not often work (Winn, 1997b). Winn suggests that this is because they are based on a false premise, that human behaviour is predictable. He further argues that when an empirical approach fails to identify appropriate instructional methods then the designer must be able to use principles of learning theory to guide him or her.

A large number of different learning theories have been proposed over the last decade. Marks (1999) identified around 32 different theories and Kearsley (2001) has compiled an online database of over 50 such theories. In attempting to find a learning theory for VR no one theory has been recommended above any others, although situated learning, collaborative learning and constructivism have been proposed. Chiou (1995) reviewed several rationales for the design of VR learning software (constructivism, case-based learning, problem-based learning, apprenticeship and situated learning), but was unable to decide on one rationale because they all have useful points to consider. It was decided that for the purposes of this study to take an approach that would not recommend any one learning theory, but to consider aspects from a number of the learning theories of the last century. Around sixty different learning theories were considered and twenty-eight were identified as having possible value for VR. A list of these theories can be seen in Table 3.1.

Pont (1991) distinguished between behavioural and cognitive learning theories; Mergel (1998) classified learning theories into three types; behaviourist, cognitive and constructivist. However, these categories were limiting for the number and types of theories that were assessed in this thesis. Instead, four categories were identified: stimulus-response theories, cognitive theories, active learning theories and computer media learning theories (see Table 3.1). The term stimulus-response was used as this encompasses behaviourism and other associationist models and theories that were being proposed at the start of the last century. Cognitive theories remain as a category but are theories that related mainly to the information-processing concept. Active learning theories have been chosen as a description of the third category rather than the term constructivism because it encompasses a larger range of theories, it also includes adult learning theories and because it includes the idea of guidance, which is often considered unnecessary by pure constructivists (Jonassen, 1991). It is not proposed here that these theories are not cognitive, but that many of these theories and frameworks might also be considered as a subset of cognitive theories, similar to the argument by Di Vesta (1987) who suggested that constructivism was a cognitive learning theory. Several theories and models, which do not really fit into any of the previous categories but are relevant to the design of computer media and are also presented in this chapter under the category of computer media learning theories.

Table 3.1 List of Learning Theories/Models with Relevance for Instructional Design

Stimulus-Response Learning Theories	Cognitive Learning Theories
Association: Ebbinghaus Classical Conditioning Theory: Pavlov Connectionism: Thorndike Behaviourism: Watson Contiguity Theory: Guthrie Operant Conditioning: Skinner Learning Outcomes: Gagné	Gestalt Theory: Wertheimer Genetic Epistemology: Piaget Subsumption Learning Theory: Ausubel Mastery Learning: Morrison/Bloom Information Processing Theory: Miller ACT: Anderson Multiple Intelligences: Gardner
Active Learning Theories	**Computer Media Learning Theories**
Discovery Learning: Bruner Experiential Learning: Rogers Andragogy: Knowles Adult Learning: Cross Situated Learning: Lave Participatory Learning: Freire Action Learning: Revans Anticipatory Learning: Botkin	Information Pickup Theory: Gibson Minimalism: Carroll Symbol Systems Theory: Salomon Dual-Coding Theory: Paivio The Parallel Instruction Theory: Min Multimedia Learning Theory: Mayer

Many of the learning theories and models presented here have been applied in a variety of learning situations and in the last 30 years have included the design of computer-aided learning materials. Behaviourism has influenced programmed instruction (Kulhavy and Wager, 1993); cognitive theories have led to artificial intelligence and more sophisticated types of CAL programs (Bai, 1996). Active learning principles are being investigated for use with adult learning programs and the Internet (Pickering, 1995). More recently several learning theories have been proposed to explain factors that assist the learning process when dealing with technology based learning such as simulation and multimedia (Moreno and Mayer, 1999).

3.2 Framework for VR Design

In reviewing the literature on VR and learning theories, three theories dominate: constructivism (Rose and Billinghurst, 1995; Roussos, 1997; Winn 1993), situated learning (Chiou, 1995; McLellan, 1991) and collaborative learning (Chee, 2001a; Jackson et al, 1999; Schwienhorst, 1998). There is also a case for developing a VR paradigm on the basis of experiential learning (Psotka, 1995; Osberg, 1997a; Wagner and Campbell, 1994). However, as stated previously, the following four categories of twenty-eight theories will be considered for the basis of a new general VR design framework and model (see Chapter 5).

3.2.1 Stimulus-Response Theories

Most of the learning theories before the 1960s were stimulus-response theories that embraced the ideas of associationism, classical and operant conditioning, behaviourism, purposive behaviourism and connectionism (Hill, 1997; Schwartz and Robbins, 1995). Many of these theories have also been described as reductionist or 'black-box' theories, mainly because they reduce their ideas to observing what went into the brain (the stimulus) and what came out (the response) (Gray, 1979). They did not deal with what went on inside the brain. Stimulus-response theorists believed that they could categorise learning as the response to certain stimuli (Skinner, 1950). They attempted to give mechanistic explanations for human learning from observations of human behaviour.

Stimulus-Response Principles for Instruction

Ebbinghaus was the first person to consider the investigation of learning as a science and concentrated upon the area of memory using himself as the only participant (Hill, 1997). He found that nonsense syllables were quickly forgotten and had to be constantly rehearsed. Pavlov is associated with the concept of classical conditioning, which asserted that natural behavioural responses to certain stimuli could be transferred to other stimuli. He developed four principles which could influence the learning of this new association; reinforcement, extinction, inhibition and generalisation (Gray, 1979). These principles cannot be directly applied to instructional design but paved the way for other more appropriate concepts. Four principles were developed by Thorndike, who contended that learning was a form of 'trial-and-error', which could be influenced by positive and negative reinforcements (rewards and punishments) (Schwartz and Robbins, 1995). From his research, Thorndike (1932) determined three laws of learning (see Figure 3.1).

Law of Effect	Responses to a situation, which were then rewarded, became strengthened, or if punished became weakened, until they formed as habits
Law of Readiness	A series of responses could be chained together to reach some goal. Annoyance would result if obstacles to the goal were in place
Law of Exercise	Connections become strengthened with practice and weakened when practice was discontinued

Figure 3.1. Thorndike's Laws of Learning (Thorndike 1932).

Thorndike's ideas were very influential in the field of education where the elements of reward, punishment and practice were considered necessary ingredients for successful learning (Hill, 1997). These ideas were extended into a theory of behaviourism by Watson (Vasta et al, 1995). Watson proposed that a stimulus could be predicted, given the response; or a response could be predicted, given the stimulus upon the frequency and recency of a response (Hill, 1997). He further suggested that the strength of the stimulus-response connection could be made stronger with practice - called reinforcement (Hill, 1997). These principles were argued against by Guthrie (Hill, 1997) who contended that all learning was an 'all-or-nothing' response. The theory of contiguity, developed by Guthrie (Hill, 1997) highlighted key principles (see Figure 3.2) for instructional design (Kearsley, 2001)

In order for conditioning to occur, the organism must actively respond (i.e. do things)
Since learning involves the conditioning of specific movements, instruction must present very specific tasks
Exposure to many variations in stimulus patterns is desirable in order to produce a generalised response
The last response in a learning situation should be correct since it is the one that will be associated

Figure 3.2. Guthrie's Contiguity Theory Principles (Kearsley, 2001)

Contiguity theory introduced the idea of motivating the learner in order to create and maintain a state of arousal to enhance the conditioning of appropriate behavioural responses

(Kearsley, 2001).

Skinner introduced the idea of operant conditioning and greatly influenced the area of programmed instruction in the 1950s and 1960s (Kulhavy and Wager, 1993). Skinner proposed that there were only two types of learning; classical conditioning (stimulus-response) and operant conditioning or (trial-and-error learning) and that most learning was of the latter type (Hill, 1997). Classical conditioning was considered to be involuntary behaviour that could be elicited by a stimulus without any reinforcement. Operant conditioning was voluntary behaviour, emitted by the learner rather than elicited by the stimulus, which could be learnt by association with a cue that reinforced the behaviour. Skinner's ideas highlighted the importance of reinforcement and showed that control of rewards (positive reinforcers) and punishments (negative reinforcers) could shape behaviour (Schwartz and Robbins, 1995). Complex learning was regarded as a series of refined responses, each building on the previous, reinforced appropriately (Romiszowski, 1986). Skinner did introduce the idea of individual differences in learning, but limited this to the pace of learning. He argued that people did not need different types of information but they did need to learn it at their own pace.

Table 3.2 Nine Instructional Events (from Gagné, 1988)

External Instructional Event	Internal Learning Process
Reception (gaining attention)	To ensure a reception of coming instruction we give the learner a stimulus
Expectancy (tell learners the learning objective)	Tell the learner what they will be able to do because of the instruction
Retrieval (stimulating recall of prior learning)	Ask for recall of existing relevant knowledge
Selective Perception (presenting the stimulus)	Display the content
Semantic Encoding (providing learning guidance)	Help understanding (semantic encoding) by providing organisation and relevance
Responding (eliciting performance)	Ask the learner to respond, demonstrating learning
Reinforcement (providing feedback)	Gives informative feedback on the learners performance
Retrieval (assessing performance)	Require more learner performance, and give feedback, to reinforce learning
Generalisation (enhancing retention and transfer to other contexts)	Provide varied practice to generalise the capability

Gagné's theory of learning outcomes is based on the behaviourist view, although later it incorporated more cognitive ideas (Mergel, 1998). His theory has been described as an instructional design theory more than a learning theory (Gagné, 1985) as it emphasised a systematic approach for designing of instructional material to achieve specified learning outcomes where skills were learnt one at a time and built upon previously acquired knowledge. This approach, being both clear and practical, influenced a large number of instructional designs in the latter part of the last century. Gagne identified a number of different types of mental processes/learning, which he arranged into a hierarchy with problem-solving at the top and stimulus-response learning at the bottom (Lovell, 1980). He also highlighted nine different instructional events and proposed methods of supporting these events (see Table 3.2).

One of the important aspects of this theory is the emphasis on giving help and feedback to support the learning process. Gagne's work has made significant contributions to the scientific knowledge base in the field of instructional technology particularly in the area of instructional design (Srisethanil and Baker, 1995).

Importance for VR Design

Stimulus-response theories have not been proposed as a suitable framework for VR learning in the literature. Although many have criticised it for only explaining simple learning processes, there are several points that could be relevant for VR. These include trying to elicit correct behaviours to presented stimuli, positive and negative reinforcement of correct behaviours, self-paced instruction and independent learning. VR worlds are often designed to simulate a real-world setting for example a car simulator, fire-escape training (Mason, 1994), or clinical phobias. In these worlds, realistic behaviours of objects and events are critical. Learners do not passively watch the action as they would in multimedia, but they participate in it. As such they are very much behaving as a result of presented stimuli in the VR world, often without thinking. In these conditions behaviourist principles do seem relevant.

Design of VR simulation worlds therefore needs to consider appropriate stimulus-response principles and use them to ensure that training does elicit the correct responses in the case of emergencies. Even in desktop worlds that have been used for training to escape from burning buildings, users had panic feelings and became stressed, trying to figure out what to do in order to escape (Mason, 1994). Thus VR simulations can be used as 'safe' environments where they can try out different behaviours and hopefully learn from their mistakes. However there is a need to make sure that users do not learn incorrect behaviours that they might reproduce in an emergency situation in the real world. Designers need to make sure that the consequences are appropriate and use of 'a punishment' might be included to try and hinder incorrect behavioural responses. For example learners who do not escape from the burning building actually die (transported away from the scene to the virtual graveyard). This would help to ensure that interference is not created and that learners do transfer the correct responses in real-life situations. Designers also need to ensure that learners can use the VR at their own pace. VR is not a linear type of medium, but there may be need for the user to stop the sequence of events or the actions if possible for whatever reason.

VR involves a lot of user actions and it is impossible for the software to know what is going on inside the user's mind; thus a stimulus-response 'black box' approach seems appropriate for design. Assessment of the user's actions can only be done by observing and recording behavioural responses to the 3D stimulus objects. This recording could be done by the software or by an observer using a multi-user VR system. Learning must involve the use of user behaviours rather than presentation of material.

According to the stimulus-response theories outlined above, VR designers may need to ensure that correct stimuli are introduced into the world to ensure that correct behaviours are elicited from the users. This is especially important when designing VR worlds as training applications for emergency conditions where users have to react to situations because there is no time for thinking. VR worlds need to be designed to ensure that users learn the correct behaviours or habits to be reproduced in these situations.

Designers need to be aware of the type of behaviours that might be elicited from the stimuli in the world (objects, sounds, etc) and design sequences that can shape new behaviours, perhaps using principles of reinforcement, extinction and inhibition (Schwartz and Robbins, 1995) and the laws of effect, readiness and exercise (Hill, 1997). Awareness of the associations that are being made by the users as they explore the world is important. This is especially important when designing applications for use in clinical situations such as when dealing with phobias.

3.2.2 Cognitive Theories

By the second half of the last century several researchers contended that stimulus-response concepts could not explain all types of learning, in particular, problem-solving. Tolman found that rats would not take a certain route because they had learned that it was blocked and Bandura and Walters found that children modelled behaviour that had not been reinforced (Mergel, 1998). As a result of such observations the field of cognitive psychology emerged. Cognitive psychologists shared a belief with behaviourists that the study of learning should be objective and empirical but believed that by observing an individual's behavioural responses, inferences could be made about the nature of the underlying internal cognitive processes (Saettler, 1990). Unlike the behaviourists, cognitivists were interested in discovering more about these mental processes that took place during learning. The most prevalent theory about these processes, information-processing theory, described these processes as input, processing, storage, and retrieval stages (Patel, 2001). Such ideas were easily related to computing and became the basis for much of the computer-based instruction software (Patel, 2001). Cognitivists firmly believed that the learner was a little more active in the learning process than behaviourists (Bruner, 1960). In terms of instructional design they contended that instruction was not simply something that was done to a learner but involved the learner and empowered their internal mental processes (Saettler, 1990).

Cognitive Principles for Instruction

Gestalt psychologists were among the first cognitive psychologists to consider learning. They based their ideas around issues of human perception and developed several important laws of perception such as the laws of proximity, similarity, simplicity and closure (Schulte, 1938), which were important for instructional design (Kearsley, 2001). Some the Gestalt psychologists concentrated upon the issue of problem-solving and contended that learning was a process of insight whereby gradual learning by trial-and-error could be interpreted as a series of small, partial insights (Hill, 1997). Piaget concerned himself with the way that children learn as they grow up (Singer and Revenson, 1978) and concluded that learning occurred as a result of both hereditary and environmental factors and that learning developed with age and experience of the child, knowledge being continual invented and reinvented (Brainerd, 1978). His theory proposed that children develop and build a set of schemata about the world and teachers needed to present concepts that were appropriate to these schemata and the developmental stage that the child was at (Brainerd, 1978). Piaget's ideas were a major influence on the teaching of young children because they emphasised the importance of active learning. His ideas also formed the beginnings of constructivist principles.

Ausubel formulated the theory of Reception or Subsumption Learning based on the premise that all new learning was dependent on what was already known (Ausubel et al, 1978). This supported the view that learning concepts were hierarchical and that simpler concepts needed to be learnt first. It was important for instructional design because it emphasised the importance of structure and organisation of material for the learner. The theory of Mastery Learning, developed by Bloom (1981), contended that all knowledge could be learned, given sufficient time and appropriate presentation. He categorised learning into cognitive, affective and psychomotor types. For each type of learning, a taxonomy of skills was developed (see Appendix 1), listing how these can be assessed in the classroom, which was useful for teachers (Levine, 1985).

One of the strongest paradigms of cognitive learning was that of information-processing, which attempted to describe the internal learning processes using a computer metaphor. Miller, one of the first pioneers of this theory, identified the processes as encoding (gathering and representing information), retention (maintaining the information) and retrieval (accessing the information) (Miller, 1956). The theory suggested that designers of learning environments should organise new information, link to previous concepts and use techniques to support the three processes. Miller also proposed that short-term memory was limited and that information be chunked into meaningful groups in order to increase its capacity, although recently these ideas have been criticised as being inaccurate and oversimplified (Cowan, 2001). Miller's ideas were extended by Anderson who developed a general cognition and learning theory called Adaptive Control or Thought (ACT) (Anderson, 1996, Anderson and Lebière, 1998). The theory assumed three types of memory structures: declarative (semantic net linking propositions and sequences by associations and images), procedural (productions which are based on sets of conditions and actions based in declarative memory) and working memory (part of long-term memory that is activated). Anderson proposed that all knowledge began as declarative information and that procedural knowledge was learned by making inferences based on declarative knowledge (Schneider, 1994). ACT became the basis for many intelligent tutor systems (Anderson et al, 1987). It was particularly important in emphasising the need for giving immediate feedback of errors, reducing memory load and providing instruction in the context of problem-solving (Kearsley, 2001).

The theory of Multiple Intelligences was developed by Gardner (1993) and identified eight different types of intelligences that were related to perceptual modalities (see Chapter 4). The eight intelligences were identified as linguistic, logical-mathematical, spatial, musical, intrapersonal (understanding one's own goals), body-kinaesthetic, interpersonal (interacting with others). Gardner contended that they were genetically determined but could be enhanced through practice and learning (Veenema and Gardner, 1996). Gardner disliked the fact that there was a bias in education towards certain intelligences and skills and labelled pupils as bad learners if they were not good at these skills especially when these 'bad learners' were gifted in non-academic subjects such as music and art. The theory suggested that teachers should be trained to present their lessons in a wide variety of ways using music, cooperative learning, art activities, role play, multimedia, field trips, inner reflection, and much more in order to provide something for all the eight types. If a teacher is having difficulty reaching a student in the more traditional linguistic or logical ways of instruction, the theory of multiple intelligences (Gardner, 1993) suggested several ways in which the material might be presented to facilitate effective learning (see Figure 3.3).

Word (linguistic intelligence)
Numbers or Logic (logical-mathematical intelligence)
Picture (spatial intelligence)
Music (musical intelligence)
Self-reflection (intrapersonal intelligence)
A physical experience (bodily-kinaesthetic intelligence)
A social experience (interpersonal intelligence)
An experience in the natural world (naturalist intelligence)

Figure 3.3 Gardner's Eight Intelligences (Veenema and Gardner, 1996)

Importance for VR Design

The use of advance organizers, mnemonic devices, metaphors, chunking into meaningful parts and the careful organization of instructional materials from simple to complex reflected the influence of cognitive psychology in instructional design (Mergel, 1998). However, such things do not seem to be of use for learning in a VR environment where learning seems to be more about behaviours and events and procedural steps as discussed earlier in this chapter. It is possible that for some learning worlds, which emphasise the visualisation of 3D complex scientific concepts, there may be a chance to design a sequence of events which start from the simple and move on to the complex. It may, in some cases, be appropriate for a teacher to give an overview of what may happen before the learner enters the virtual world, but other cognitive constructs do not seem valid for VR.

One of the important aspects of learning that was starting to be considered was that of individual differences. Cognitive research was discovering that learners differed in the capabilities and preferences of the mental processes used in learning (Riding and Rayner, 1998). Gardner's theory of multiple intelligences was one way of interpreting these differences but others are discussed in Chapter 4. It is likely that VR can assist teachers to provide for learners of differing intelligences as suggested by Gardner (McLellan, 1994). The nature of VR should be able to provide a context for many of the intelligences (Bricken, 1992). It certainly could encourage spatial intelligence and with the incorporation of sound and speech it can support students with linguistic and musical intelligences. The addition of haptic devices would provide for bodily-kinaesthetic intelligences and multi-user VR systems would allow for interpersonal intelligences. Creating a realistic natural world could provide support for naturalistic intelligence.

If designers are building applications that involve problem-solving activities then designers may need to be aware of how people perceive objects in the world, using the Gestalt principles (Schulte, 1938), in order to design a more effective environment.

If designing worlds for children, then designers need to be aware of the different developmental stages of learning and design content appropriate to that stage (Brainerd, 1978). They need to be aware that learning is easier if it can build upon concepts that are already known. It is difficult to design different material for different age ranges in a VR world and it is more likely that worlds with different content would be needed.

VR systems need to be designed to be multisensory, as this will ensure that they can meet the needs of different types of learners with different intelligences (Gardner, 1993). VR is usually designed as a visual medium, but use of sound and haptic devices can ensure that learners can use their auditory and kinaesthetic channels. Other cognitive differences such as learning styles etc are discussed in the next chapter.

3.2.3 Active Learning Theories

Active learning ideas arose from a number of theories. Active learning emphasises the need to regard the learner as an active part of the learning process. The learning environment becomes a learner-centred one instead of being teacher-centred and the role of the teacher moves to one of facilitator (Winn, 1991). Such learning empowers the student but is not always suitable for all students and all learning situations. Active learners need to know how to learn and need to be able to work out relationships and rules between concepts for themselves. This contrasts with the passive ideas of previous theories. Active learning environments need to be carefully designed and support is needed for learners at the start (Jonassen, 1991).

Active Learning Principles for Instruction

One of the earliest active learning theories, developed by Bruner (1960), was that of Discovery Learning, which encapsulated behaviourist ideas of reinforcement and cognitive ideas of structured information. This theory emphasises learning as an active process whereby learners are encouraged to find meaning and relationships from practical experiments (Bruner, 1960). Bruner's conception was not that students discover every bit of information by themselves, but that they discover the inter-relatedness between ideas and concepts by using what they already know. Bruner determined five major components of his theory (see Figure 3.4) which would help the learning process, but which implied a great deal of preparation on the part of the instructor.

Curiosity and Uncertainty	Experiences and activities need to be designed to encourage a willingness to learn
Structure of Knowledge	The teacher must specify the ways in which knowledge could be structured so that it is more readily grasped by the learner
Sequencing	Instruction should be designed to gently lead the learner through the content in order to increase the student's ability to grasp new concepts
Motivation	Extrinsic rewards and punishments (from teacher or system) should be replaced with intrinsic rewards (self-satisfaction of solving a problem)
Feedback	The teacher should encourage learners to develop their own techniques for obtaining feedback on their own

Figure 3.4 Bruner's Discovery Learning Theory (Bruner, 1960)

Bruner's theory emphasises the need to build on prior knowledge and was specifically applied to the teaching of scientific concepts and languages (Schneider, 1994). Although the theory stresses the idea of students discovering their own information, teachers have found that it is most successful when students have prerequisite knowledge and undergo some structured experiences (Edwards et al, 1997). This theory was mainly applied to the teaching of young students but the theory of Experiential Learning, developed by Rogers seems to be more appropriate for adult learners (Cross, 1981). The theory distinguishes between two types of learning: cognitive (meaningless knowledge such as multiplication tables) and experiential (significant knowledge such as learning about car engines) (Rogers, 1969). Rogers (1969) ascertained that all humans had a natural desire to learn and that the role of the teacher or the instruction is to facilitate such learning by ensuring that it is meaningful to the learner. He highlighted the importance of using strategies that help the learner 'learn to learn' and increases their self-motivation. Five particular principles were identified for instructional purposes (see Figure 3.5). Experiments carried out by Specht and Sandlin (1991) suggested that experiential learning activities show that learners form a better understanding of learning concepts and retain them for longer when compared to traditional teaching methods.

Set a positive climate for learning
Clarify the purposes of the learner(s)
Organise and make available all necessary learning resources
Balance intellectual and emotional components of learning
Enable learner to share feelings and thoughts

Figure 3.5 Experiential Learning Principles (Kearsley, 2001)

Other researchers concentrated upon providing instructional principles for adult learning. Knowles (1975) formulated a theory of Andragogy or adult learning, which stresses the need for adults to self-direct their learning and to take responsibility for their own decisions. He highlighted the differences between Andragogy and Pedagogy (child learning) (see Table 3.3). His theory was important in recognising that adults needed to be motivated to learn and were most motivated when the subject was of immediate relevance and when instructional design could be related to the learner's own experiences (Knowles, 1975).

Table 3.3 Pedagogy vs Adragogy (Knowles, 1984)

	Pedagogy	Andragogy
Concept of the Learner	Role of learner is independent Teacher takes responsibility for the whole learning process	Role of learner is essentially self-directing Role of teacher is to encourage and nurture this self-directed need
Role of Learners' Experience	Learners bring little experience to the learning situation Learners dependent on 'expert' input Main techniques are transmittal techniques	Learners' experience accumulated over a lifetime is a great resource for learning both for self and others Learners attach greater significance to what they experience rather than what they are told Main techniques are experiential techniques
Readiness to Learn	Learners learn what they are conditioned to learn to obtain parental and societal approval Fear of failure is a great motivator Learning is standardised and progressive because it is aimed at the same age group, which has similar learning needs.	Learners learn when they feel a need to learn Learning should meet their needs to help them cope with the demands of their world - home, work etc. Learning should be organised to meet learner needs and sequenced according to individual's ability and readiness to learn
Orientation to Learning	Learning is subject-oriented, with emphasis on content, most of which they may forget because it has no immediate relevance (principle of 'deferred gratification')	Learners seek to acquire competence to cope with the demands of their world; they seek personal development and achievement of potential; they seek immediate gratification; learning must be relevant and immediately applicable

Knowles et al (1998) stressed that adult learning should focus upon the process rather than the content and use strategies such as case studies, role playing, simulations, and self-evaluation to ensure that learning was meaningful. The role of the instructor became less of a teacher and more of a facilitator. Knowles (1984) applied his principles to the design of courses for learning computers emphasising the need for proper explanations and task-oriented instructions that take into account individual differences.

Cross (1981) extended the ideas of Adragogy into a theory of Adult Learning, which she called the Characteristics of Adults as Learners or CAL model. The model also included ideas of experiential learning and life-long learning. The theory or model emphasised the idea of two constructs, personal characteristics (aging and life situations) and situational characteristics (part-time versus full-time learning and voluntary or compulsory learning). The CAL model stressed that adult learning programs needed to be designed to take into account the differences in these characteristics.

Brookfield (1995) criticised Cross's ideas in that she had not addressed the fact that adults learners were socially embedded learners and brought with them more culturally formed goals. Other researchers agreed and Lave introduced the theory of Situated Learning, which proposes that learning occurs as a function of the activity, context and culture in which it is situated (Lave and Wenger, 1990). The theory proposed that learning requires social interaction and collaboration and that knowledge needs to be presented in an authentic setting (Kearsley, 2001). Lave particularly disliked classroom settings, arguing that they are not the appropriate setting for experiential learning. The main requirement for instructional design is to ensure that they take place in a realistic context. Traditionally this would probably mean field trips, but use of video could be used to show realistic situations. Resnick (1987) suggested that there was more need for situated learning in schools and college in order to prepare students for real life situations and work experiences. Brown et al (1989) later developed the theory by introducing the idea of cognitive apprenticeship where learners pick up skills from experts in an authentic situation.

Freire developed the theory of participatory learning which is based on the theories of adragogy and active learning but which was applied to the field of literacy (Freire and Macedo, 1987). It highlights the need for learners to become active participants in their own learning process and suggests that a variety of methods should be used for discussion (text, newspapers, journals, letters) (Auerbach, 1992). Active and Participatory learning principles are also the basis of the theory of Action Learning, first introduced by Revans (1971) in the context of management education but which has since been applied to other learning situations (Morgan and Ramirez, 1983). It emphasises the need for learners to organise their own learning activities with a minimum of external help but with the need for people to come together to learn from each other's experiences (Morgan and Ramirez, 1983).

There is no true theory of Anticipatory Learning but the framework was developed from a project carried out by Botkin and colleagues (Botkin et al, 1998). The project showed that when the environment changed or challenges arose, learners were forced to undergo shock learning. Shock learning was found to be detrimental to performance (Senge and Fulmer, 1993). In some cases experiential learning activities can bring about emotions, remembrances and responses, which have not been anticipated (Leigh, 2000). As a result the researchers recommended that learning situations should support and encourage innovative or anticipatory learning by making learners aware of the different cause-effect relationships of a learning situation in order for them to identify how to affect and react to different learning outcomes (Sashkin and Franklin, 1993). Recently, research has considered the use of intelligent agents that could be used to anticipate the users needs (Butz, 2001).

Issues for Design

VR has been described as an active participatory environment (Mason, 1996) and many of the principles highlighted in the preceding active learning theories have relevant points to consider in the design of VR learning environments.

The theory of Discovery Learning (Bruner, 1960) emphasises a need for self-directed, learner-centred activities and an environment that will encourage active learning. A first-person perspective will ensure that activities become user-centred. VR worlds need to be designed to incorporate a great deal of interaction and incorporate strategies to encourage and motivate users to explore and discover new concepts. Active learners will explore different areas and different objects in the world so designers need to ensure that objects that would be perceived as interactive are programmed to be so in order to encourage this activity and motivate users to explore more. It is not motivating for users to try and interact with objects that do nothing. Designers also need to be aware that some structure and guidance is needed in the world. This is more important for training situations where a certain sequence of procedures or rules must be learnt in the correct order. If the application requires a certain sequence of events, then clues may need to be designed to encourage users to explore the appropriate objects. Feedback is still needed on objects that are not part of the expected sequence.

The key concepts of the theory of Experiential Learning (Rogers, 1969) have some relevance for the design of VR. By making the world very interactive, with lots of scope for different activities the student is able to have control over what they do in the world and therefore how they learn. VR worlds should be designed to encourage participatory action and interaction. Designers need to be aware that much of the learning will take place as a result of the learner's experiences in this world. These experiences need to be appropriate for the application.

Knowles (1975) and Cross (1981) both argued that adults prefer activities that can be related to their job or personal life and which provide hands-on experiences. VR can certainly offer a learning environment that would meet these needs if it were designed to mimic real-world situations in looks and behaviour and which perhaps could offer haptic feedback. It would also be easy to create problem-centred content within the activities that are required to be performed by the users. However, Knowles does suggest that adults prefer fewer but longer sessions of training because of time responsibilities (Knowles, 1975) and this might be a problem for immersive VR systems because of the possible health and safety risks. Even looking at a computer monitor for long periods of time can cause strain to the eyes (Ingraham and Bradburn, 2002). In these cases, different forms of learning material would need to be used as well. Many VR applications for adult training will need to be designed to be relevant to the real world (Knowles, 1984). Objects, behaviours and events need to be designed realistically so that learning can be transferred directly to the real world (Resnik, 1987). Multisensory systems would encourage a larger range of skills to be included in this transfer. Designers of non-multisensory worlds need to ensure that activities, which cannot be directly transferred to the real world, are made known to the users.

The key elements of situated learning are presenting knowledge in an authentic context, social interaction and collaboration (Lave and Wenger, 1990). All of these can be supported using a well-designed multi-user VR system. VR worlds can be designed to provide authentic settings (e.g. workplace, foreign country, space-vehicle etc) that look and behave realistically. This means that behaviours and sounds etc should be realistic. There should also be a suitable number of characters for that situation. Worlds that do not contain any characters or actions will appear 'dead' and unrealistic. Use of avatars and communication channels can provide a means for social interaction and collaboration. In many cases VR can provide an environment that will facilitate the performance of authentic activities that might otherwise be dangerous in the real world.

Participatory learning strategies such as advocated by Auerbach (1992) using materials such as text, newspapers, journals, letters would not be appropriate for the design of VR worlds but the ideas of self-direction and active activities, which she also proposed are suitable for VR. Students not only have to participate in the VR world also have to participate in controlling the events and consequences of their actions. Many of the Action Learning principles (Revans, 1971) are also easy to incorporate in the design of VR environments:

realism, pro-action, intelligent action, different kinds of understanding, individual and social interactions etc. Revans (1971) argued that people needed to come together to discuss their experiences. VR worlds, therefore, need to have an element of social interaction built within them and the design of suitable multi-user worlds and communication facilities would enable this to happen. If designing for a multi-user world, then appropriate communication channels can be designed to encourage social and collaborative learning. If designing a stand-alone system, then virtual characters need to be designed to communicate with the user, which involves the use of speech recognition systems.

Anticipatory learning concepts (Botkin et al, 1998) suggest that designers need to anticipate the many different actions and experiences that the users may have and ensure that they are all accounted for in the underlying programming. Anticipatory learning is based on the collection and organisation of data in order to learn about the causal effects. VR offers a perfect medium to do this by use of visualisation and simulation techniques. In this manner, designers need to ensure that users can specify what data they wish to see and what parameters they wish to observe. Results might encourage anticipation of possible outcomes in order to assess future possible parameters. There is also a possibility that just changing parameters and observing simulations might encourage passive learning. VR worlds might need to be designed to introduce ways so that the user would actively be involved in these simulations in order to perhaps change parameters during the action as a result of anticipating future events. It is very likely that such realistic simulations could evoke emotions and remembrances that might need to be dealt with. In some cases, such responses might well be desired, for example, in applications for clinical phobias and disturbed behaviours (North et al, 1998; Hodges et al, 2001).

3.2.4 Computer Media Learning Theories

The following theories are a mixture of ideas, theories and concepts that may have specific relevance to the design of multimedia learning environments and which might offer guidelines for the design of VR worlds. In the past 10 years or so multimedia computers have been available for learning but in some ways the use of multimedia is similar to the use of television, video and simulations. Some of these theories are to be commended in their attempts to emphasis the need to use more than one modality of instruction or symbol system to help the learner.

Principles for Design

Gibson's proposed theory of Information Pickup was a theory of perception based on cognitive Gestalt principles that could be applied to simulator training (Gibson, 1966). The theory suggested that perception was a direct consequence of the properties of the environment and did not involve any form of sensory processing or assimilation with past experience. Gibson proposed a process of proprioception where a human perceived information from the environment solely by reference to the body position and functions. Gibson's work on human perception, especially visual perception, had many strands (Gibson, 1979) and identified three key elements (see Figure 3.6).

Optic Flow And Texture Gradients	These were developed as specific examples of powerful sources of visual information that had been largely neglected
Invariants	These were perceptual properties of objects that were independent of viewing position and were seen as key to reliable visual information pickup
Affordances	These were properties of the relationship between an object and the observer that specified potential interactions, not abstractions such as shape or identity.

Figure 3.6 Gibson's Principles of Information Pickup Theory (Gibson, 1979)

Gibson argued that environmental information was available in the optic array in the form of spatial and temporal patterns that were used to guide behaviour; a view that contrasted with the normal concept that perception involved the retina (Goldstein, 2002). Gibson also suggested that cognitive processes as: associating, organizing, remembering, recognizing, expecting, and naming were all operations of the mind, whereas perceptual processes such as: differentiating, establishing, covariation, extracting invariants, and separating off the variants are biological (Gibson, 1966). Although this theory may not have much to offer the general area of learning and education, it does seem to have implications for the design area of still and motion picture research, especially with reference to simulations and virtual reality.

A theory of Minimalism Learning was developed by Carroll that is best described as a framework for instructional design (Carroll, 1990). Originally intended for the design of training materials for word-processing or spreadsheet software users, it can be applied to other computer-based applications (Kearsley, 2001). The key ideas of minimalism included; making learning tasks meaningful, active and self-directed learning, making error handling explicit, and linking training with actual use of the system. The Symbol Systems Theory, developed by Salomon, was intended to explain the effects of different types of media content on learning. One of the critical concepts of Salomon's theory was the idea that the effectiveness of a medium depended upon a match with the learner, the context and the task (Salomon, 1981). Five key principles for instructional design were found and can be seen in Figure 3.7.

The symbolic coding elements of particular media required different mental transformations and hence affected the mastery of specific skills

The level of knowledge and skill that an individual possessed would be affected by the impact of specific media sequences

The nature of the learning/information processing tasks could affect the impact of specific media sequences

The social context of media presentations could influence what messages was perceived

There was a reciprocal relationship between media and learner; each influencing the other.

Figure 3.7 Symbol Systems Theory (Salomon 1981)

Emphasis was placed on choosing the media that would save the learner from difficult mental elaborations but that different users could extract different meanings from the same media. Originally the theory was applied to media such as television and videos but in the 1990s, this framework was extended to multimedia-based instruction (Salomon et al, 1991).

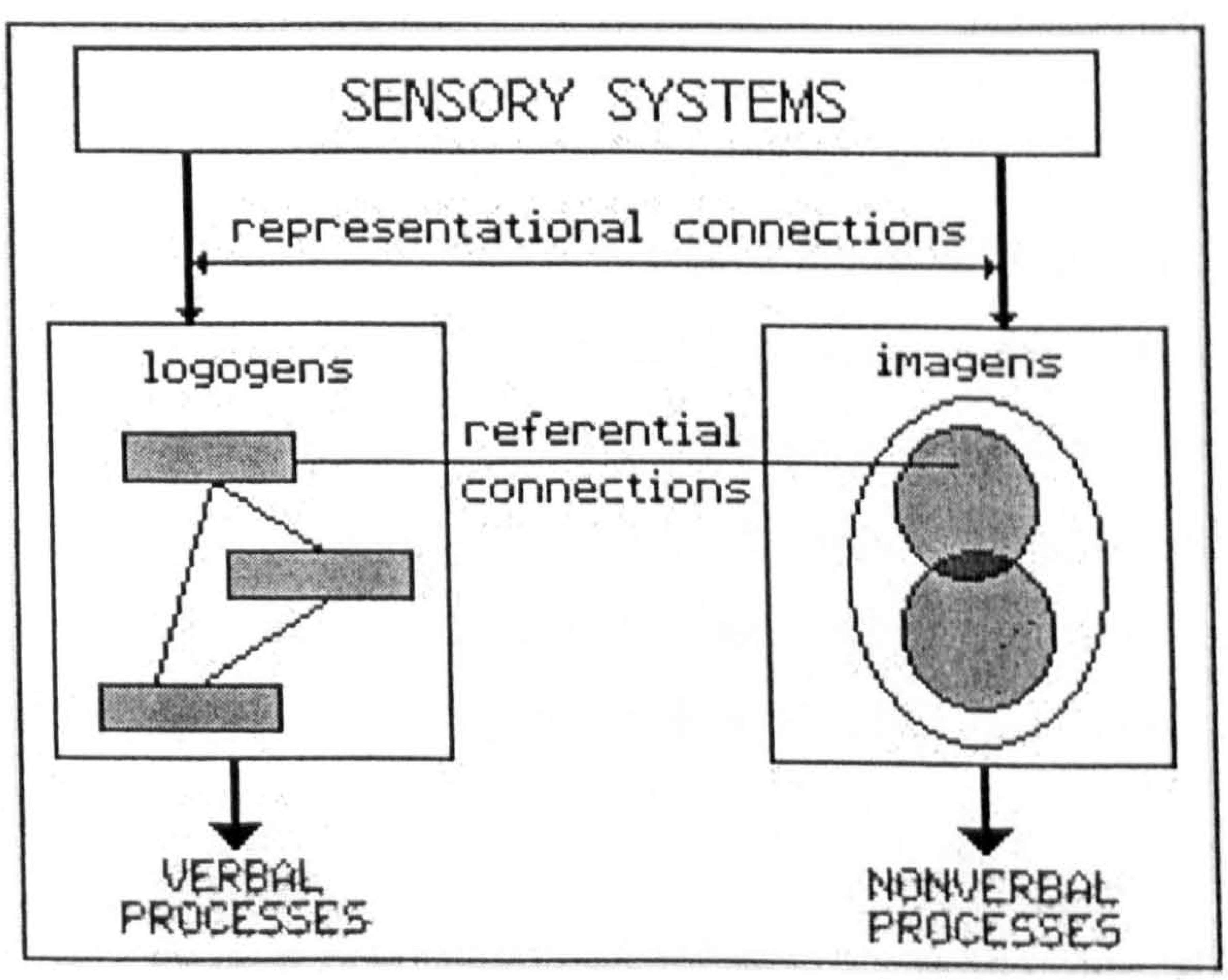

Figure 3.8. Pavio's Dual-Coding Theory (Paivio, 1986)

The Dual-coding theory, proposed by Paivio (1986), assumed that a human had two specialised and separate cognitive subsystems; one for dealing with language; and the other for the representation and processing of nonverbal objects/events (i.e., imagery) (see Figure 3.8). Dual-coding concepts have been applied to many cognitive phenomena including: mnemonics, problem-solving, concept learning and language (Kearsley, 2001). Clark and Paivio (1991) presented dual-coding theory as a general framework for educational psychology. The main principle for the design of instruction was that presenting information in both visual and verbal form simultaneously could enhance processes of recall and recognition. They also criticised most computer-aided-learning software for providing images only as an illustration, the main information still being represented by text. However, it was envisaged that the power of interactive multimedia could exploit the power of the dual-coding theory (Clark and Paivio, 1991).

The Parallel Instruction (PI) theory or Parallelism (Min, 1992) focused on simulation and e-learning environments. It emphasised the need for learners to have access to multiple screens of information at the same time. Paper-based work could be laid out around the student in order to provide extra non-computerised windows. Min suggested that learners could only work in an open learning environment if all the relevant information was visible to them because of the limitation of short-term memory (Min, 1994). Min (1992) viewed learning tools such as computer simulation not as an instructional tool but as a means to motivate pupils to increase their learning levels to understand why other earlier and possibly boring lessons were required.

Recently a new type of learning theory has been formulated called multimedia learning which has proposed research-based principles for the design of multimedia learning environments (Mayer, 1997; Moreno and Mayer, 1999). The theory is based on the principle, already outlined by the dual-coding theory, that a learner possesses a visual information processing system that deals with animations and a verbal information processing system that deals with auditory narration. It also draws upon ideas from cognitive load theory and from memory studies and Mayer (1997) presented a diagram to show his ideas (see Figure 3.9).

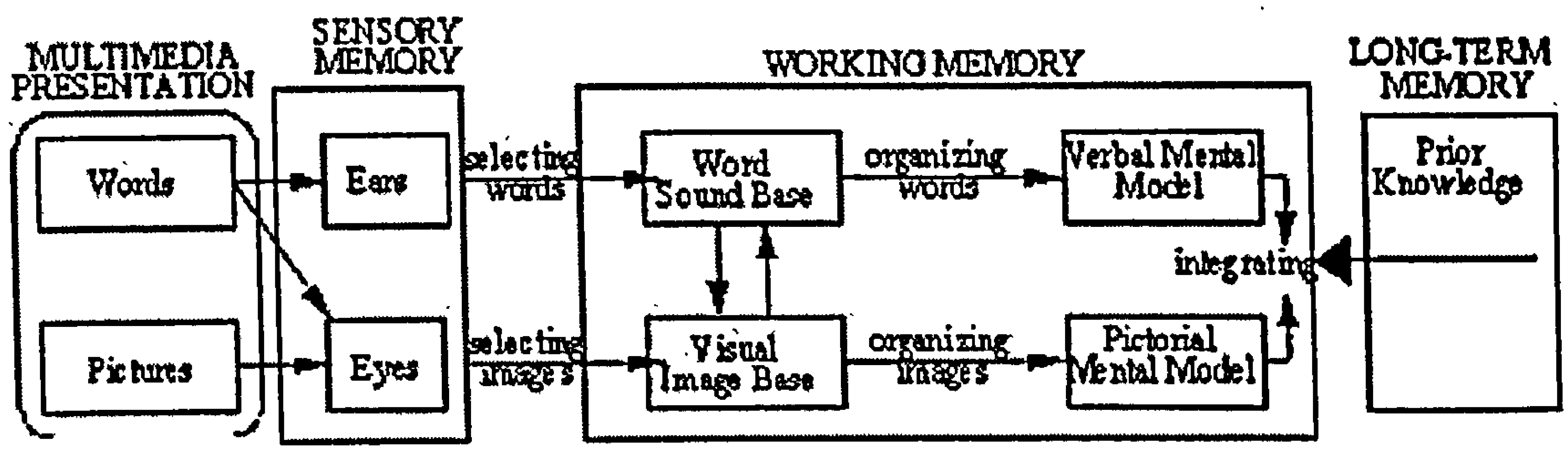

Figure 3.9 Multimedia Learning Theory (Mayer, 1997)

A number of studies were carried out to show evidence supporting the five key principles of the theory (Mayer, 1997; Mayer and Anderson, 1991; Mayer and Sims, 1994; Moreno and Mayer, 2000). These principles can be seen in Figure 3.10.

Multimedia Principle	To use text and images rather than text alone
Contiguity Principle	To place text close to corresponding images or to present narration concurrently with corresponding animation
Coherence Principle	To minimise extraneous text, images, and sounds
Modality Principle	To present words as speech rather than as on-screen text enhances learning.
Individual Differences Principle	To use these design principles particularly for low-experience rather than high-experience learners and for high-spatial rather than low-spatial learners.

Figure 3.10 Multimedia Learning Theory Principles (Mayer, 1997)

The basis of the multimedia learning theory is that multimedia can improve learning by presenting different types of information to the user at the same time. Information processed through both channels is called preferential processing and has an additive effect on recall (Mayer and Anderson 1991, Paivio, 1991). Moreno and Mayer continue to investigate factors that might be relevant to virtual reality learning (Moreno and Mayer, 2001).

Issues for Design of VR

A number of issues raised by these theories might be relevant to the design of VR worlds. Gibson's theory (Gibson, 1979) was related to perception but perceptual processes are very relevant to the design of VR since it is a visual medium that usually mimics a real-world situation. Perceptual cues could be used to help navigate and orientate users in the world, which have been found to be a problem (Bricken and Byrne, 1993) and could improve the sense of depth. The design of VR worlds may need to consider the use of perceptual cues in order to make them more realistic to users. Use of optic flow and texture gradients might be difficult to implement at present (Vince, 1998) but should be considered for adding perceptual realism, which could enhance the learning experience. The issue of affordances (Gibson, 1979) is relevant to VR, especially when trying to design objects that represent abstract concepts and no real world clues are available (Dede et al, 1999; Salzman et al, 1999).

The main aspect of Minimalism (Carroll, 1990), that seems relevant to VR, is that learning activities should provide meaningful tasks, error recognition and recovery activities giving self-contained learning experiences that are independent of sequence. All these can be applied to the design of usable VR learning environments with the use of imaginative programming. One interesting point to take from this theory is the need to minimise passive reading activities. On-screen text is often a part of current VR design and, therefore, this needs to be minimised, perhaps by including verbal communication instead.

The theory of Symbol Systems (Salomon, 1981) deals with the concept that different forms of learning media pass on different messages and understandings. Research is needed to investigate the types of learning that can be gained from VR rather than other forms of media and whether it is suitable for all types of individuals. It is suggested here that VR is likely to require more mental processing than television but maybe less than with reading. It is also likely that some studies would show the novelty effect in that some students may show a preference of VR because it is novel and not because it is appropriate for them. Further research is needed to look at whether different messages can be gained from using VR by different types of learners to help ascertain who would benefit from VR learning rather than other forms of media.

The Dual-Coding Theory (Paivio, 1986) emphasised the need for speech rather than text when dealing with images because these each access a different human processing channel. VR mainly accesses the visual channel and that means that learning can be enhanced by use of sound and speech. The use of natural sounds and appropriate speech needs to be incorporated in the design to ensure that the world still appears natural to the user.

At first glance, Min's theory of parallelism (Min, 1992) does not seem to apply to VR but the issue of short-term memory problems may do so. Tools could be designed into the VR interface to help users to recall certain information. Some games use the PC monitor to show icons representing information such as items that are being carried or points scored. However, this would not seem appropriate for most VR worlds as such on-screen information would detract from the sense of immersion or presence and decrease the size of the window. Such tools would need to be a natural part of the VR world and designers could implement virtual objects that could be activated in order to access information about what had already happened. Although users in an immersive VR would only have access to one window, use of different viewpoints could give access to other so-called windows on the world. This would not seem very natural but could certainly prove useful. Otherwise virtual objects, which could access useful information, would need to be designed in the world. Alternatively, virtual characters could also be consulted to give access to information than cannot be seen or has been forgotten by the user.

Of the five principles of the multimedia learning theory (Mayer, 1997), the last two seem the most appropriate to be applied to the design of VR worlds. The modality principle suggests that learning is enhanced if sounds are used rather than text since sounds would use the auditory channel. This also supports the view that natural sounds and speech would be an important component for a VR learning environment. Designers need to ensure that sounds, appropriate for the situation, are utilised whenever appropriate instead of on-screen text dialogue boxes. The principle of individual differences is a very important one and this will be considered in more detail in the next chapter of this thesis. Mayer (1997) emphasises differences in experience and in high and low spatial learners. Experience of VR systems is not covered by the literature, but some studies are looking at the issue of spatial ability in VR. Vincente and Williges (1998) found that low spatial students were getting lost in hierarchical databases, and Stanney and Salvendy (1995) suggested that visual mediators could be used to help low-spatial students. Winn et al, (1999) found that some low-spatial students were getting lost in VR worlds and Billinghurst and Weghorst (1995) proposed that sketch maps could be used to help low-spatial users navigate in virtual worlds but these would need to be designed for use within the world. However, there are a number of other individual differences that may need to be considered by designers.

This chapter has thus reviewed a large number of learning theories and identified those theoretical principles that have relevance to the design of VR learning environments. How they can be further applied to the design of effective learning is discussed in more detail in Chapter 5.

CHAPTER 4: INDIVIDUAL DIFFERENCES AND HELP

4.1 Introduction

Kozma (1991) suggested that the differences in the capabilities of a particular media were heavily influenced by the type of task and in particular the type of user. Learners varied in their processing capabilities, the information and procedures that they have stored in long-term memory, their motivations, their purposes for learning, and their meta-cognitive knowledge of when and how to use these procedures and information. A number of learning theories (Bloom, 1981; Gardner, 1993; Knowles 1984; Mayer, 1997; Riding and Rayner, 1998) that were discussed in the previous chapter have emphasised the need to consider individual differences in the learning process and thus in the design of learning material. A large number of individual differences have been identified that might impact on learning; age (Knowles, 1984; Worden et al, 1997), gender (Byrne and Furness, 1994; Cranton, 1992), ability (Winn et al, 1999), experience (Satalich, 1995) skills (Gardner, 1993), cognitive styles (Durling, 1994; Kearsley, 2001), motivation (Inkpen, 1997; Pintrich and Schunk, 1996), learning strategies (Weinstein and Mayer, 1986), learning styles (Duff, 2000; Kolb, 1984), communication styles (Lawrence, 1995; Myers and McCaulley 1985), learning modalities (Fleming and Mills, 1982; Pimentel and Teixeira, 1992).

Learning is now becoming a life-long necessity because it is impossible to learn all the skills that a human will need early in life, especially with most people having to change careers more than once because of the fast pace of technological advancement (Smith, 1990). More adults are returning to formal education and this means that there are more differences among the student population than ever before. Adults bring to the learning situation a multitude of differences. As a group, adults tend to be older and have a wider age range of experiences than traditional students (Cross, 1981; Knowles, 1984). They also tend to be part-time learners with demands and responsibilities on their time. They do, however, tend to be more motivated to learn their chosen subject, if only because they may be paying for the learning themselves. Over the years, their prior knowledge, experiences and skills will be diverse, especially compared with the more traditional student straight out of school. These differences will certainly impact on their learning and should be utilised to enhance the process. In some cases, education will need to take into account that fact that some of these adults may not have had much formal education earlier in life, or it may have not been a positive experience. Thus an important aspect of any learning establishment is to help these learners to learn how to learn. Smith (1990) further suggested that both teachers and students needed to be aware of individual differences especially learning styles, in order to improve their learning skills.

Most of the research involving individual differences in learning has been focused upon the differences of learners and how the learning material might match these. It seems, therefore, important for the designers of VR learning material to also consider the design of material that takes into account individual differences. There is some research on the aspects of teaching differences, in particular teaching styles, but no research on the styles of designers of learning material and how that affects learners. Investigation of all the different types of individual differences is beyond the scope of this thesis, given the constraints of time and space. Instead, four areas are focused upon that might have the greatest influence on VR design; factors such as affective processes, learning styles, communication styles and learning modalities. In addition, the use of help systems is covered in this chapter. Help systems are necessary to guide the user and to give assistance to users who are having problems. Design of help systems can be linked to learning styles, communication styles and learning modalities as discussed in this chapter. They can also be related to the issues of dual-coding and natural communication discussed in the previous chapter.

4.2 The Affective Process

According to Litzinger and Osif (1992), the learning process can be broken down into three sub-processes (Litzinger and Osif, 1992):

(1) Cognitive Process: the means by which an individual acquires knowledge.

(2) Conceptualisation Process: the manner in which an individual processes the information acquired perhaps looking for relationships between unrelated events or perhaps looking for new ideas.

(3) Affective Process: the way that an individual's motivation, decision-making styles, opinions, values, beliefs, attitudes and emotional preferences can define their learning styles.

The third sub-process, termed the affective process, is an area that covers many different factors; most of which are personal to the individual. These personal opinions, values, beliefs etc. are very subjective and difficult to measure using objective methods. However, useful insights can be obtained using surveys with open-ended questions and self-ratings (Hayes, 2000). Another problem is that whilst some factors can remain stable throughout an individual's lifetime, it is more likely that they will change depending upon different circumstances and new information (Litzinger and Osif, 1992).

4.2.1 Affective Factors and Learning

Motivation, attitudes, beliefs, values etc. are all factors in the affective learning process. Ames and Ames (1989) argued that motivation was important because it determined the extent of the learner's active involvement and attitude towards successful learning. Thus it seems important that VR designers take into account the motivation of users in their design process.

Oxford and Shearin (1994) analysed a total of 12 motivational theories or models and found that attitudes and beliefs were factors that had an impact on motivation. There does not seem to be an agreed definition of motivation in the literature. Skinner (1954) believed motivation was an extrinsic concept and occurred when there are proper reinforcements in the learning environment. Lovell believed that it was an intrinsic process and defined motivation as "the process that leads an individual to attempt to satisfy some need" (Lovell, 1980, p109). Kleinginna and Kleinginna (1981) found at least 140 different definitions of motivation and Landy and Becker (1987) suggest that there are many more. Numerous theories have been presented to explain motivation (Ambrose and Kulik, 1999) and this has led to differences in opinion as to how it should be defined or measured (Pinder, 1984). Indeed it is now being argued that as a result of the problems in defining that the concept of motivation may be disappearing from the literature (Ambrose and Kulik, 1999).

Motivation has been found to have an impact on learning outcomes (Baldwin et al, 1991). This study found that learning performance increased when trainees perceived that they had been given the training method of their choice compared to those who had not received their first choice and those who had no choice (even though they all actually received the same treatment). Furthermore, it was found that those trainees who had not been given their choice of training method were less motivated and learnt less than those who had been given no choice at all.

Positive motivation is needed to improve the learning performance of individuals (Pintrich and Schunk, 1996). Adults tend to be more motivated to learn than their younger students, (Inkpen, 1997) probably because the learning is more meaningful to their lives (Knowles, 1999). Konvalina and Wileman (1983) found that older students were less likely to give up computer science courses than younger students.

Motivation and attitude were found to be the two best predictors of students' grades (Hendrickson, 1997) and attitudes were found to have a profound influence on learning behaviour (Cotterall, 1995) and learning outcomes (Weinert and Kluwe, 1987). A study carried out by Shih and Gamon (2001) found that there was no relation between attitude and performance but there was a significant association between motivation and performance. It seems, therefore, that motivation could be a stronger predictor of learning success than attitudes alone. However, a study by Loomis (2000), found that attitude was a significant determinant of students' performances on exams and assignments, and motivation was not.

Research studies have considered the impact of a negative attitude towards using computer-learning media and found that worrying about learning always impairs the quality of performance even if the student works harder (Eysenck, 1979; Sarason, 1986). One of the main areas of investigation has been that of anxiety both from students and from teachers who need to use new computer technology in the classroom (Bohlin, 1999). Feelings of anxiety toward computers and computer use, is common, affecting 30% to 40% of the population (Tseng et al, 1998). Arnold and Brown (1990) stressed that unless attention was given to the negative aspects of the affective process (anxiety, fear, stress, anger etc.) then these teaching tools would be useless. The major factor in computer anxiety is that of inexperience but often the fearful do not wish to get more experience (Pederson, 1989 cited by Orr, 2002). A change in attitude towards the computer technology is needed to reduce this anxiety (Orr, 2002) but these studies have not produced any meaningful statements about how to go about changing these attitudes. They also lack any coherent theory of anxiety and in most cases they suggest that further research is needed to address the situation.

4.2.2 Affective Factors and VR

Bricken (1992) pointed out that it is important to consider the whole learner in the learning process and suggested that VR provides a context for both cognitive and affective learning by engaging the user in a rational and emotional, organised and spontaneous situation. Many studies that have considered VR and learning (Byrne and Furness, 1994; Moreno and Mayer, 2001; Youngblut, 1998) have suggested that most students have enjoyed using VR and have been motivated to continue using it, sometimes without breaks (Adams and Lang, 1995). Byrne and colleagues (Bricken and Byrne, 1993; Byrne 1992) found that learning with VR was highly motivating for most of the young children at a summer camp. These children were being taught how to build their own worlds using the software. One of the children, a young girl who was anxious towards using the technology, did not like it but the others really enjoyed the experience. Byrne and Furness III (1994) conducted a study with 69 students, aged 9 to 16. The students created and visited virtual worlds in a fully immersive VR system and reported that they have totally enjoyed their experience and felt that it was very motivating.

Rose (1996) reviewed four non-VR studies that had showed a strong relationship between student attitudes and performance in learning a language. Students with a negative attitude towards learning did not perform as well as those who were more positive towards learning. Rose proposed that the reason for the negative attitude was usually that the students found learning a language in a traditional classroom was an unmotivating experience because of its passive nature and unexciting environment. VR was suggested as a means of teaching a language in a less passive and more exciting manner. A study by Talkmit (Youngblut, 1998) with students aged 14 to 15 showed a general positive attitude towards using VR. Osberg (1995) reported a study of students aged 16 to 18 years and found that whilst they still enjoyed using VR this enjoyment was slightly less than for younger students. Schaefer and Wasserman (1995) gave preliminary results on adult students' reactions and attitudes toward using VR. They reported that whilst there were positive attitudes towards the concept of using VR, there were negative views towards the equipment used. It seems that as the age of the learner increases the attitude towards enjoying the novel experience changes towards worrying about more practical issues of using the VR for learning.

Most of the studies argued that VR was motivating because of its active, participatory manner, however more research is needed to investigate this further. Although some studies have shown that VR is more motivating than traditional instructions (Fitzpatrick, 2000; Youngblut, 1998), no studies have isolated the active nature of VR and compared an active learning environment with a non-active learning environment to see if there is a difference in motivation and in learning performance. Another problem with these studies into VR and learning is that they have not looked at VR over longer periods of time. Within a short period of time, it is hard to say whether VR is motivating because of its active nature or because of its novelty factor. Research suggests that students are often motivated to work with new forms of instruction (Fuhrmann and Greimel, 2000). It is also possible that the VR was motivating because the researchers' attitudes towards the medium were positive and encouraged the students to use it. It is not clear if this would be still be the case if the teacher had negative attitudes towards using VR in a classroom situation.

Research has suggested that teachers with a positive attitude towards computers in the classroom have a benefit on students' learning (Cox, 1997; Todman and Dick, 1993). Within the literature there have been no studies on attitudes of teachers or trainers towards using VR in training or educational environments or their effects on learning performance. There are also no data on the attitudes, experiences etc. of designers of VR, which may well, have an influence of the design of learning or training material. Research is needed to investigate the effects of these factors on students' learning performance and on the design of VR learning media. Insight into the designers' attitudes and beliefs might well give clues to how VR software is being designed. This thesis will, therefore, carry out a survey to determine what general attitudes and beliefs VR designers have towards VR design (see Chapter 6).

4.3 Learning Styles

Learning style can be defined as the "individual's characteristic ways of processing information, feeling, and behaving in learning situations" (Smith 1990, p. 24) or the "different ways in which children and adults think and learn" (Litzinger and Osif, 1992, p 73). The theoretical underpinnings of learning styles were that people have biologically determined learning preferences in respect of environmental, emotional, sociological, physical and psychological conditions (Duff, 2000). Combinations of these preferences provide an individual learning style profile and this can be measured. Knowing his or her own learning style profile can help a student to learn more effectively (Duff, 2000; Kolb, 1984; Wakefield, 1995; 2001).

This thesis has argued that VR is an active type of learning environment and thus it is possible that it might suit an active type of learning style. A number of different learning styles have been identified in the literature (Bates and Leary, 2001; Riding and Rayer, 1998) but an active type of learning style was identified by Kolb in his theory of experiential learning (Kolb, 1984) which was later developed by Honey and Mumford (1992).

4.3.1 Kolb's Experiential Learning Theory

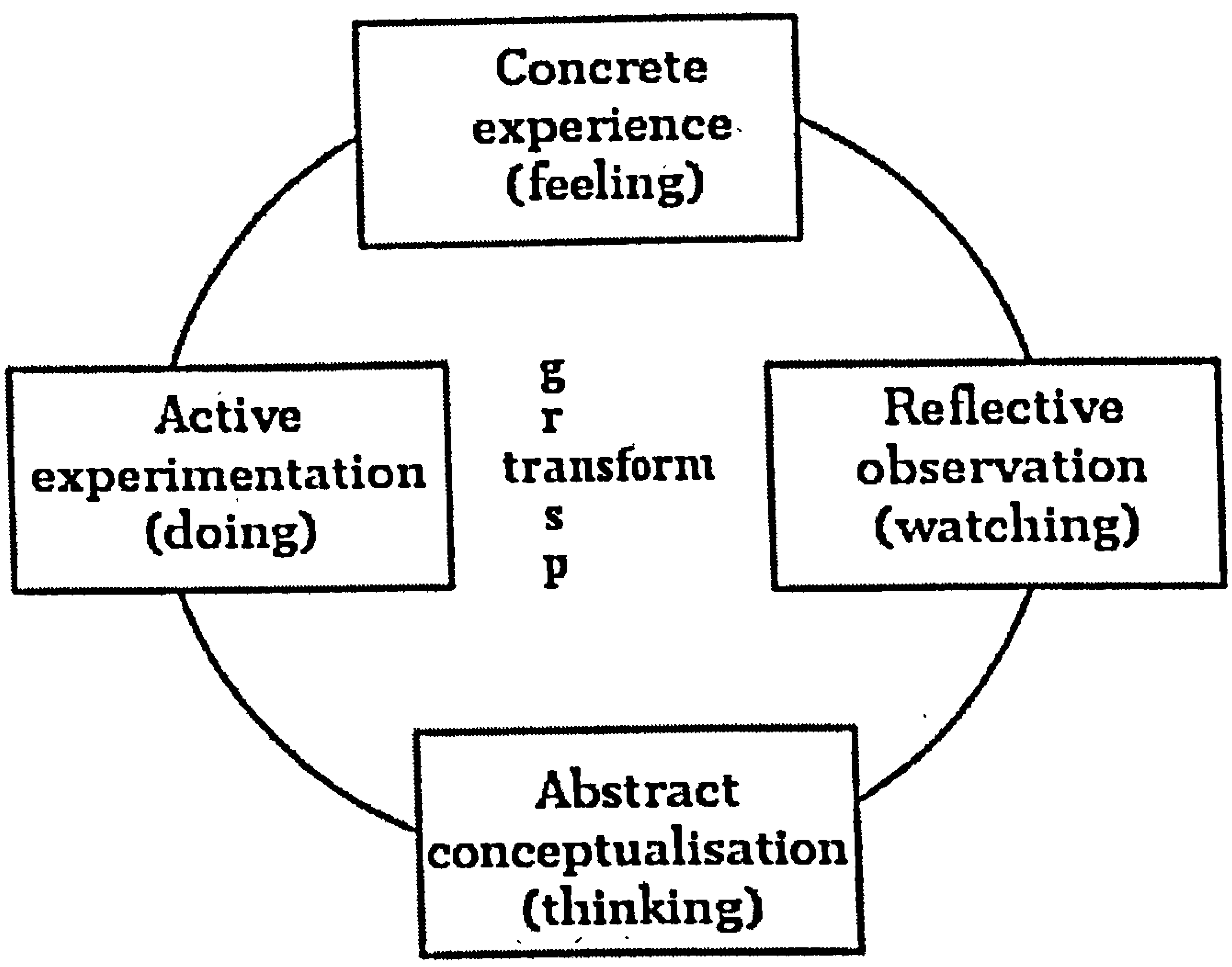

Figure 4.1 Kolb's Cycle of Experiential Learning Cycle (Kolb, 1984)

Concrete Experience	Learning begins with a 'here and now' experience. This could conform to existing views or contradict them
Reflective Observation	This experience is followed by a collection of data and observations or reflections about that experience
Abstract Conceptualisation	A continuation with an analysis of the data when we begin to conceptualise and commence the internalisation process of what has been learnt from the experience
Active Experimentation	The final stage when we modify or alter our behaviour. At this stage we enter a stage of experimentation and test the new knowledge or concepts to see if they work in practice

Figure 4.2 The Four Stages of the Experiential Learning Cycle (Kolb, 1984)

Ideas such as those of Piaget, Bruner, Rogers, Freire (as discussed in Chapter 3) considered that learning was based on experiences and that the learning process could be described as a cycle of action and reflection (Kolb, 1984). Kolb extended these ideas into a theory of experiential learning, which proposed that individuals learn and problem-solve in a continual process of four distinct stages (see Figure 4.1 and Figure 4.2) (Kolb 1984). The learning cycle was based on two popular, bipolar, cognitive dimensions; the active-reflective dimension (grasping) and the abstract concrete dimension (transforming) (Kinshuk, 1996).

Kolb believed that when one cycle ended a new cycle began, so the process of learning was continual (Duff, 2000). This cycle included both active and passive learning and both concrete and abstract experience. The theory also suggested that different abilities were needed for each of the stages, but individuals tended to be more skilled in some stages than others. For example active learners learned primarily by manipulating the environment, whilst reflective individuals typically learned by introspection and internal reflection (Kolb, 1984; 1985).

In order to determine which preference a learner had, Kolb (1976) developed a measure called the Learning Style Inventory (LSI). This was a self-description questionnaire, which asked individuals to rank nine sets of four words in the order that corresponded with their learning orientation (Kolb, 1985). This was later revised in 1985 to include 12 items instead of 9 (Kolb, 1985) (see Appendix 4). The scores indicated the individual's preference along the two cognitive dimensions (active/reflective and abstract/concrete) and indicated which learning stage was preferred and how this affected the learner (as shown in Figure 4.3).

Active Experimentation	People who would describe themselves as practical, doing, active, responsible
Reflective Observation	People who would describe themselves as tentative, watching, observing, reflecting, reserved
Abstract Conceptualisation	People who would describe themselves as analytical, thinking, evaluative, logical, rational
Concrete Experience	People who would describe themselves as receptive, feeling, accepting, intuitive, present orientated

Figure 4.3 Kolb's Four Types of Learner (Kolb, 1984)

By drawing lines across the circle representing the two cognitive dimensions; active-reflective continuum (how people process information) and the concrete-abstract continuum (how people perceive information) an experiential learning kite can be produce (see Figure 4.4).

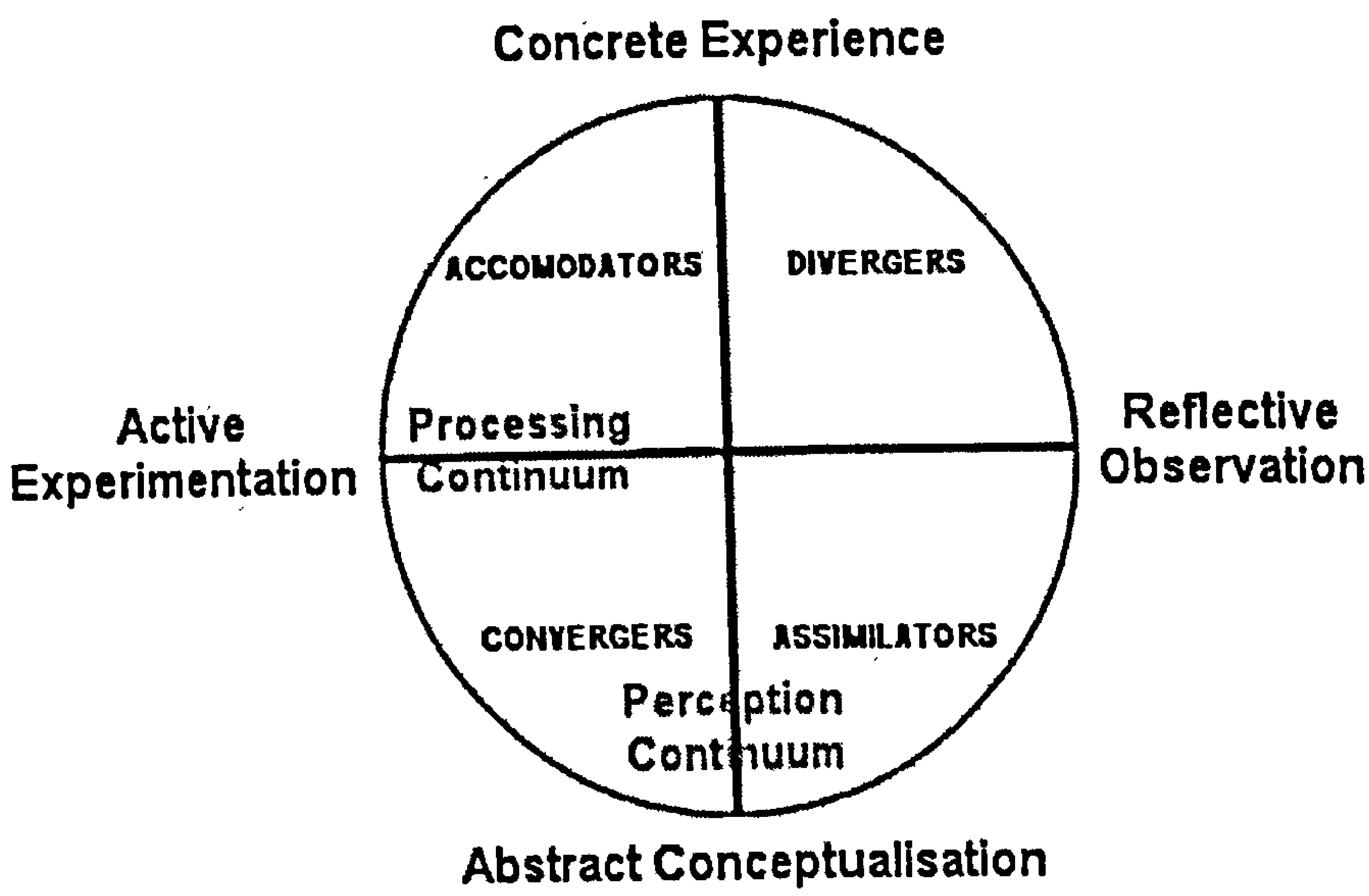

Figure 4.4 Kolb's Experiential Learning Kite (Kolb, 1985)

Scores from the LSQ can be represented on the kite by using the two lines as four axes with points falling in each of the four quadrant areas (Kolb, 1985). This indicates which of the four learning styles were dominant in their overall makeup (Kolb 1985). The four learning styles are described in Figure 4.5.

Accommodators	Prefer a non-linear multifaceted environment and excel in situations where they must apply theories to specific circumstances with open-ended solutions
Assimilators	Prefer logical sequential structure using their ability to create theoretical models using inductive reasoning with exact well-rehearsed information
Convergers	Prefer step-by-step sequential structure, thinking and analysing, then practically applying ideas and concepts with exact direction
Divergers	Prefer a harmonious non-linear environment acquiring knowledge through intuition and personal experience

Figure 4.5 Kolb's Four Learning Types (Kolb 1985)

The active experimentation style seems to be the style most closely associated with an active, participatory learning style and Accommodators are the most likely to enjoy active learning activities and therefore may enjoy using VR.

There was widespread acceptance of Kolb's experiential learning theory but his LSI attracted a large amount of criticism (Duff, 2000) although it is still a popular tool in the United Stares

(Dangwal and Mitra, 2000; Sharp, 2001). Several studies assessed the scores produced by the instrument, and found that there was low internal consistency reliability, test-retest reliability and construct validity (Duff, 2000, Kinshuk, 1996). In the United Kingdom it is more usual for the people interested in learning styles to use the Honey and Mumford Learning Style Questionnaire which is based on Kolb's theory of experiential learning and considered more reliable (Kinshuk, 1996).

4.3.2 Honey and Mumford's Learning Cycle

Mumford (1982) was particularly interested in the theory of experiential learning as it coincided with his own ideas and experiences about the learning process. He did not, however, approve of the LSI questionnaire, which based its results on the ranking of just thirty-six words. He also did not think that business managers (his own field of expertise) would be impressed with an instrument that was based on abstract words rather than practical work activities. Mumford decided, therefore, to develop a more practical and valid instrument. Honey and Mumford (1986) developed a learning cycle model as a basis for the questionnaire (see Figure 4.6).

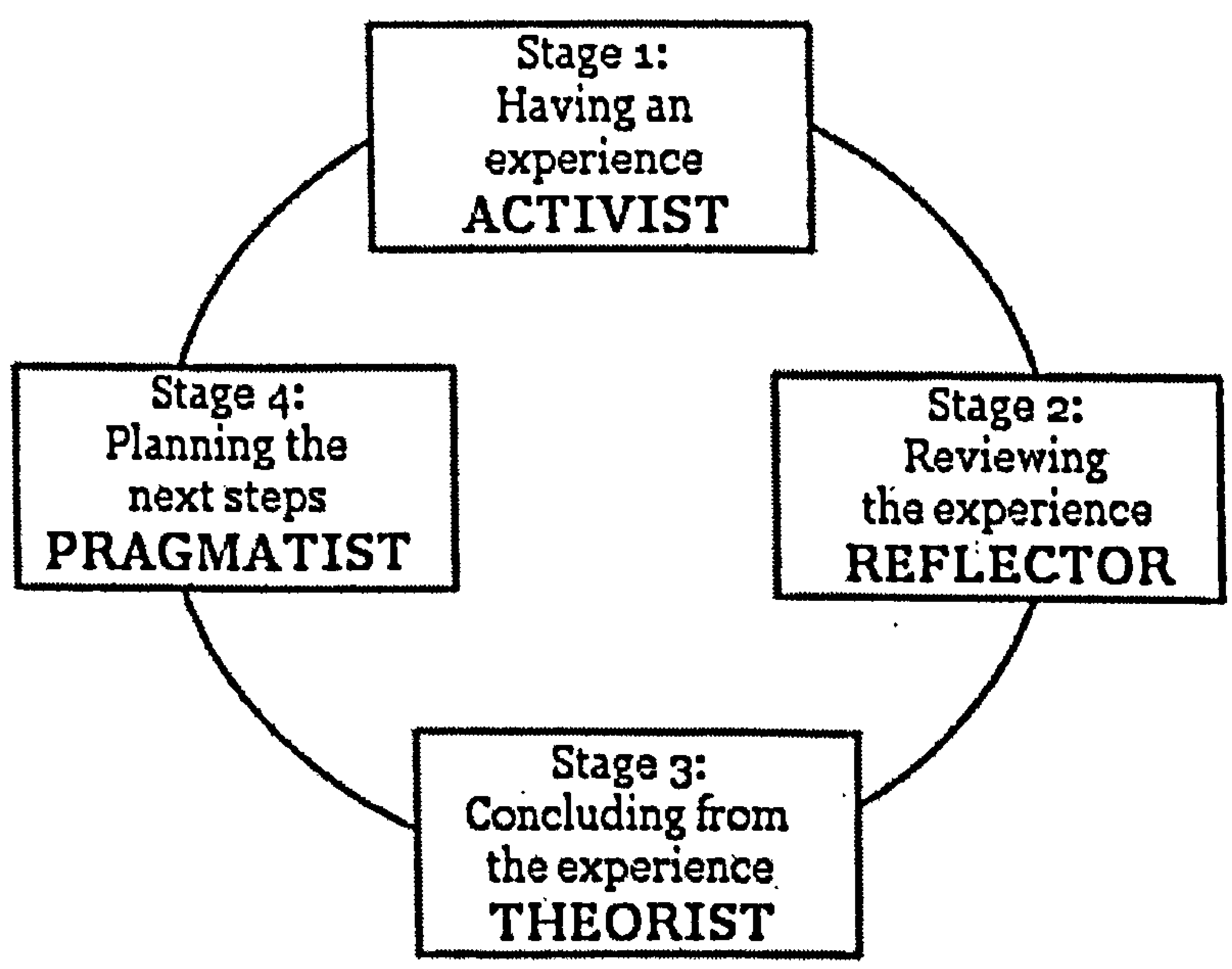

Figure 4.6 Honey & Mumford Learning Styles (Kinshuk, 1996)

This model consisted of four stages; having an experience, reviewing the experience, concluding from the experience and planning the next steps. Each of the four stages are mutually supportive, none being more important than the other, and it was proposed that people developed preferences for one stage rather than another in the learning cycle (Honey and Mumford, 1986). Each of the four stages or processes was identified with a particular learning style: activist, reflector, theorist and pragmatist, which are described in Figure 4.7.

Activists: Enjoy the here and now, dominated by immediate experiences, tend to revel in short-term crisis, fire-fighting. Tend to thrive on the challenge of new experiences but are relatively bored with implementation and longer-term consolidation. They are the life and soul of the managerial party.	**Reflectors:** Like to stand back and ponder on experiences and observe them from different perspectives. They collect data and analyse it before coming to any conclusions. They like to consider all possible angles and implications before making a move so they tend to be cautious. They actually enjoy observing other people in action and often take a backseat at meetings.
Theorists: Are keen on basic assumptions, principles, theories, models and systems thinking. They prize rationality and logic. They tend to be detached, analytical and are unhappy with subjective or ambiguous experiences. They like to make things tidy and fit them into rational schemes.	**Pragmatists:** Positively search out new ideas and take the first opportunity to experiment with applications. The sort of people who return from management courses brimming with new ideas that they want to try out in practice. They respond to problems and opportunities as a challenge.

Figure 4.7 Honey and Mumford's Four Learning Styles (Mumford, 1992)

It was also proposed that people could change their learning styles if necessary (Honey and Mumford, 1992). Honey and Mumford developed the first version of the Learning Style Questionnaire (LSQ) in 1982 and revised this in 1986 (Honey and Mumford, 1992) and can be seen in Appendix 5. The premise behind the LSQ instrument was that if people knew about their learning strengths and weaknesses, their learning experiences could be enhanced. The LSQ was considered to be more objective in scoring than the Kolb inventory (Kinshuk, 1996), because the questions did not directly ask people how they learn. Allinson and Hayes (1988) also found the LSQ to be preferable to the LSI in terms of validity and reliability.

The LSQ has been used widely to help managers to learn more effectively (Honey and Mumford, 1992) and can also be used to determine which learning activities suit which style. Activist types preferred role-playing exercises and other active learning techniques. Reflectors preferred written materials and self-assessment techniques that could be taken away for further study. Theorists preferred lectures and discussion. Pragmatists preferred applied techniques and opportunities for situated learning.

4.3.3 Learning Styles and VR

Learning styles have been proposed as powerful but hidden methods of determining the way that people prefer to learn (Smith, 1990) and have been shown to be most effective when they are matched to the learning media (Duff, 2000). Matching cognitive and learning styles with instructional learning media has been found to be very important in enhancing student learning (Ford and Chen, 2001). Studies have shown that students perform better if their learning style matches that of the teacher who designed or gave the course (Felder, 1993). In the case of computer-based-instruction, the designer may be considered the teacher who designed the course and so learning styles of designers may be an important factor for effective learning. Matching the learning styles of VR with the students is just as important (Byrne, 1993). It seems logical that VR might suit active type learners more than other types of learners but it might also attract or require active designers to do this. Active type designers may well understand how to design an active learning environment because of their preferred styles. They are probably more likely to exploit the interactive nature of the medium and make sure that there are lots of activities to do in the world.

It has been suggested that Virtual Reality offers an active, participatory learning or training environment (Mason 1996; Pantelidis, 1993). If VR is an active, participatory environment then it seems logical that it would be most suitable for active learner types. It may also be possible that non-active learner types may not like to learn using VR learning media and this may have significance for the design and use of VR in the future. Few papers have explored the idea of active learning styles for VR worlds (Byrne, 1993). A number of research papers have linked the idea of active learning and the concept of constructivism to look at how people use VR worlds to learn (Byrne, 1996; Rose, 1995; Winn, 1993). However, these worlds only used young children and it has not yet been proved that such constructivist techniques would be useful for adult learning and training. The participants in these studies had not used VR before and it is possible that the any initial enjoyment, due to the novelty factor of the immersive technology, might be short-lived (Clark, 1993).

Ideally, designers of VR worlds should be aware of their own learning style bias and how this might influence their designs. They should design VR worlds to be as active as possible, which suggests that they should have an active learning style. However, they also need to consider methods that might help non-active types or else propose that VR be used alongside other non-active educational media as suggested by Byrne (1993).

It is likely that the activist types are the most likely type to prefer to use VR or to design appropriate active VR environments; however, there are no data to confirm or reject this hypothesis. This thesis, therefore, intends to investigate the learning styles of VR designers and assess whether or not they have an Activist learning style (see Chapter 7).

4.4 Communication Styles

The previous section explored the ideas of Kolb's experiential learning theory, which was influenced by the ideas of Jung (1971). According to Jung, all people are either taking in information or processing information. Just as people have different learning styles, they also have different ways of perceiving and processing information. The ways that people communicate and deal with information is also important for the learning process. Support for this idea comes from Hsia (1988) who contended that all learning was a communication process and from Luckin and Plowman (1998) who stated that learning involved complex communicative and meaning-making competences. Communication styles have also been linked with learning styles and preferences for learning material and learning environments (Lawrence, 1995). The idea of learning being a communication process was also supported by Durling (1994) who stressed that an important aspect of communication between the tutor and the student was the match of communication or learning styles.

4.4.1 Jung's Theory of Psychological Types

Jung spent many years observing people's behaviours and personalities and believed that he could find some order in the many different ways that people process information (Jung, 1971). He developed a theory based on his observations that has been called the Theory of Psychological Types (Felder et al, 2002). The theory contended that all conscious mental activity could be classified into two perception processes ('sensing' and 'intuition') and two judgement processes ('thinking' and 'feeling') (Lawrence, 1995). These processes were considered as polar opposites. Jung also identified a third dimension which he called personality structure which consisted of 'extraversion' or external-looking and 'introversion' or inward-looking (Myers and McCaulley, 1985).

4.4.2 The Myers-Briggs Type Indicator

The work of Jung in the 1920s and 1930s was fascinating but was found difficult to understand and implement by most people (Myers and McCaulley, 1985). Katherine Briggs decided to find a way of making it more understandable and useful in people's lives (Myers and Myers, 1995). Over a period of many years Briggs attempted to validate a number of understandable questions that could identify the types of different people according to Jung's theory (Reed, 2000). This work culminated in a questionnaire called the Myers-Briggs Type Indicator (MBTI) (Myers and McCaulley, 1985). This indicator not only measured an individual's preferences for the three dimensions proposed by Jung, but also added a fourth dimension that was developed from Myers' own work. This fourth dimension related to whether a person preferred to be either taking in information ('perceiving' or 'perception') or processing the information in order to make a decision ('judging' or 'judgement') (Myers and McCaulley, 1985). Each of the four dimensions is bi-polar with each person having a preference for one of the eight resulting preferences. These preferences were specified by a particular letter as indicated in Table 4.1.

Table 4.1 The Four MBTI Bi-Polar Dimensions (various sources)

Extraversion processing information externally	**Introversion** processing information internally
Sensing processing details	**INtuition** processing meanings
Thinking processing based on logic	**Feeling** processing based on values
Judgement making a quick decision	**Perception** preferring more information

The eight preferences highlight the way that people prefer to process the information (internally or externally), the type of information that they prefer to process (details or meanings), how they determine the importance of the information (logic or values) and whether they prefer to process information or to come to a quick decision. A description of these preferences is shown in Table 4.2 (Durling, 1994). It is also to be noted that many of these terms arise from the MBTI and therefore have specific meanings, which may not match colloquial usage.

Combinations of the eight preferences produce the 16 MBTI types. These types are considered to be stable throughout a person's life (Myers and McCaulley, 1985). The 16 types and a small description of each type are given in Appendix 8.

Table 4.2 The Eight MBTI Preferences (Durling, 1994)

Extraversion Relates to the outer world of people and things: extraverts are comfortable in the company of other people and seem to draw energy from them. Their best work is done in action with others.	**Introversion** Relates to one's own inner world of ideas and concepts. Introverts are more comfortable with working quietly alone. They may have preference for reading or for concentrated study over long periods.
Sensing Is perceiving reality directly through the senses. It focuses on factual data, prefers practical outcomes, and is rooted in the present. There is a concentration on details.	**INtuition** Is an internal process, which utilises imagination, seeks possibilities, and prefers relationships and associations to facts. There is a more holistic view.
Thinking Are more objective, analytical, logical, evaluative and objective modes of thought. This is an impersonal basis for choice.	**Feeling** Feeling people are more subjective, utilise sympathy and empathy, and are more comfortable with value judgements. Judgements are made by reference to personal standards.
Judgement Emphasises thinking in a decisive, planned and orderly manner, aims to control events, and is associated with closure and the settling of things.	**Perception** Is associated with keeping options open, living a more flexible, spontaneous existence, aiming to understand life and adapt to it.

Myers and Briggs spent many years perfecting and developing the MBTI and it is considered to be a well-validated and highly reliable tool (Kinshuk, 1996). *Oxford Psychologists Press*, who market the MBTI in England, have compiled a huge database of types for many different occupations; unfortunately there is no data for VR designers. However, there is some evidence to indicate that computer programmers tend to be TJ and TJ types (Myers and McCaulley, 1985; Tognazzini, 1992) and design students tend to be NT types (Durling, 1996).

4.4.3 MBTI Models for Learning

Although all preferences have been linked with different learning needs (Lawrence, 1995) Schroeder (1993) presented a model that considered the first two dimensions to be the most important for learning and associated the introversion-extraversion dimension with that of the active-reflective dimension in Kolb's theory. Durling (1996) suggested that the second and third MBTI dimensions were the most important for learning and proposed a model that could show learning style patterns for designers. These models will now be discussed further.

Schroeder's MBTI Model and Learning

The first two dimensions of the MBTI (Extraversion-Introversion and Sensing-iNtuition) were considered to be particularly helpful in understanding learning styles (Schroeder, 1993). Schroeder proposed that the resulting patterns of preferences could be linked to the following four learning styles:

(1) ES pattern: concrete active.

(2) IS pattern: concrete reflective.

(3) EN pattern: abstract active.

(4) IN pattern: abstract reflective.

The 16 MBTI types could be arranged in a grid, using these two dimensions, to highlight these patterns as shown in Figure 4.8.

	active Extraversion		*reflective* Introversion	
Sensing	ESTJ	ESFJ	ISTJ	ISFJ
concrete	ESTP	ESFP	ISTP	ISFP
iNtuition	ENTJ	ENFJ	INTJ	INFJ
abstract	ENTP	ENFP	INTP	INFP

Figure 4.8 MBTI Grid Relating To Shroeder's Ideas

Schroeder's work linked the S or Sensing preference with concrete learning and the N or iNtuition preference with abstract learning styles. The E or Extraversion preference was associated with active learning and the I or Introversion preference with reflection. From this model it seems that VR would suit the Extravert type; the ES type preferring more real-world environments that the EN type.

CAIUS Model

Another model for MBTI learning was proposed by Durling (Durling, 1996; Durling et al, 1996). This model proposed that the two most important dimensions for learning were the Sensing versus iNtuition dimension and the Thinking versus Feeling dimension. Durling based the model on results from earlier studies that had shown that various occupational groups had shown preferences for these two dimensions or four quadrants (see Figure 4.9).

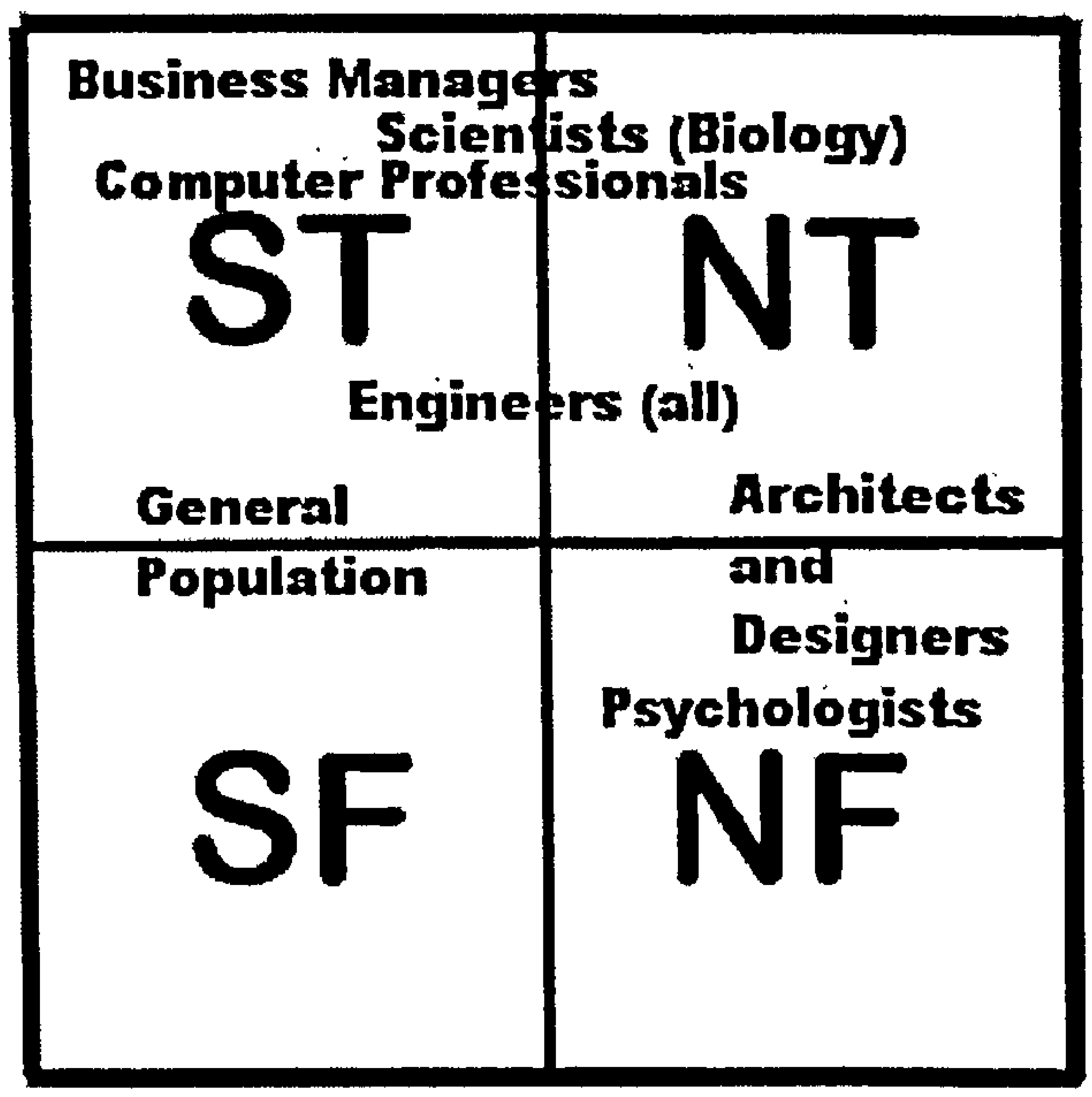

Figure 4.9 Occupational Groups in the Four MBTI Quadrants (Durling, 1996)

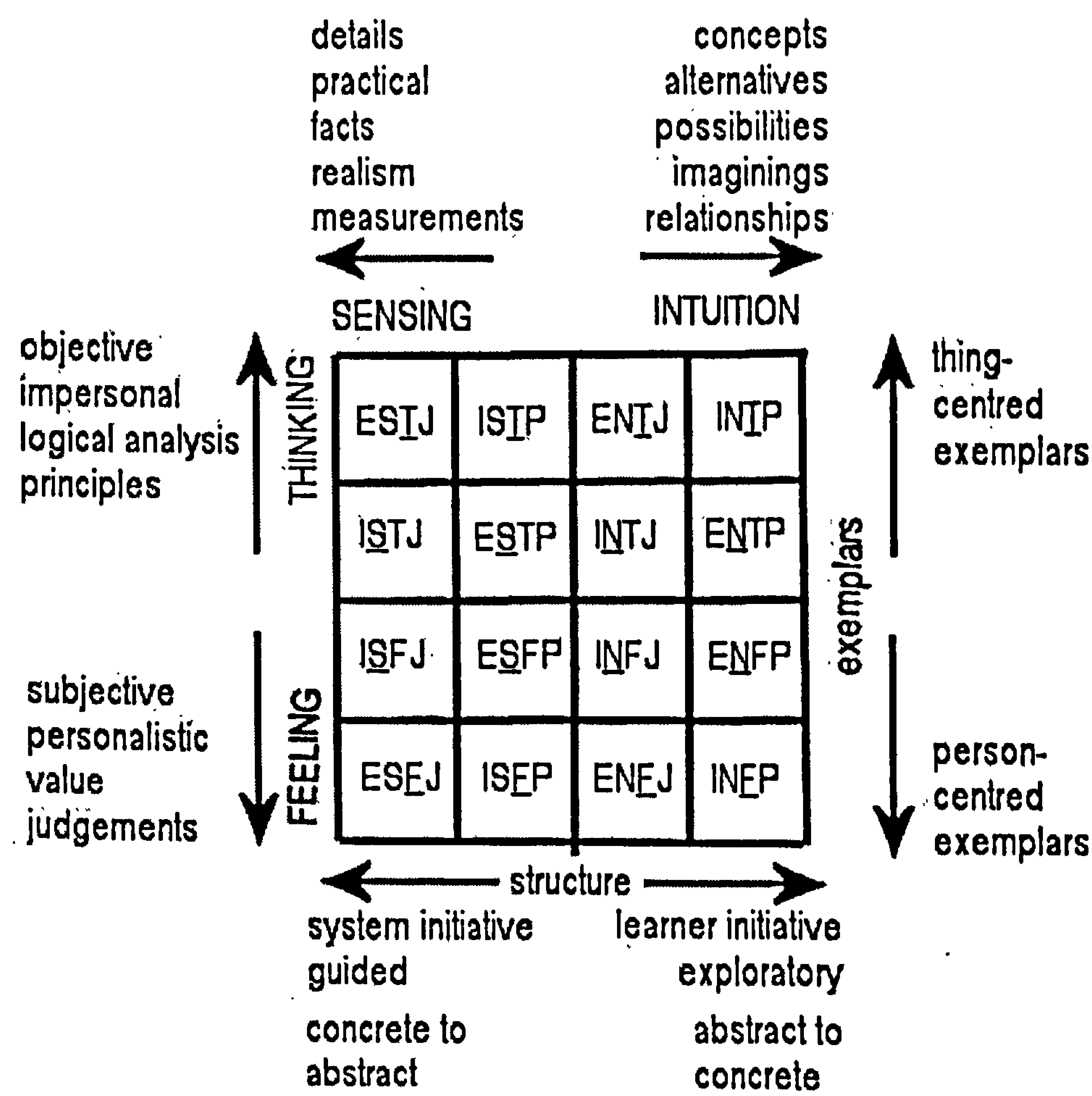

Figure 4.10 CAIUS Model (Durling, 1996)

The model was called CAIUS (computer-aided-instruction using styles) and was developed as an instructional model for delivering effective CAI. In the CAIUS grid (see Figure 4.10), Durling highlighted the dimensions of Sensing - iNtuition and Thinking - Feeling to illustrate his ideas for the design of computer-aided learning material.

According to this model, VR learning material would be based on the right hand side. If the VR worlds had communication with characters, it would suit the types in the bottom right hand corner; if it did not have characters, then it might suit the types found in the top right hand quadrant.

4.4.4 MBTI and Learning

The MBTI has been connected with learning styles (Lawrence, 1995; Myers and Myers, 1995). Lawrence (1995) discussed how each of the types needed different types of learning material. He also used the MBTI to study teacher's learning styles in order to look at matching their styles with those of their students (Reed, 2000).

Research has attempted to look at identifying relevant learner characteristics for the eight MBTI preferences. It was found (O'Conner, 1997) that Extraverts processed verbal material well, but Introverts had better long-term retention of information. Intuitive types did best on almost all measures of college success because they grasped concepts and ideas faster than Sensing types. Sensing types needed more repetition of details and facts, unable to grasp meanings of the concepts. Thinking types needed logical order in the presentation of material to make decisions whilst Feeling types needed to process how they felt about information before making any decision about its worth. Judging types paid more attention to the credibility of the instructor, whilst Perceptive types preferred to sit back in the classroom and see what happened, reacting to events now and then with spontaneity.

A review by Durling (1994) found that different MBTI types correlated with different learning approaches. A preference for independent study and self-pacing activities has been found among introverts. Extraverts preferred to participate in group activities. Sensing types tended to be good at memorising facts and figures and liked television as a learning medium. Intuitive types were good at generalising from example to concept. Thinking types preferred courses with clear goals and structure and liked lectures and demonstrations. Feeling types preferred to work on group projects and need personal interaction. Judging types also preferred to learn from materials presented in an orderly way and like lectures and demonstrations. Perception types found self-pacing activities difficult to do and found it difficult to hand assignments in on time because they wanted to keep finding more information.

By assessing combinations of preferences, it has been found that the IN (Introverted-iNtuitive) type of student did well in school learning but the ES (Extravert-Sensing) student found it difficult to do well at school because they could not make any sense of the use of symbols and meanings (Myers and Myers, 1995). It was also suggested that S or Sensing types did not do well in timed tests because they had to repeat the question over and over to make sure they were certain of the details (Myers and Myers, 1995).

4.4.5 MBTI and VR

The MBTI has not been used to look at learning styles and VR; however, it has been used to measure temperament, which was considered by Howe and Sharkey (1998) to be a possible factor in assessing the suitability of an individual for VR.

Howe and Sharkey's MBTI Model

Howe and Sharkey (1998) proposed that two factors, competency and temperament, were considered important in deciding how suitable a person would be for VR. A chart model was proposed to show how the position on the chart indicated the suitability of the person for learning in VR (see Figure 4.11).

Competence		Temperament: Low	Temperament: High
	High	Effective users in a specific/targeted virtual environment	High-aptitude user
	Low	Low-aptitude user	Effective user in a specific/targeted virtual environment

Figure 4.11 How Competence and Temperament Affect a User's Aptitude for VR (Howe and Sharkey, 1998)

In this model, competency is equated with ability and is determined using measures of mental adaptability, special awareness, visual perception, and co-ordination. Temperament is the term given to an individual's person inclination and preferences in terms of the way that they communicate with information in the real world and is measured using the Myers-Briggs Type Indicator. If a task is not suited to someone's temperament then they will not perform well.

Table 4.3 MBTI Traits and Weightings (Howe and Sharkey, 1998)

MBTI	*Personality Preference*	*Suitability for VR*	*Weighting*
I	Introvert	High	2
E	Extrovert	Medium	1
S	Sensing	Medium	1
N	iNtuitive	High	2
T	Thinking	Medium	1
F	Feeling	Low	0
J	Judgmental	Medium	1
P	Perceptive	High	2

Different types are given weightings by the authors suggested by the compatibility with the concept of VR (see Table 4.3). These weightings are entirely subjective and no empirical evidence is provided to support them. By applying these weightings to all the 16 MBTI types it can be seen which types are best suited for VR on a basis of temperament (see Table 4.4).

Table 4.4 Weightings for the 16 MBTI types (Howe and Sharkey, 1998)

	S		*N*		
I	ISTJ (5)	ISFJ (4)	INFJ (5)	INTJ (6)	*J*
I	ISTP (6)	ISFP (5)	INFP (6)	INTP (7)	*P*
E	ESTP (5)	ESFP (4)	ENFP (5)	ENTP (6)	*P*
E	ESTJ (4)	ESFJ (3)	ENFJ (4)	ENTJ (5)	*J*
	T	*F*	*F*	*T*	

From this table it can be seen that INTP and TP types will benefit from a VR learning environment but ESFJ types and FJ types overall might not do so well. No studies have confirmed these predictions but other learning studies with VR can give more insights into which types would prefer VR to other kinds of learning media.

A summary of data from several studies (Piirto, 1998) suggested that Introverts did not like experiential learning, but preferred to learn through lecture and structure and liked to study on their own. This suggests that Introverts will not like to use VR as it represents a means of providing experiential learning activities. Extravert types preferred learning in a group where they could discuss issues, especially if there were experiential activities (Piirto, 1998). Although this suggests that Introverts may not wish to discuss issues with other people, Livingood (1995) found that Introverts were able to discuss issues by email and Dewar and Whittingham (2000) found that Introverts preferred discussion in on-line forum rather than face-to-face. Extraverts are therefore more likely to prefer multi-user VR systems that enable communication with other users. However, it may be that Introverts are willing to converse with other users by text if given sufficient time to do this.

The learning styles of sensing types are characterised by a preference for direct, concrete experiences; moderate to high degrees of structure; linear, sequential learning; and, often, a need to know why before doing something (Durling, 1996). These students often lack confidence in their intellectual abilities and are uncomfortable with abstract ideas (Schroeder, 1993). They have difficulty with complex concepts and low tolerance for ambiguity. Sensing types were good at memorising facts and details but could not generalise concepts. They also benefit from using television and audiovisual aids and laboratory demonstrations (McCaulley and Natter, 1980). Learning performance and MBTI types were also investigated by Eggins (1979) who explored the effects on sixth grade learning performance and found that iNtuitive (N) types especially NP types benefited most from a less-structured and active type of learning model such as would be represented by VR. These studies seem to suggest that iNtutives might benefit from learning in VR worlds more than Sensing types. In order to appeal to Sensing types, designers may need to provide worlds with lots of detail and structure, which would enable them to have concrete experiences that could be applied to the real world.

Work by Dewar and Whittingham (2000), that investigated the learning styles of students of on-line courses, found that Feeling types liked to use on-line forums whereas Thinking types did not. This seemed to support the suggestion from the MBTI theory that Feeling types tended to be more social in their learning (Myers and McCaulley, 1985). Another study (Piirto, 1998) found that amongst a group of college students, Thinking types preferred structured courses with clear goals whilst Feeling types liked group assignments. One study (O'Connor, 1997) found that Perceptive types had much higher college grades than Judging types, probably because they seemed to prefer to take in and absorb more information. These studies suggest that Thinking types may find it difficult to learn in active, exploratory worlds, unless they can see some sense of structure or logic behind the design. Feeling types will not like VR worlds unless there are other virtual characters in the world and possibly some form of communication between users or characters. Judging types may prefer to have some kind of expert virtual teacher within the world. Perceptive types are likely to enjoy exploring large VR worlds that contain a lot of information.

Overall the models and studies seem to suggest that iNtuitive types would do best in VR environments. Extraverts and Feeling types might do well if the worlds enabled them to communicate with other people. Introverts would prefer worlds which did not involve other users and which enabled them to go at their own pace. The other types could find it difficult to use these worlds. Sensing types need lots of details and explanations and Thinking types would need to see some sense of logical order within the world. There is no evidence to indicate the types of styles that would be found in VR designers and students, and how these might affect the design of VR. This thesis aims to investigate the learning styles of VR designers showing how these might affect the design of VR worlds (see Chapter 8).

4.5 Learning Modalities

Whilst no one person has actually proposed a theory of Learning Modalities the concept seems to have drawn upon the theory of Multiple Intelligences (Gardner, 1993) and work in neuro-linguistic programming (O'Connor, 1995).

4.5.1 Perceptual Modalities

Perceptual modality refers to the primary way our bodies take in information through our sensory channels (Reiff, 1992). Humans usually have five senses: vision, hearing, touch, smell and taste. Researchers believe that by presenting information in different modalities, accelerated learning can take place and the learned information or skills are less likely to be forgotten (Yates, 1966). Other research has pointed to the idea of individuals having preferences for learning with a particular modality (Fleming and Mills, 1992). The main sensory modalities for learning seem to be visual, auditory and kinaesthetic (Eislzer, 1983). However, some researchers have suggested that the visual modality can be divided into visual-verbal and visual-nonverbal (Becker and Dwyer, 1998) and that the kinaesthetic modality can be divided into tactile and kinaesthetic (Grinder, 1989). Students are usually able to learn with all their modalities, but with different strengths and weaknesses and this leads to preferences for one specialist mode over another (Pimentel and Teixeira, 1992; Reiff, 1992).

There are simple questionnaires available on-line that can help a learner to find out their predominant learning modality (see Appendix 10). One of the most popular is that of the Barsch Learning Style Inventory (see Appendix 10) which distinguishes between three types of learning styles:

(1) Visual Learners: Like to learn by seeing. They think in terms of images and have good imaginations. They have greater recall of concepts that are presented visually (Barbe and Swassing, 1979). They relate to written information, notes, diagrams and pictures and like to take notes. Fleming and Mills (1992) further divided this group into those who preferred to learn via images and those who preferred to use written words.

(2) Auditory Learners: Talk about what to do in order to learn. They enjoy listening, but cannot wait to have the chance to talk to others. The students respond well to lecture and discussion (Barbe and Swassing, 1979). They relate more to the spoken word and tend to listen to a lecture and make notes later and tend to make eloquent speakers.

(3) Kinaesthetic/Tactile Learners: Want to try things out, touch, feel, and manipulate in order to learn. The kinaesthetic learners express their feelings physically. They are poor listeners and they lose interest in long speeches and lectures. The students learn best by doing (Stronck, 1980). They learn more effectively by touching and moving and learn skills by imitation and often tend to be considered slow learners, mainly because lectures present auditory and visual material (Hill, 1997).

Little research has been presented that describes the percentages of adults' learning modalities but two studies have found that the visual learning style is present in about 40% of children, the auditory learning style in about 20%-30% and the remaining 30%-40% are kinaesthetic (small muscle movements) or tactile (large muscle movements) (Dunn and Dunn, 1978; Haggart, 1995).

4.5.2 Modalities and Learning

According to the multiple intelligences theory (Gardner, 1993), individuals differ in their mental representations of knowledge and therefore need learning media that can favour their type of mental representations or modalities. Veenema and Gardner (1996) argue that multimedia can enhance learning by presenting information in both pictorial and textual styles. They also support the view that individuals have dominant learning modalities. Visual learners tend to like shape, form and images, auditory learners like to hear the sound of their own or others' voices. Even if they see text they learn by saying the words to themselves. Kinaesthetic learners want to sense the position and movement of the material; tactile learners want to touch the material.

The literature suggests that matching learning styles with teaching styles enhances the learning performance (Fleming and Mills, 1992). However, with so many different learning styles and combinations, making a perfect match seems to be a daunting if not impossible task. Fleming and Mills (1992) concluded that of all the different styles, learning modalities seemed to be the most important factor to take into account when designing effective instruction. Traditional lectures tend to put emphasis on the auditory communication modality, whilst multimedia and VR seem to emphasise the visual modality (Montgomery, 1995). Laboratory sessions and field trips can include the kinaesthetic modality. When students are presented with information that is not in their preferred modality they often try and transfer it; for example, it has been found that when images are presented to an auditory person, that person has to talk about the pictures to himself in order to encode it to an auditory format (Pimentel and Teixeira, 1992). Similarly presenting auditory narration to a visual person will work if that person can conjure up images from the words (Pimentel and Teixeira, 1992). This, however, takes time and effort; so ideally, a designer needs to ensure that all modalities are represented in the learning material. In particular, there is a need for more kinaesthetic activities in the classroom. An examination of students with learning problems and learning modalities found that they tended to be kinaesthetic learners who were finding it difficult to cope with the usual visual and auditory methods of classroom teaching (Hill, 1997). In support of this view, it has been shown that slow learners were able to achieve more learning when multi-sensory methods were used as a form of instruction (Dunn, 1979).

4.5.3 Modalities and VR

Learning modality has also been linked with types of occupation (Pimentel and Teixeira, 1992), but there has been no research to look at learning modalities and VR designers. Mathematicians, architects and engineers tended to be visually-oriented people who think in terms of images. Musicians obviously tend to favour the auditory mode, whilst physical therapists, sculptors and athletes are usually examples of kinaesthetically-oriented thinkers. The auditory learning style was found to the preferred learning style amongst teachers, but the visual learning style was found amongst the majority of western culture students (Wallace, 1995).

The concept of learning modalities suggests that learners with a visual learning modality would benefit from a visual type of learning medium such as VR because of its emphasis on visual graphics (Bell and Fogler, 1997). About half the population have a preference for a visual learning style (Bell and Fogler, 1997; Kirby et al, 1988). Whilst VR seems to favour visual learners it can, through the use of 2D and 3D sounds, speech recognition, verbal conversations with other characters, offer a suitable medium for auditory learner (Byrne, 1994; Pimentel and Teixeira, 1992; Durlach and Mavor, 1995). Use of haptic facilities such as tactile and force-feedback would be necessary to benefit kinaesthetic learners (Pimentel and Teixeira, 1992; Durlach and Mavor, 1995). Few current VR systems offer haptic facilities, so it is likely the current VR systems would not be suitable for kinaesthetic/tactile learners. Unfortunately these are the types that do not do well with traditional instructional methods (Winn, 1997). Over the ages, design of learning material has often reflected the bias of the designer (Pimentel and Teixeira, 1992) and there is no evidence to suggest otherwise in VR. No data are available on the learning modality preferences of VR designers, therefore, this thesis aims to carry out a study, which will determine the learning modality preference of VR designers and VR design students, and discuss how these might affect their VR learning environments (see Chapter 9).

4.6 Help Systems

Learning can be gained using a variety of learning media in different situations or environments (Brandl, 1995). However, learning cannot occur easily without some form of support system. Although this was traditionally the role of the teacher, the increase of technology in the classroom indicates that computers have to provide feedback, guidance and help for students (Brandl, 1995).

4.6.1 Help Systems and Learning

A person having difficulties in the real world needs help and it is the same when an individual has problems with learning (Sellen and Nicol, 1990). The literature on learning has not really investigated the issue of help and its effects on learning. Help, it seems, was usually provided by the teacher, who chose what help to give and to whom within the constraints of time and resources. Some authors have, however, considered the issues of feedback and learning and the use of on-line help systems, which will now be discussed.

Feedback

Feedback has been claimed to be an essential condition for effective learning (Gagne, 1985; Sales, 1998). Feedback involves providing learners with information about their responses and can be distinguished from reinforcement that affects the tendency to make a specific response again (Kearsley, 2001). Feedback can be positive, negative or neutral and is almost always considered external (Kearsley, 2001). A large number of studies have looked at the effects of different types of feedback on learning (immediate feedback, delayed feedback, informative feedback; elaborative feedback, collaborative feedback) but the results have been mixed and inconclusive (Fisher and Mandl, 1988; Irving and Hunt, 1995; Kulhavy and Stock, 1989; Kulhavy and Wager, 1993; Ross and Morrison, 1993; Wager and Wager, 1986).

Immediate feedback was considered an important part of programmed instruction because it reinforced the required behaviour (Skinner, 1950). However it had to be given within seconds of the stimuli (the student's answer), otherwise it would not be effective. This type of feedback only indicates if the answer is right or wrong and Glaser (1965) found that such feedback was not making a significant difference in the learning performance of some students, while Kulhavy and Wager (1993) concluded that in some situations students given no feedback at all were doing better than those who received correct/incorrect response types of feedback.

Cognitive information-processing theories tended to emphasise the importance of informative feedback to improve understanding of the concepts (Wager and Wager, 1986). Computer-based tutorials included a range of types of feedback (e.g. indication of correct/incorrect answer, indication of correct answer, verification of answer with elaboration to assist learner), immediate reinforcement and remedial lessons to give better understanding (Ross and Morrison, 1993). Kulhavy and Stock (1989) considered the feedback message to consist of two parts, verification about the answer and elaboration to help the learner understand the correct answer. However, their research suggested that while feedback was beneficial in computer-aided-instruction, added elaboration did not improve learning performance. They concluded that it was better for designers to adapt the content of the lessons to the individual learner rather than provide more elaborate feedback.

Active learning theorists also support the idea of feedback but suggest that it should be of a supportive nature e.g. encouragement, guidance and help. Within more experiential active learning environments such as laboratory work, field-trips, role-playing, simulations and VR, feedback is obtained naturally and directly as a consequence of actions taken, as is representative of what might happen in the real-world situation (Brackbill et al, 1964). Collision-detection methods can help to improve the realism of the world and give direct feedback to users. In some cases this may occur immediately or it may occur once a chain of events has taken place and the outcome is revealed. However, if the delay of feedback is too long it is likely to confuse the user as to which one or more of the series of actions carried out was the cause for an incorrect outcome.

Whilst early computer programs were capable of delivering limited feedback, modern multimedia learning resources are able to deliver much more adaptive, individualised and multi-modal feedback to the learner (Sales, 1988). Such feedback, however, is not always available to the user and most help facilities seem to be of a more basic type, mainly text with a one style suits all approach (Harrison, 1995). Very little has been written on how to help students in a multimedia environment, although there is research that has investigated the use of different types of media. It seems that most research has assumed that good design of multimedia components is more important than design of a good help system.

Park and Gittelman (1992) showed that visual feedback in animated form was often superior static images for users of multimedia. Broady and Le Duc (1995) showed that video was a good form of media for providing feedback to students learning a new language. Often teachers are unable to give immediate feedback to the students and delayed feedback has been found inappropriate as the student can remember what they said. Watching a video of the student's performance can give delayed feedback, which can be related to the word that were spoken. Akamatsu et al (1993) compared tactile, auditory and visual feedback conditions for teaching skills using multimedia. The skill in question was a simple target selection and then position task. A mouse with added tactile feedback was used in one of the conditions. No differences were found between conditions for overall response times and rates in target selection; however, tactile feedback was significantly quicker in final positioning times than visual or auditory feedback. This seems to suggest that tactile feedback could be an important aspect of providing feedback and guidance in VR systems.

Although many research studies have looked at different types of feedback conditions, few have discussed different types of feedback for different types of user (Buscemi et al, 1995). Little is known about students' preferences for different kinds of feedback or how students interact with feedback in a computerised environment (Brandl, 1995). Freedman (1991) found differences in gender preference for types of feedback. Girls liked static images and light colours; boys preferred animated images and bold colours. It is also possible that different types of help media could be linked to learning modality preferences. This thesis aims to investigate this last issue further (see Chapter 9).

Adaptive instruction is designed to change the content of lessons to match the needs of the user (Ross and Morrison, 1993). Adaptive feedback aims to diagnose learner errors and adapt the feedback to the nature of the error and the learner's needs in terms of complexity and sensitivity. Such personalised feedback is more likely to have cognitive and motivational benefits; however, this type of feedback is not very common in computer software. Teachers are probably the best way of giving personalised feedback but this can be hard when there are large numbers of students in a class. Interestingly a study by Sales and Johnston (1992) looked at delivery of feedback by a familiar teacher and an unknown stranger. Results showed that students from both conditions achieved the same levels of learning performance. However, those who received feedback from the known person were more attentive to the feedback and needed to have feedback statements repeated only half as often as the other group (Buscemi et al, 1995). It seems that students prefer to have feedback given from people that they know. This may mean that if virtual characters are used to give feedback to users then they need to resemble people or animals that are familiar to the users. Perhaps because they trust them? More research is needed to clarify this.

On-line Help Systems

The main form of help in computer software programs in called an on-line help system and it usually takes the form of text information (Harrison, 19956). The questionnaire study, in Chapter 6 of this thesis, showed that VR designers tend to produce text based information for VR in the form of dialogue boxes or on-line text systems. Sellen and Nicol (1990) described on-line help systems as exacerbating to the user. Studies showed that users were not able to find relevant information because most on-line help systems consisted of a complex database of programming terms. It was also apparent that users found it difficult to get back from the help system to the task. Hysell carried out a study (Harrison, 1996) which found that users had several complaints about on-line help systems; difficulty in finding information, failure to deliver the relevant information, difficulty of switching between help and task in hand and the overall quality and layout of the help information. Thus it seems that users do not even try on-line help but instead prefer to keep on with the task trying various strategies or finding someone who knows how to use the program.

One of the main reasons why users have difficulty in finding relevant help for their task is that the help language is written in terms of the program features or systems functions rather than the needs of the task (Adams et al, 2001). Users typically need to enter a key word into the help facility to initiate a search. Unfortunately many were unable to find the correct keyword as it was not always a term with which the user was familiar, being program-related rather than task-related (Sellen and Nicol, 1990). Users also criticised the type of help that they were receiving. This invariably consisted of definitions and descriptions of commands and program features which were important to the programmer but not to the user. Users wanted to be given procedures for carrying out tasks. Much of this research investigated early forms of computer software; however, more modern on-line help systems do not seem to have improved much. Adams et al (2001) found that help systems were particularly problematical for novice users who found them too large and difficult to use (Adams et al, 2001). Students refused to explore all the help features available because they were afraid of getting lost in the computer program and therefore restricted themselves to particular features such as the dictionary (Scott, 1990).

Elkerton (1988) pointed out that whilst a number of studies had looked at the design of on-line help systems, no one had discovered the particular aspects or elements that pointed to good design. In studies that compared hard-copy instructions with on-line instructions, it was found that the on-line condition always seemed to perform significantly worse (Dunsmore, 1980). Adams et al (2001) described some of the problems with using a typical on-line help system. They were that users were often switched out of the software when invoking help, and then were switched out of help when they try to carry out the instructions in the software. Because of these reasons, users had to read and remember all the instructions in order to try to perform their chosen task. Often users would recall the instructions incorrectly and get steps out of sequences and users also mistook visual icons and buttons in the help system as real functional ones. This does not seem the case with the latest versions of word-processing software.

Several studies have investigating the use of different types of help and these can be categorised into visual versus written text, sound versus text, visual versus audio, and animations versus still graphics (Harrision, 1996). LeFevre and Dixon (1986) found that students preferred to follow a visual example than written instructions. Harrison (1993) found that students given visuals with text outperformed those who were only given text. She also found that it did not matter is the visual material was still-graphics or animations. Auditory information is transient in nature (Kozma, 1991), which means that it is often difficult to memorise verbal material given the limitations of short-term memory. Visual material gives the student a greater chance of learning the material (Hapeshi and Jones, 1992; McDowd and Botwinick, 1984). However, Mayer and Moreno (1998) found that students were able to retain more information when they received images and verbal information rather than images and text. This result supported the dual-coding theory, which suggests that presentation of information in two different modalities enhances the overall learning effect (Clark and Paivio, 1991). Palmiter et al (1991) showed evidence that indicated that animated instructions were better for immediate recall, but written instructions were superior for long-term retention.

4.6.2 VR and Help

There is little research or information about help systems for VR. One of the characteristics of VR, discussed in the previous chapter, highlighted the need for natural interaction and communication. If this is applies to the design of help systems, then they need to be natural and 'within-context' in order to maintain a sense of presence. Good examples might include avatars that follow the user around or appear when needed and speak to the user. Other methods could include use of virtual mobile telephones, books, posters other similar techniques, which can access text, image or verbal instructions as appropriate. Unfortunately text is difficult to create in virtual worlds (W. Bricken, 1990) as it usually entails the use of textures or actual 3D letters. The first is not easy to read as texture text is not always clear due to resolution problems and the latter takes a long time to produce. The more usual methods of providing help in VR systems is by on-screen text dialogue boxes that appear in the middle of the screen (and thus world) or text windows that appear next to the VR world window. These types of help systems could be considered as 'without-context' systems as they appear to be outside the VR world and thus may decrease the sense of presence and realism for the user. The idea of dialogue boxes appearing from the ceiling of a burning building from the press of key or button is inappropriate for VR (Mason, 1996; Roussos and Bizri, 1998). Sellen and Nicol (1990) support the idea that future help systems need to be context-sensitive, less obtrusive and more adaptive for the user. Text boxes are the easiest way to provide help and a compromise might be to use text boxes that appear when the user interacts with a book in the world. The user can then imagine that these boxes represent pages from the book, although ideally these should be created from textures to give more realism. Research is needed to investigate this possibility (Mills and Noyes, 1999).

In considering natural forms of help for the user of VR the real-world metaphor must be used. In a real-world situation the usual method of obtaining help would be to ask the teacher or some other expert, thus speech would be the most natural means of getting such help (McGlashan and Axling, 1996). Karlgren et al (1995) suggested that whilst speech is also a natural way of communicating in a VR world, such a feature is not common in VR systems. Two-way verbal communication would involve the use of speech recognition systems that are still limited in use (see Chapter 9). One-way communication could be implemented via an intelligent agent that speaks to the user according to their needs; however, this is rarely done. More information is needed about the design of help systems in VR especially the use of on-screen text or verbal instructions and the use of 'helpful agents'. This thesis aims to carry out an experiment that will provide such information (see Chapter 9).

This chapter has discussed a number of issues relating to individual differences and the design of VR learning environments. Clearly VR seems to favour certain learning styles and modalities and these need to be considered in any general design model. If VR is to be put forward as a medium that can be used by all types of people, then ways of helping those who do not suit VR are needed. These might include the incorporation of different learning content or the addition of appropriate help facilities. Any design model or framework needs to highlight these issues and suggest practical guidelines for how this can be done. However, this is difficult without much more empirical evidence to identify how this can be done. The next chapter discusses how some of these issues can be incorporated into a general design model.

CHAPTER 5: DESIGN MODEL

5.1 Designing VR Worlds for Learning

A virtual world can be informative, useful, and fun; it can also be boring and uncomfortable; the difference is in the design (M. Bricken, 1990). Designers need knowledge of the physiological and psychological capabilities of users in order to design appropriate systems (Shelbourn et al, 1998). They also need to have an underlying knowledge of how people learn (Winn, 1993).

M. Bricken (1990) proposed a design strategy for VR learning environments with the following components:

(1) Designers work with engineers to test the usability of VR systems in order to tailor the technology to people's physical and psychological needs.

(2) Designers work with participants to customise the virtual worlds for their particular needs, preferences and capabilities.

(3) Designers compose worlds that contained the appropriate graphical contexts and interactive possibilities for the particular application.

(4) Designers evaluate the effectiveness of the worlds by observing the learning, accommodation and performance of participants.

However, there are no guidelines as to how designers actually go about meeting these components.

The first component concerns the use of technology and a number of studies have argued the strengths and weaknesses of various devices that can be considered for use in a virtual environment (Kawalsky, 1993; Vince, 1998). Kaur (1998) has argued that research into usability issues has focused upon the human factors aspects of VR interface devices but not the usability of the VR content. She found that designers used ad-hoc methods for designing the content and developed a model that would assist them in providing appropriate interactivity. This study goes some way towards answering the problems of component number three. The last component can be resolved by carrying out formal evaluations during the design process to assess the effectiveness of the learning content. Cronin (1997) suggests that pre- and post- tests are the most common methods for assessing structure learning environments and video-taping and self-report surveys are preferred for non-structured learning. Rose (1995) used a three-part assessment model for evaluating the results of learning experiments carried out using the Virtual Reality Roving Vehicle (VRRV) project. The three parts were instructional factors, virtual environment experiences and activities, and external factors such as classroom conditions and student differences. Evaluation methods are beyond the scope of this thesis but student differences are considered. There seems to be little evidence to show designers how to consider aspects of student differences. This needs knowledge of how people learn and how the characteristics of VR can enhance their learning experiences. It also needs to consider how to meet the support needs of the users in terms of help and guidance. It is these issues that are the main concern of this thesis.

5.1.1 General Design Model for VR Learning

A general model is now presented (see Figure 5.1) that attempts to address the design of learning environments. A number or elements and corresponding guidelines are included. The overall design covers four main areas covered so far in this thesis: theoretical learning principles, VR characteristics, individual differences and provision of help facilities. For ease of use, these areas have been divided into elements identified from the literature and organised into groups or boxes in the design. Arrows show that each of these areas needs to be considered by designers in the development of the overall VR learning environment. The VR learning environment includes the VR system, VR world and VR content and this is shown by italics in the centre box.

The rest of this chapter looks at each group of this model and attempts to present practical guidelines for designers to follow taken from the literature discussed so far. The elements of each box are based on the results of the literature review as discussed in previous chapters. Page numbers are given, which refer to the pages where the information, from which the guidelines are derived, is presented. It must be noted that although all elements are discussed separately, many of them are inter-related. The details of the general model, as shown in Figures 5.2-5.11 give guidelines where possible, however, when there is no literature to support guidelines, this is shown in bold letters. It is intended that fieldwork studies will be carried out in this thesis in order to investigate these particular elements and provide guidelines, which will be discussed in Chapter 10.

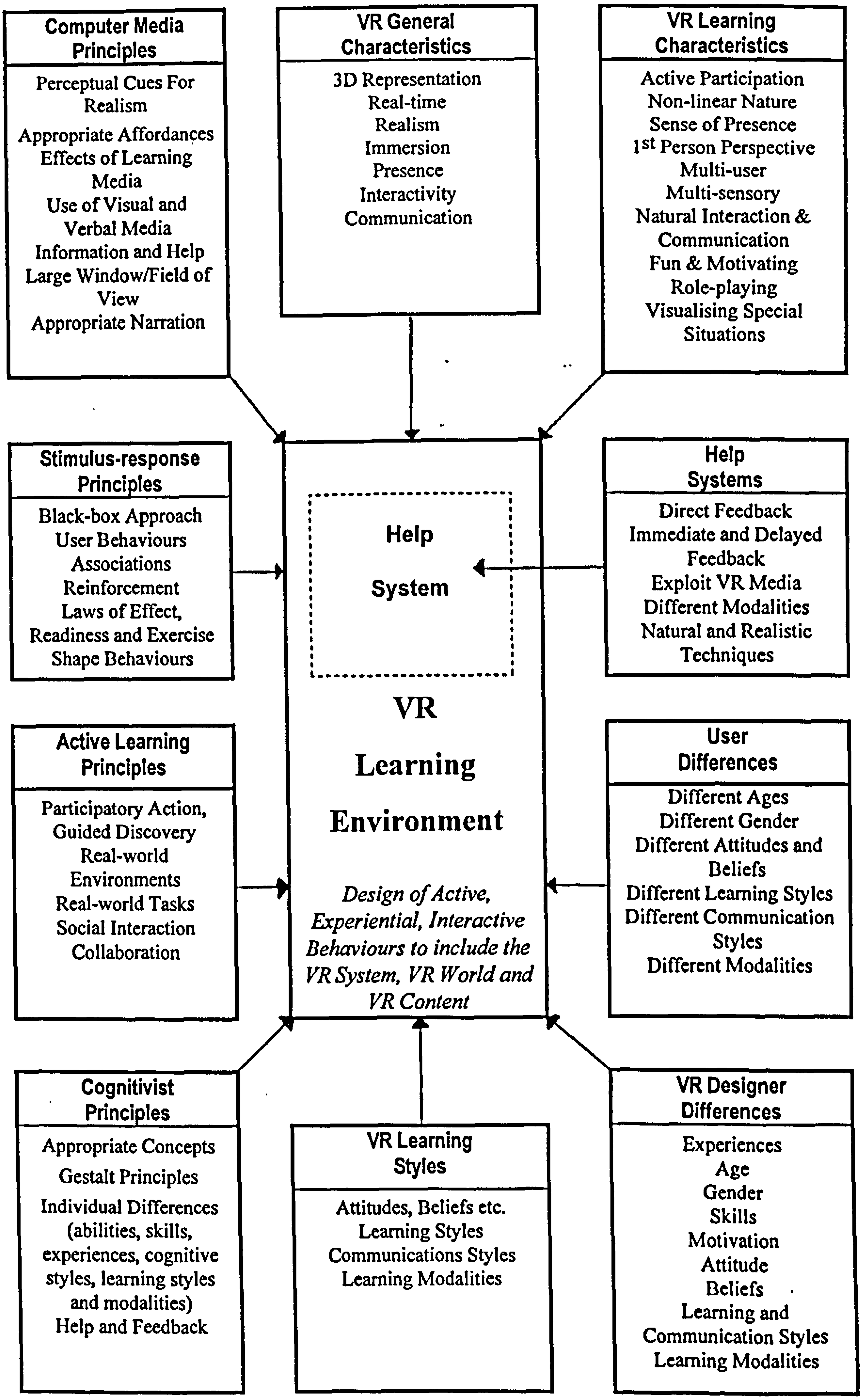

Figure 5.1 Overview of General Design Model for VR Learning Environments

5.1.2 VR Characteristics

Elements of the VR General Characteristics

Page numbers are used to help the reader refer back to relevant information in this thesis.

VR General Characteristics
3D Representation (p. 24) *Creation of 3D objects rather than 2D textures* *Use of 2D and 3D depth perception cues e.g. linear perspective, distancing of details, use of lighting and shadows*
Real-time (p. 24) *Use of high refresh rates, low latencies and lags* *World should give immediate feedback to the input of the user* *Limited use of textures and distancing of details is needed to maintain a high frame rate*
Realism (p. 25) *Concentrate upon realistic objects, behaviours and interactions rather than textural graphics* *Provide sounds and characters as appropriate* *Verify that features like collision detection and gravity are implemented* *Ensure that the world is designed to scale* *Give user a sense of realism by ensuring that they can climb, and fall in the world and that they can move and manipulate objects in the world* *Provide haptic devices, if possible*
Immersion (p. 26) *Use headset or projection display devices, if appropriate* *Concentrate upon psychological and motivation immersive factors rather than the technology* *Ensure that the desktop VR window is as large as possible*
Presence (p. 27) *Provide plenty of interactivity and realistic behaviours* *Ensure that there is interaction between users and objects and virtual characters*
Interactivity (p. 28) *Users should be able to activate appropriate objects in the world as they would in the real world* *If not using natural interaction devices, then intuitive methods of using simple input devices are required such as navigation bars* *Designers should concentrate upon creating interactive 3D objects rather than realistic 2D graphics*
Communication (p. 29) *Users need to be able to talk to each other in a multi-user environment* *Virtual characters should speak to users as appropriately single- and multi-user worlds*

Figure 5.2 General Characteristics of VR Systems

Elements of the VR Learning Characteristics

VR Learning Characteristics
Active Participation (p. 32) *Ensure that there are a large number of activities that the user can perform in the world*
Non-linear Nature (p. 33) *Design for exploratory learning and expect the user to be able to go anywhere in the world and do anything, in any order*
Sense of Presence (p. 34) *Ensure that the user is motivated and create activities that interest the user* *Give the user a sense of presence by ensuring that they have control in the world*
1st Person Perspective (pp. 34) *The user must have a viewpoint that places them inside the action as a possible character in the world. Viewpoints should not follow characters around from above, behind etc.*
Multi-user (p. 35) *A multi-user environment is necessary for discussions and collaborative learning* *Users need to be able to see each other in the world and communicate with each other*
Multi-sensory (p. 36) *Use of visual, auditory and kinaesthetic or haptic (tactile, force-feedback) facilities should be incorporated into VR worlds to cater for different learning modalities*
Natural Interaction and Communication (p. 39) *Users should be able to interact with objects in the world in a natural and realistic manner* *Speech recognition devices should be incorporated to allow for natural communication* *Characters should be designed to move and speak to the users as appropriate*
Fun & Motivating (p 40) *Users should feel safe and in control within the world.* *The world should be designed to be interactive and fun for a particular user*
Role-playing (p. 41) *Make use of the role-playing aspect of VR in design of learning content*
Visualising Special Situations (p. 41) *Explore possibilities of allowing the user to become either a very large or very small object to enable then to explore parts of the world that could not be done in real life* *Exploit the ability to simulate dangerous situations within a safe learning environment.*

Figure 5.3 Characteristics of VR Learning Environments

5.1.3 Theoretical Learning Principles

Elements of Stimulus-Response Theories

Stimulus-response Principles

Black-box Approach (pp. 46 and 50)

Designers need to ensure that learning content is based on the interpretation of users behaviours and actions in the world

Account for User Behaviours (p. 50)

Programming needs to account for the users actions and behaviours, these may need to be recorded in some manner to provide appropriate action or feedback. These behaviours should control the learning content of the world and the following actions as a consequence.

Association (pp. 47, 48 and 51)

Learning content needs to be aware that users will associate certain behaviours and activities with certain responses in the world

Objects need to be designed to elicit the correct associations and responses

Designers need to provide methods that will hinder incorrect associations, maybe by use of sounds or object behaviours

Reinforcement (pp. 48 and 50)

Objects should be designed to give direct feedback as reinforcement of a user's response

Characters could be designed to give positive or negative feedback in order to assist the user

Law of Effect (p 47)

Behaviours and interactions should be natural and consistent in order to ensure that users can interact easily in the world

Law of Readiness (p. 47)

Users need to be able to interact freely in the world carrying out a number of sequential interactions without inappropriate obstacles. Objects, which do not behave as expected, can become an obstacle for the user and detract from the learning process

Law of Exercise (p 47)

Designers should create learning content that allows users to repeat certain actions in order to strengthen the learning association

Shape Behaviours (p. 50)

For certain applications, new behaviours may need to be learned and content is needed to shape these new behaviours

Figure 5.4 Principles of Stimulus-response Learning Theories

Elements of Cognitive Learning Theories

Cognitivist Principles
Appropriate Concepts (p 52) *Learning content needs to be appropriate to the age range* *Designers need to build upon concepts that have been learned at that stage of development*
Gestalt Principles (p. 51) *Designers need to be aware of how the Gestalt principles may affect the way that users perceive the world*
Multiple Intelligences (p. 53) *Designers need to be aware that there are differences in individual skills and take these into account within their design.* *VR may suit individuals who have practical skills but appropriate input devices will be needed to ensure that interaction will make these skills realistic* *Multi-modal learning content may be needed to benefit different types of users*
Learning Styles (p. 74) *VR seems to suit an active type of learning style, interactivity is necessary to encourage this* *Methods may need to be used to assist passive learners, e.g. watching another character within the world, providing a spectator viewpoint and programming a series of events that can be observed by the users*
Abilities, skills, experiences (p. 34) *Learning content needs to ensure that there are a range of activities available in the world that will suit the various abilities, skills and experiences of the user*
Gender *This is not covered in this thesis and there needs to be more research in this area.*
Help and Feedback (p. 56) *Users who find it difficult to learn in a VR world need to be given guidance and feedback on learning performance*

Figure 5.5 Principles of Cognitive Learning Theories

Elements of the Active Learning Theories

Active Learning Principles
Participatory Action (pp. 55 and 58) *Users will benefit from carrying out practical experiments in the world* *Learning content should be designed to encourage experiential learning*
Guided Discovery (p. 55) *Users can be guided by virtual characters* *Or by text boxes which give hints and clues in their discovery process*
Real-world Environments (p. 58) *Environments and should be designed to mimic real-world settings in order to encourage situated learning* *Learning tasks need be carried out in the appropriate real-world context to encourage positive transfer*
Real-world Tasks (pp. 58 and 60) *Learning content and activities for adults need to be relevant to their personal and work situations*
Social Interaction and Collaboration (pp. 58 and 61) *Characters are needed in the world which can be intelligent or controlled by other users* *Methods for collaboration between users are needed to discuss learning issues and to carry out group projects*

Figure 5.6 Principles of Active Learning Theories

Elements of the Computer Media Learning Theories

Computer Media Principles
Perceptual Cues for Realism (p. 62) *Designers may need to consider how to design for perceptual cues pickup by users when moving around the world*
Appropriate Affordances (p. 62) *Content should take into account the properties of an object, other than shape or identity that might specify potential interactions between it and the user.*
Effect of Media (p. 64) *Different media will affect users in different ways. There needs to be more information about how VR affects people and the different meanings that users can extract.*
Use of Visual and Verbal Media (pp. 64 and 65) *Verbal narration and messages should be used to enhance the mainly visual learning of VR rather than text*
Information and Help (p. 64) *Users need access to all information and help within the world as they only have one window* *Designers could try and create virtual windows within the world but these need to seem realistic to the context*

Figure 5.7 Principles of Computer Media Learning Theories

5.1.4 Individual Differences

Elements of VR Learning Styles

This group of elements refers to the styles and differences, suggested by the literature covered in Chapter 4, that seem most appropriate for VR. It is implied that VR designers and VR students should have these styles. Field studies in this thesis will address these issues.

VR Learning Styles
Learning Style (pp. 74 and 80) *Activists are more suited to an active, participatory VR learning environment*
Communications Styles (p. 84, 86 and 89) *Extraverts are more suited to active learning in VR worlds and may prefer multi-user VR* *The INTP psychological type is the most appropriate type for VR*
Learning Modalities (p. 92) *VR suits visual learners*

Figure 5.8 The Most Likely Styles Found in People who Suit VR

Elements of the Designer Differences

There is little information in the literature about VR designer differences and Figure 5.9 highlights some of the questions, rather than principles, that need to be addressed, in order to produce guidelines. The fieldwork in this study will attempt to address some of these questions.

Elements of User Differences

The fieldwork in this thesis will review the literature on population learning styles that might be relevant to this section of the model (see Chapters 7, 8 and 9). It is beyond the scope of this thesis to address issues relating to users (see Figure 5.10), but further research is needed to investigate these.

VR Designer Differences
Experiences (p. 1) *What experiences are suitable for design of VR learning worlds?*
Age, Gender (p. 69) *Do age and gender make a difference on VR designs?*
Skills *What skills do VR designers have and which are suitable for VR learning worlds?*
Motivation (p. 71) *What motivates someone to design VR and do they have a positive motivation?*
Attitude, Beliefs (p. 72) *Positive attitudes towards use of technology in the classroom can help learning. Do VR designers have positive attitudes and beliefs towards VR in learning?*
Learning and Communication Styles (p. 70) *Do designers have particular learning styles or communication styles?*
Learning Modalities (p. 90) *What learning modalities do they have?*

Figure 5.9 Questions to be Answered Concerning VR Designer Differences

User Differences
Different Ages, Different Gender, Different Learning Styles, Different Communication Styles, Different Modalities, Different Attitudes and Beliefs
Information is needed about the differences in users that affect learning *Guidelines are needed to show how these differences can be matched in VR.*

Figure 5.10 Questions to be Answered Concerning User Differences

5.1.5 Help Systems

Elements of Help Systems

The help system is and should be an integral part of any VR learning environment and might be affected by many of the elements discussed so far. For the purposes of this experiment, however, the area of help systems is presented as a separate set of the most important elements and guidelines that can be used by the VR designer. Guidelines can be identified from the literature for many of the elements in this group; however, the area of different modalities is not well covered (see Figure 5.11). Fieldwork in this study will, therefore, consider the design of help systems in relation to the learning modalities (see Chapter 9).

Help Systems
Direct Feedback (p. 95) *Objects etc. should give direct feedback to the users*
Immediate and Delayed Feedback (pp. 94 and 96) *Use of collision detection feedback will increase realism and sense of presence and assist the user in navigating around the world* *If teachers or trainers are going to given overall (delayed) feedback to users after they have completed their VR session then video-tapings or other methods of recording behaviours might be necessary to link feedback to actions*
Exploit VR Media (p. 99) *Help systems are necessary in VR worlds and should exploit all the capabilities of the system*
Different Modalities (pp. 92 and 97) *More information is needed to decide if VR worlds should have auditory or visual help systems*
Natural and Realistic Techniques (p. 99) *Avatars can be used to speak to the users either by intelligence or by other expert users (e.g. the teacher or trainer)* *Help should not be accessed by key presses, it should seem to be natural to the world, so activating objects like help books, posters, PDAs (personal digital assistants) could be used as mediators between the world and the text instructions* *Textures could be used to indicate pages of a book or text messages on a mobile telephone for example*

Figure 5.11 Issues for VR Help Systems

This chapter has shown a number of guidelines that can be used in the design of VR worlds. Some questions are still to be answered. It is beyond the scope of this thesis to find all the answers or to test these elements. Instead, the field studies carried out in the next four chapters will attempt to address some of the points related to individual differences where there is a lack of research and data in the literature. These areas are: attitudes and beliefs of designers, learning and communication styles of designers and general student populations, learning modalities and VR and help systems, in particular the use of text or voiced instructions in natural help systems.

CHAPTER 6: STUDY 1 - AFFECTIVE SURVEY

6.1 Introduction

Chapter 4 showed that affective factors such as motivation, attitudes and beliefs might affect the learning process. Learners need to be self-motivated to benefit from unstructured, active learning environments such as offered by VR (Rogers, 1969; Cross, 1981). The chapter also highlighted the need for teachers to be motivated and have positive attitudes towards using technology in the classroom, as this influenced the learning of their students. It is also possible that designers' motivation, attitudes, beliefs and values might similarly affect learning outcomes. It is hoped that designers do have positive attitudes towards designing VR worlds. As there is no evidence in the literature to support or reject this hypothesis, a field study was carried out to assess VR designers' affective processes, which will be described in this chapter.

In order to assess a person's affective factors, a measurement tool is needed. Although the individuals could be interviewed, the literature suggests that the most common tool is an attitude survey or questionnaire. There are a huge number of measurement tools that have been developed to assess the attitudes, beliefs and values of people in a variety of situations (Knezek and Christensen, 2000). However, most of these have been designed for a specific purpose and cannot be used elsewhere. The common factor in these tools was the use of self-ratings using Likert scales. Two studies have investigated the attitudes of children using VR. Osberg (1997) produced a set of twenty-eight questions that could be rated on a scale of 1-10 for children using an immersive VR system for the first time. Rose (1995) created a set of twenty-eight questions that could be rated on a scale of 1-9 for measuring the attitude of participants using VR to learn Japanese. However, there are no studies that have developed a questionnaire or attitude survey for VR designers. Thus, it was decided to create a set of questions that were specific to the requirements of this experiment that would ask questions to elicit insights into a variety of issues about designers and VR. Although few VR designers design specifically in the field of learning, it could be argued that most VR worlds elicit some kind of learning from the user. Thus it was considered that a sample of general VR designers and VR design students was suitable for the purposes of this thesis.

6.1.1 Aims of this Study

This study investigates the nature of the beliefs and attitudes of VR designers and VR design students. In line with the studies outlined above, it was decided to use an attitude survey approach, with questionnaires containing both open-ended questions and Likert rating scales. The questionnaires were designed to investigate experiences, beliefs and attitudes in four particular areas of interest that might have an effect on the motivation of the designer.

6.2 Method

6.2.1 Participants

All participants had volunteered to take the MBTI. They were informed of the aims of this study and were assured that results would be kept confidential. A large number of questionnaires were handed out to participants; only those that were completed and returned were used in this study.

VR Designers

The participants were 5 females and 19 males who were all VR designers, mainly of desktop VR systems. The age of the group ranged from 22 to 47 years old with a mean age of 35 years and a standard deviation of 8 years.

VR Design Students

The participants were 17 females and 42 males in a total sample of 59 students who were H.E. students, taking a virtual reality module. They were of mixed age, ranging from 21 to 55 years old. The average or mean age was 28 years with a standard deviation of 9 years.

6.2.2 Materials

Two questionnaires were designed to produce both qualitative and quantitative data from a mixture of closed and open-ended questions.

The VR designer questionnaire was divided into four sections; work experience in virtual reality, provision of help facilities, beliefs about training media and enjoyment in using software. These questions related to their use of VR as a design tool in their job experiences.

The VR design student questionnaire asked questions that were related to experience, attitudes and beliefs about computers, general use of software, use of virtual reality in training and design of help systems in virtual reality. Questions were chosen to elicit answers that might show insights into how their attitudes might affect their work if they chose to design VR worlds in the future.

6.2.3 Procedure

The questionnaires were tested out using a small sample of VR training personnel and students to ensure that questions were not ambiguous and were easily understood. After a few minor changes in layout and in the working of some questions, the final questionnaires were produced (see Appendix 2).

Participants were given the written questionnaire to complete in their own time and then hand back to the experimenter. All answers were to be filled in on the questionnaire.

6.2.4 Data Analysis

The questionnaire provided both qualitative and quantitative data. Quantitative results were analysed using descriptive statistics in *Excel* and *Minitab* software packages.

6.3 Results

The raw data for both VR designers and VR design students can be seen in Appendix 3.

6.3.1 VR Designer Questionnaire

Work Experience in VR and training

The first four questions related to the work experience of the VR designers in the area of VR and training. These questions were of an open-ended type and produced qualitative data, which will now be discussed in more detail.

The first question asked the participant about the type of VR work that they did. Answers showed that the VR designers, as a group, had developed applications for a wide variety of areas including areas such as training, education, simulation, web development games, defence, advertising, architecture and visualisation projects. Several of the designers were actually helping to develop desktop VR software packages. Thus there seemed to be a great deal of experience in the group of designing VR applications.

The second question asked the participants to state what they liked best about developing VR applications. Most of the answers included answers related to designing the worlds and to creating code to make the worlds interactive. Three designers mentioned that they liked the chance to be creative in using colours and textures. Many of the answers related to the ability to create real-time interactive functionality. Many liked the way that VR gave them a chance to be artistic and two participants enjoyed the ability to use VR to solve problems.

The third question asked the participants if they had had any experience developing training software. Eight (30.8%) of the designers had had experience of developing applications for training whether it was VR or other software. Eighteen (69.2%) of the designers had no experience in the field of training.

The fourth question related specifically to the experience of designing VR training software. Answers from the eight designers who had had experience, included submarine and aircraft simulations, fire training, aircraft maintenance, health and safety and training of VR software design.

Design of Help Systems

The next three questions were concerned with the design of suitable help systems in VR software applications. They were open-ended questions, which gave space to enable the designers to discuss their ideas.

The first question asked the participants to write about the type of help facilities that they usually provided in their software applications. Three of the VR designers stated that they tried to create 'easy to use' worlds that needed no help. Two stated that they provided telephone support if there were problems. Two answers related to the provision of an on-line menu system. Two answers related to providing written help in an HTML document accompanying the web application. The rest of the answers related to on-line written text or dialogue boxes accessed by use of a particular key-press. Only one participant considered the use of a virtual character to 'speak' instructions.

The second question asked the designers to describe how they ensured that the help facilities were indeed helpful. Only one participant did not reply to this question. Three participants replied that they tried to write clear and simple instructions for the client. Six designers stated that they themselves tried to take on the role of user and tried to find out any problems before giving the application to the client. The rest of the sample described various methods of carrying out user trials or getting user feedback in order to develop the help facility.

The last question in this section provided an opportunity for participants to describe the type of help facilities that they would like to provide in their VR software. Two participants did not know what type of help they would design, one wrote "a good book" and two admitted to needing to think more about this issue. One designer suggested a windows type of 'right-click' help facility, another a windows wizard and another suggested a search and browse facility. Three suggested training courses and one mentioned the need for other users, across a network, which may help. Only one suggested a virtual avatar that could provide help facilities.

Beliefs about Training Media

Six questions were presented to the designers to inquire about their beliefs of VR as a training tool. Rating scales were used to indicate the strength of their beliefs.

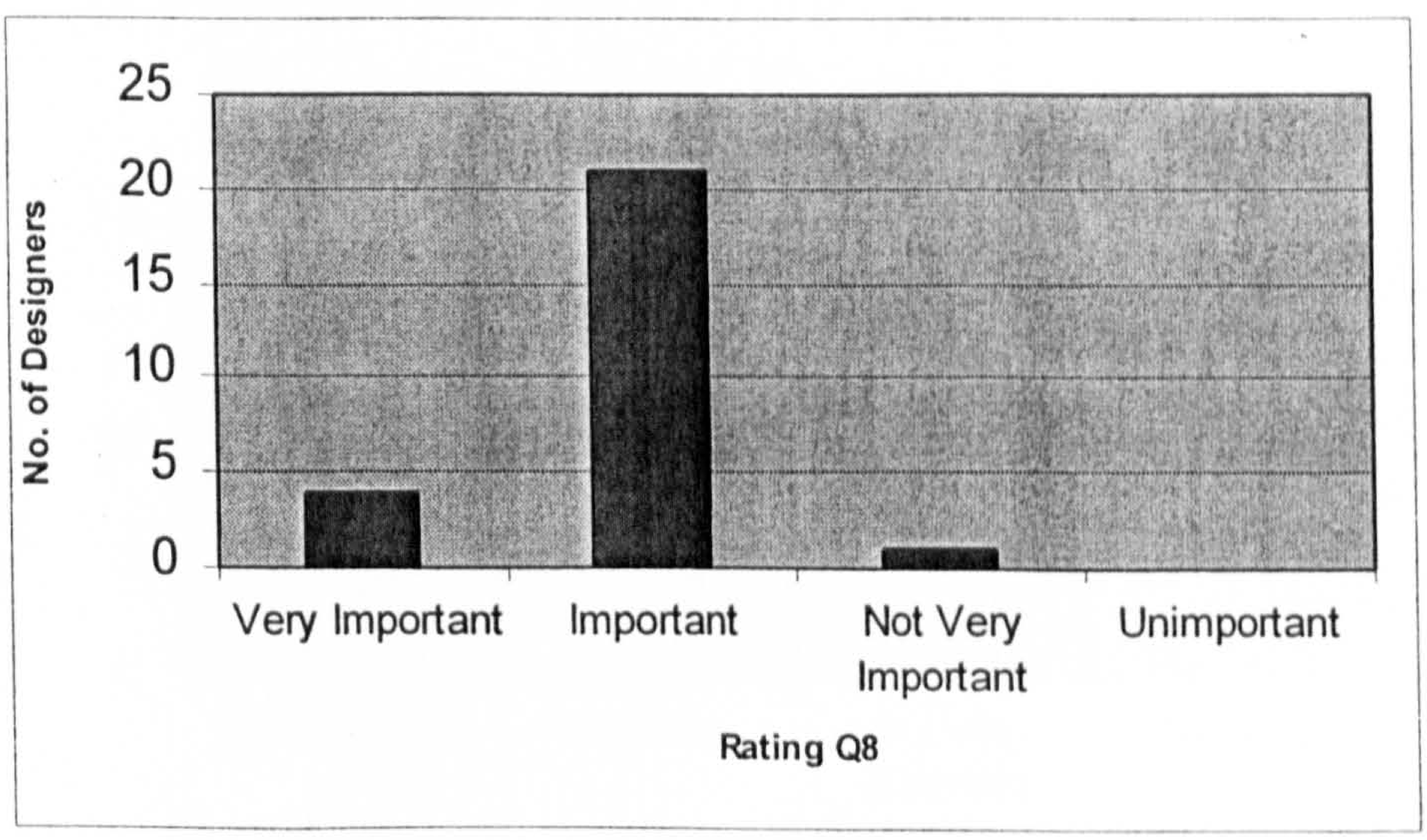

Figure 6.1 How important is the use of computers in training?

Question 8 asked the participants to rank their beliefs/attitudes to the importance of the use of computers in training. The mean rank for this question was 1.88. This equates to being just a bit more than Important. The number of designers that circled each rank is shown in Figure 6.1. The most popular category was Important (80.8%, n = 21) and the next was Very

Important (15.4%, n = 4). Only one person thought that the use of computers was Not Very Important and no one rated it as Unimportant.

Question 9 asked the participants to rank their beliefs/attitudes about the importance of the use of virtual reality in training. The results can be seen in Figure 6.2.

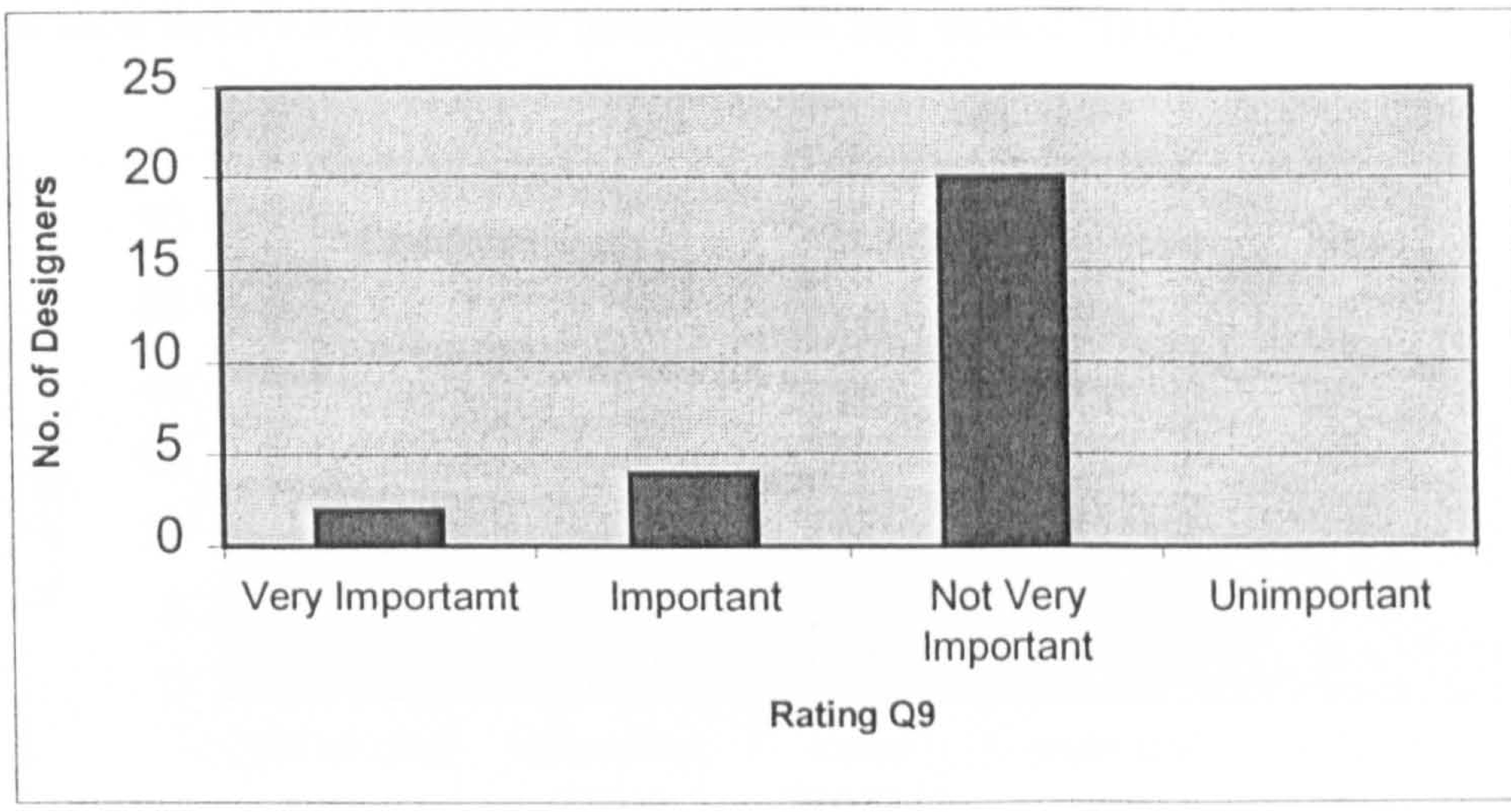

Figure 6.2 How important is the use of virtual reality as a training tool?

The mean rank for this question was 2.08. This equates to being just a bit less than Important. The most popular category was Not Very Important (76.9%, n = 20) and the next was Important (15.4%, n = 4). Two people thought that the use of Virtual Reality was Very Important and no one rated it as Unimportant.

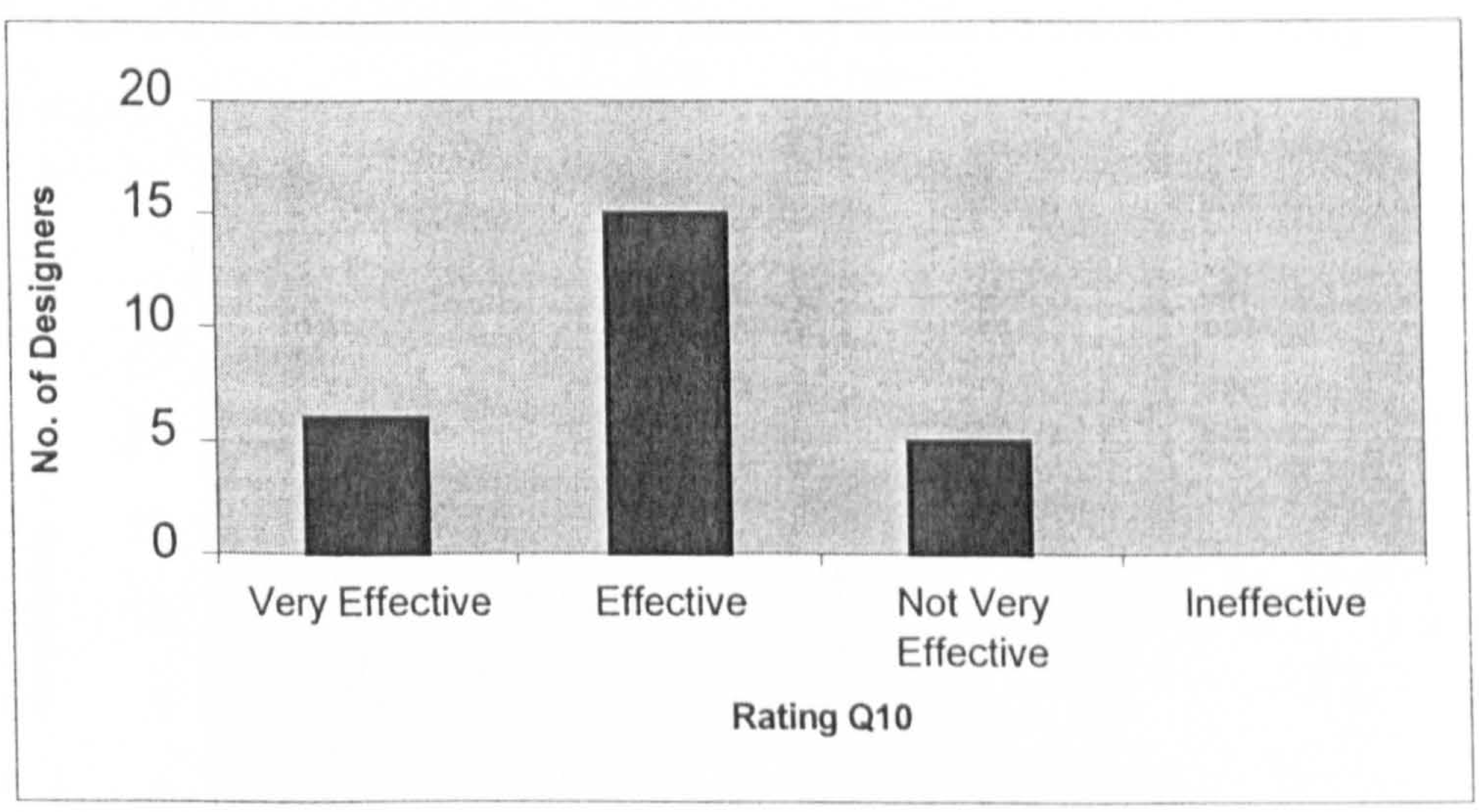

Figure 6.3 How effective is the use of virtual reality as a training tool?

Question 10 required the participants to rank their beliefs/attitudes about the effectiveness of the use of virtual reality as a training tool. The mean rank for this question was 1.96. This equates to being just a bit more than Important. The number of designers that circled each rank is shown in Figure 6.3. The most popular category was Important (57.5%, n = 15) and the next was Very Important (23.1%, n = 6). Five people considered that Virtual Reality was Not Very Effective as a training tool and no one rated it as Unimportant.

The next three questions asked the participants to tick the statements that they agreed with most about their beliefs and attitudes to computers and virtual reality.

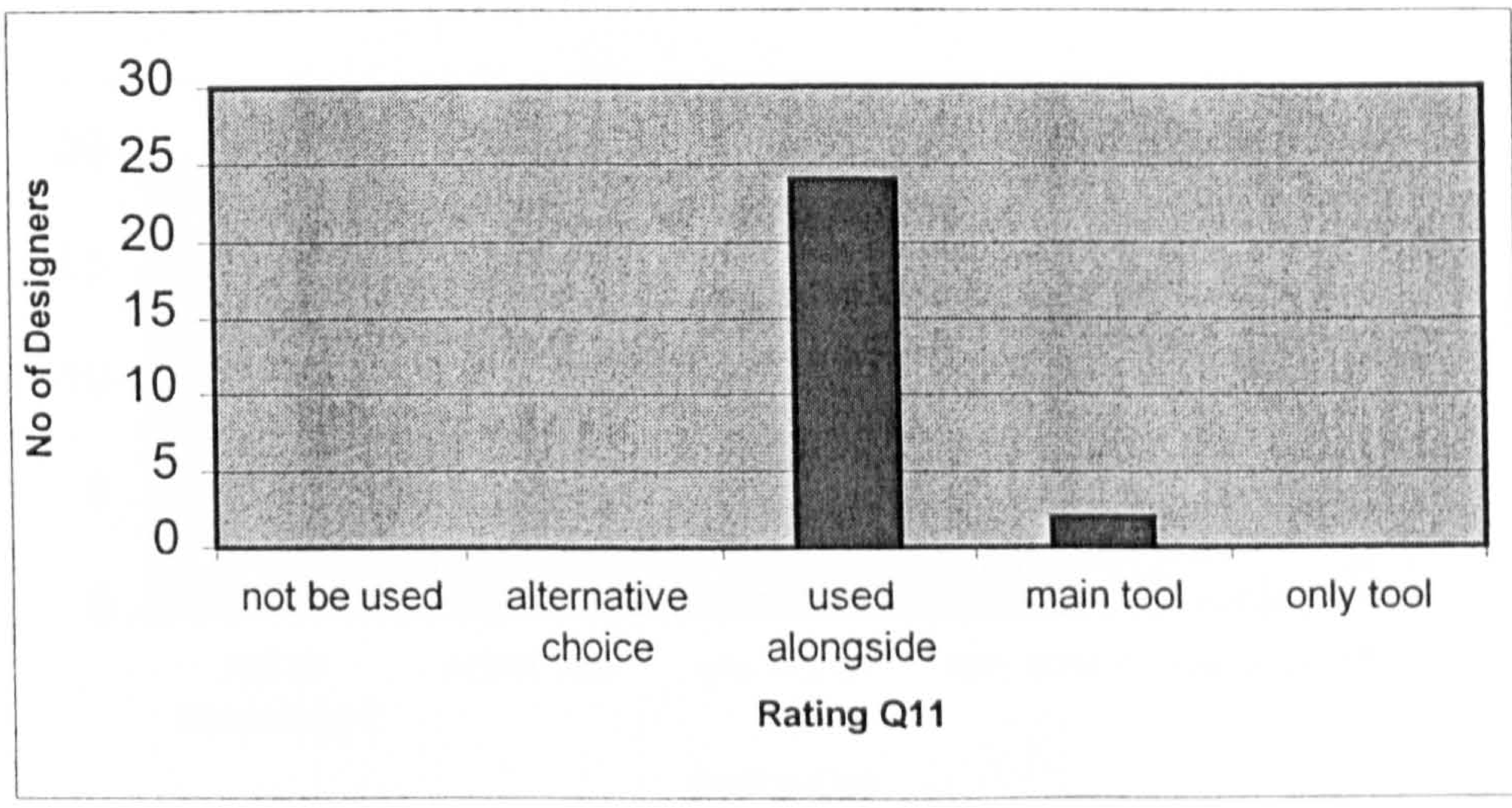

Figure 6.4 Beliefs about using Computers in Training Courses

The answers to the first question (Question 11) can be seen in Figure 6.4. By giving the first category a rating of 1 and the last a 5, the mean score for this question was 3.08. This equates to being just a bit more 'used alongside other media'. The most popular statement was that "computers should be used alongside other forms of media on suitable training courses" (92.3%, n = 24).

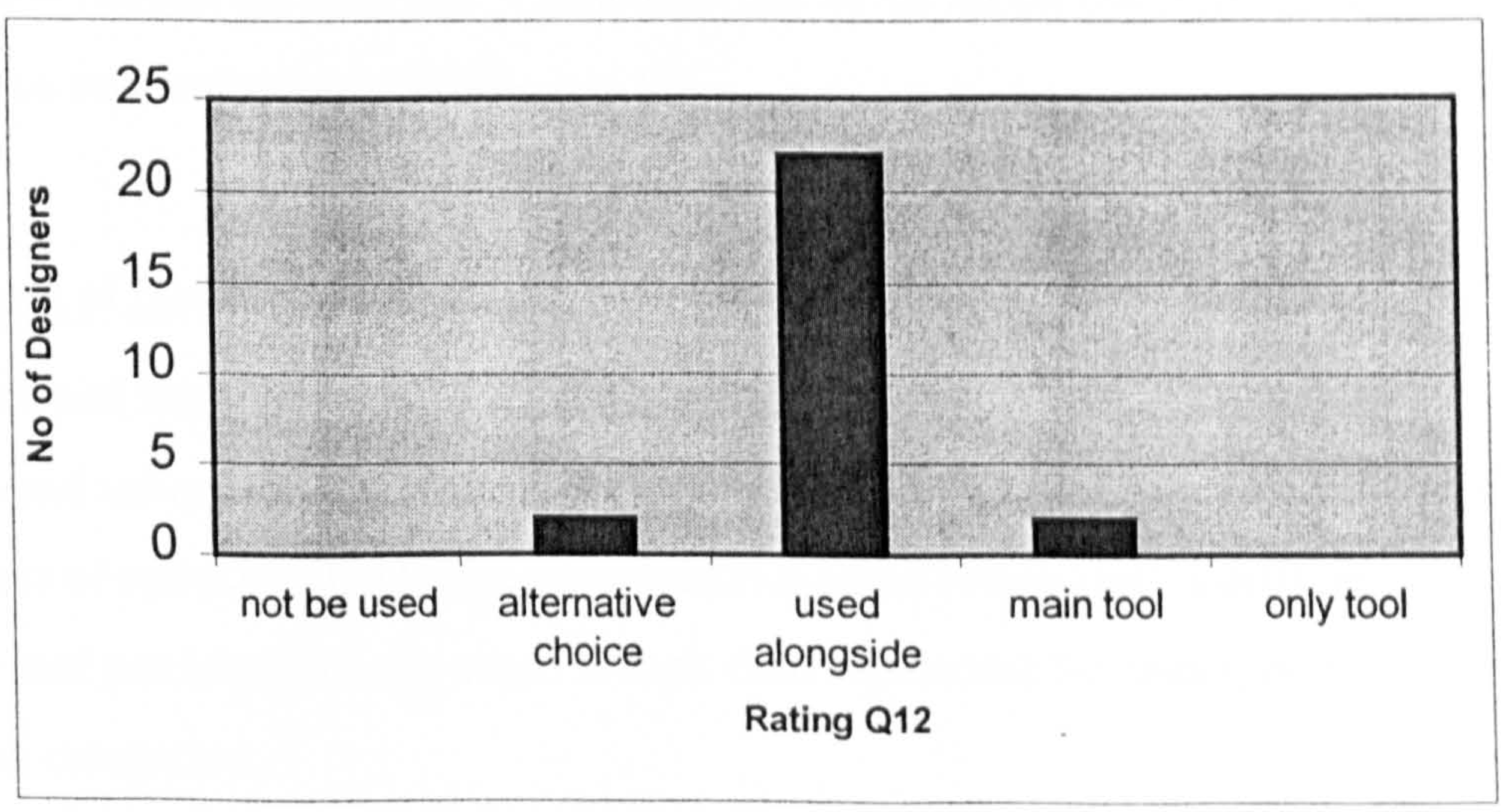

Figure 6.5 Beliefs about using Virtual Reality in Training Courses

The answers to the second question in this section (Question 12) can be seen in Figure 6.5. The mean score for this question was 3.00 that equates to 'being used alongside other media'. The most popular statement was that "virtual reality should be used alongside other forms of media on suitable training courses" (84.6%, n = 22). Two people (7.7%) thought it should be one of several choices of training tool and two people (7.7%) thought that it should be the main form of training medium.

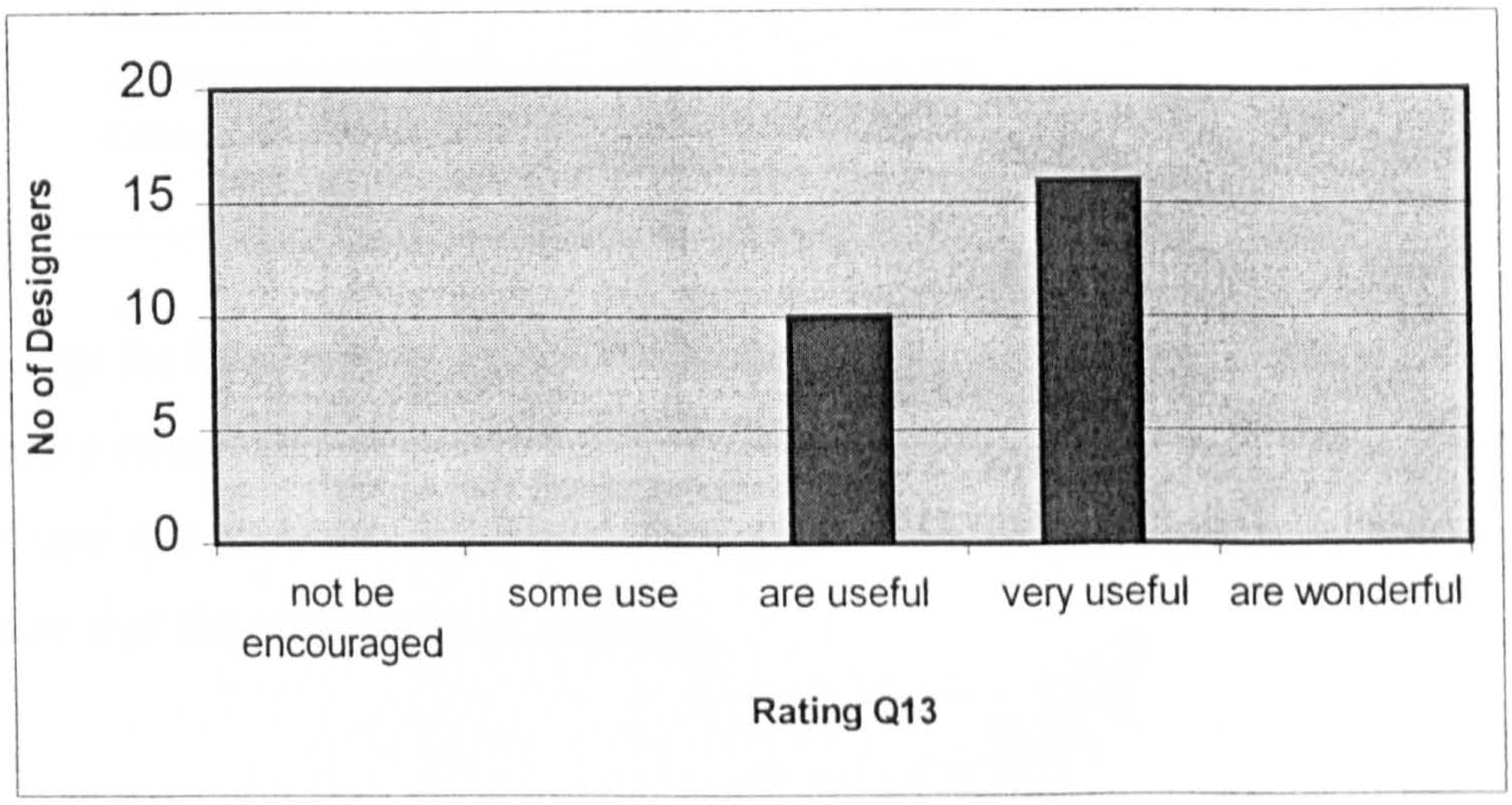

Figure 6.6 Beliefs about Computers and the future of Humankind

Question 13 asked the participants to select the statement with which they agreed about computers and humankind. The results for this question can be seen in Figure 6.6. The overall rating for this question was 3.62. This equates to being more than useful and less than very useful. All designers chose one of two statements. The most popular statement was "Computers are very useful and should be used more and more effectively in the future" (61.5%, n = 16) and the next was "Computers can be useful for many things but will not be able to take over every job" (38.5%, n = 10).

Enjoyment of Developing or Using Software

The fourth and last section contained two questions relating to the enjoyment of developing software and using software. This question enabled the answers for VR to be compared with other types of software. Each of the two questions was divided into 8 different types of software and participants were asked to rank their enjoyment for each type by circling the following categories:

1	2	3	4
Very Enjoyable	Enjoyable	Not very Enjoyable	Not Enjoyable at all

Table 6.1 Ratings for Software developed by the designers

Type of Software	*Enjoyment Rating*	*No. of Participants*
Games for Entertainment	1.17	6
Educational Games	2.0	1
Word-processing software	3.00	2
Databases	2.5	26
Computer-based training packages	2.29	7
Multimedia	3.0	10
Superscape VR software	1.31	26
Other VR software	2.50	6

The ratings for these software types can be seen in Table 6.1. The results showed that developing entertainment games was the most enjoyable of all software, but developing *Superscape* was almost as enjoyable. Both these software packages were much more enjoyable that the other types of software.

Table 6.2 Comparisons of Differences in Ratings for Designers Developing with Superscape VR Software and Other Types of Software

Software	*Mean Rating*	*N*	*P*	*Significance*
Superscape	1.31	26	-	-
Entertainment games	1.17	6	0.515	no
Educational games	2	1	N/a	
Word-processing	2	2	N/a	
Databases	2.5	10	0.000	**
CBT	2.29	7	0.004	**
Multimedia	2	10	N/a	
Other VR	2.5	6	0.057	no

* significant at $\alpha = 0.05$ level ** significant at $\alpha = 0.01$ level

Each of the categories were compared with *Superscape* VR software to see if the differences in ratings were statistical significant. Mann-Whitney statistical tests were carried out using Minitab software. In some of the categories it was not possible to do these tests because of inappropriate data (i.e. not enough data or all the data was the same rank). The results of these tests can be seen in Table 6.2.

These results show that development of games for entertainment scored the smallest mean or highest enjoyment rating. This was slightly better than *Superscape*, which scored the next most enjoyable software. *Superscape* was significantly more enjoyable to develop than Databases (p = 0.000) and CBT software (p = 0.004). It was not significantly more enjoyable than games for entertainment (p = 0.515) or other VR (p = 0.057).

The next question, Question 15, was similar to the last question but this time the designers were asked to rate their enjoyment of using the same 8 categories of software.

Table 6.3 Ratings for Software used by the designers

Type of Software	*Enjoyment Rating*	*No. of Participants*
Games for Entertainment	1.33	24
Educational Games	2.18	17
Word-processing software	2.78	26
Databases	3.14	26
Computer-based training packages	2.64	22
Multimedia	2.13	24
Superscape VR software	1.31	26
Other VR software	2.33	18

The participants were asked to rate their enjoyment of using games for entertainment. The results for this category can be seen in Table 6.3. The results showed that the designers had similar ratings for using software as for developing it. Overall *Superscape* software was the most enjoyable software to use, just slightly more enjoyable that playing games. Using word-processing software and computer-based-training packages were found to be the least enjoyable.

Table 6.4 Comparisons of Differences in Ratings for Designers Using Superscape VR Software and Other Types of Software

Software	*Mean Rating*	*N*	*P*	*Significance*
Superscape	1.31	26	-	-
Entertainment games	1.33	24	1.000	no
Educational games	2.18	17	0.000	**
Word-processing	2.78	26	0.000	**
Databases	3.13	23	0.000	**
CBT	2.64	22	0.000	**
Multimedia	2.13	24	0.000	**
Other VR	2.33	18	0.000	**

A series of individual Mann-Whitney statistical tests were carried out to look for significant differences in the ratings for between the enjoyment of using *Superscape* software compared to other types of software (see Table 6.4). These results show that in terms of using software *Superscape* scored the smallest mean or highest rating for enjoyment. This was slightly better than using games for entertainment. *Superscape* was found to be significantly more enjoyable for all other types of software and in all cases the p value was 0.000 and therefore all differences were significant at the $\alpha = 0.05$ level.

6.3.2 VR Design Student Questionnaire

Computers and Training

Seven questions were presented to the students to inquire about their experiences and attitudes towards using computers.

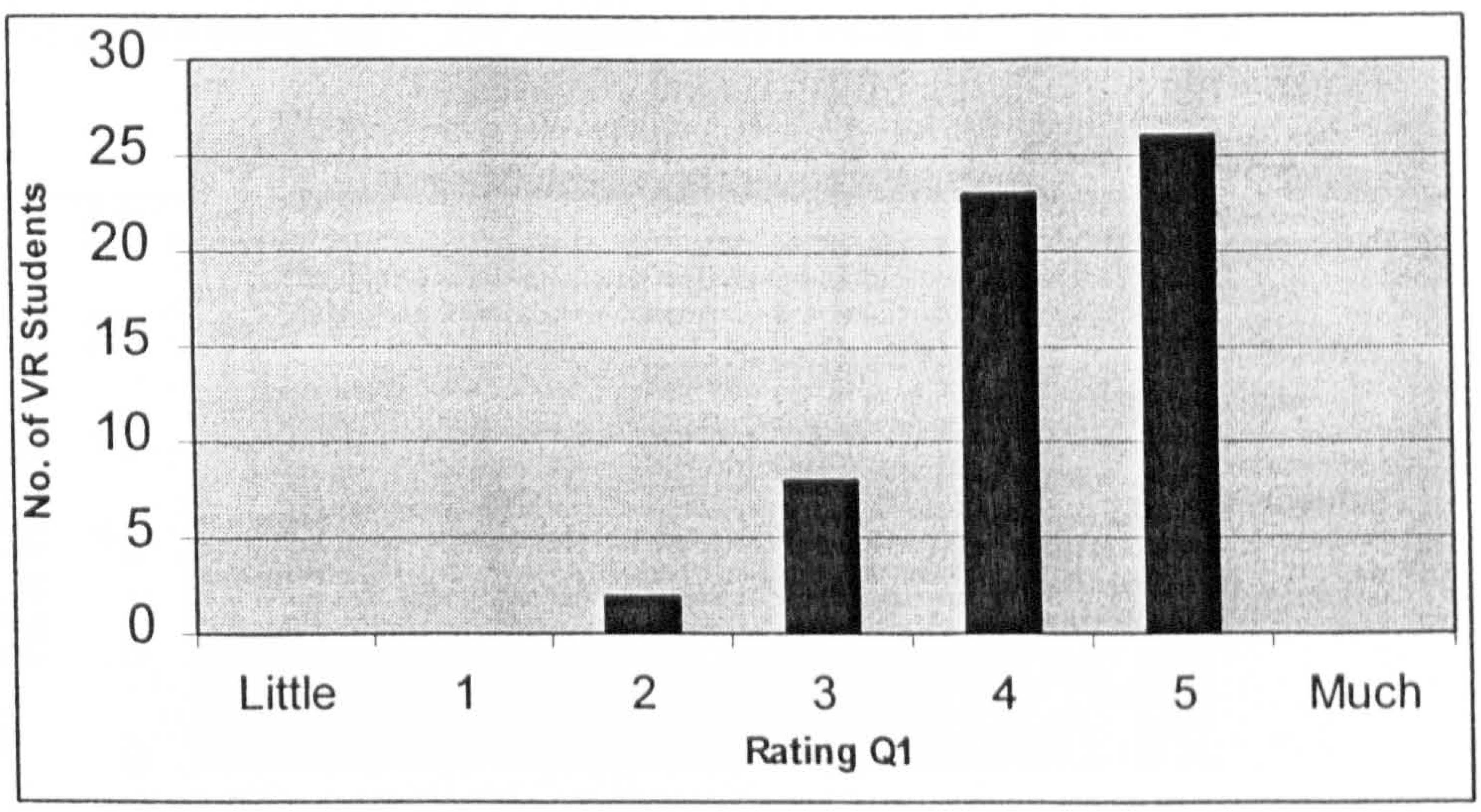

Figure 6.7 How much experience of using computers do you have?

The first question asked the participants about the amount of experience they had had using computers. The results of the ratings for this question are shown in Figure 6.7.
The overall mean rating for this question was 4.24. The most popular rating was 5 (4.1%, n = 26) and the next rating was 4 (39.0%, n = 23). Eight participants (13.16%) gave a rating of 3 and 2 (3.4%) gave a rating of 2. No participant gave a rating of 1 or Little Experience.

The second question asked the participants about their attitudes towards using computers in training. The results of the ratings for these questions are shown in Figure 6.8.

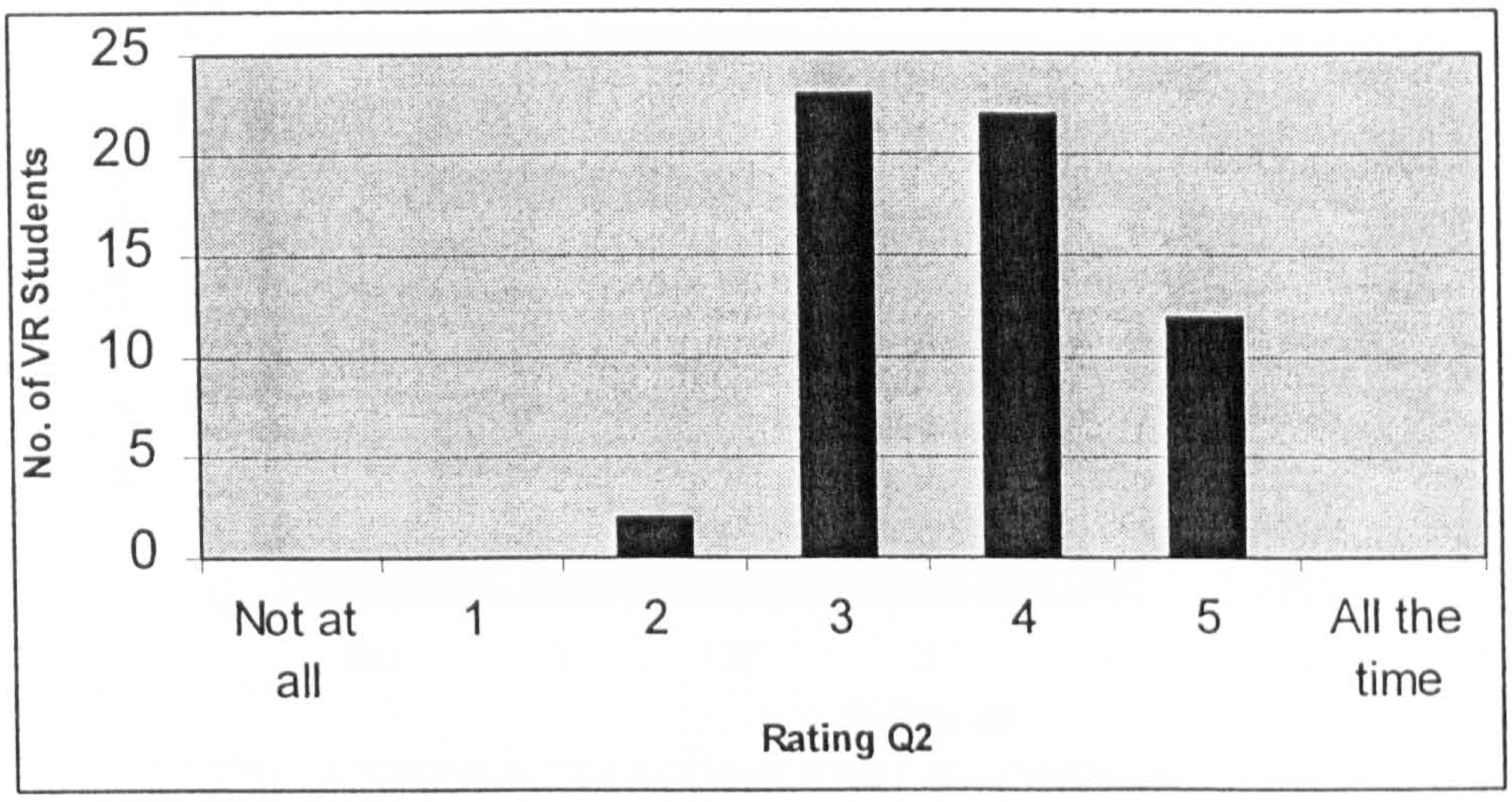

Figure 6.8 Do you think/feel that computers should be used for training purposes?

The overall mean rating for this question was 3.75. The most popular ratings were 3 (39.0%, n = 23) and 4 (37.3%, n = 22). Twelve of the VR design students (20.3%) gave a rating of 3 and 2 (3.4%) gave a rating of 2. No student gave a rating of 1 or Not at all.

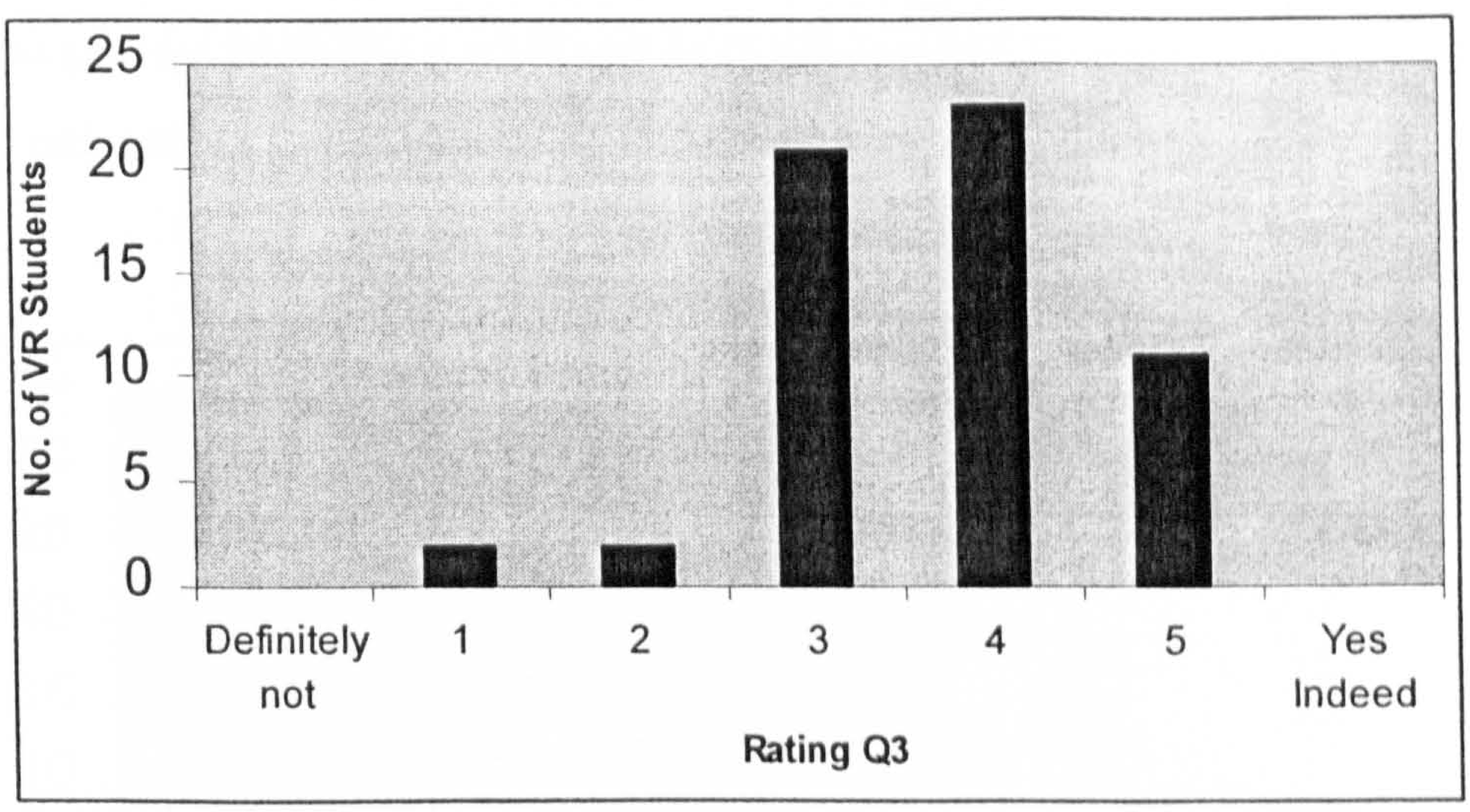

Figure 6.9 Do you think/feel that computers are good for the future of Humankind?

The third question asked the participants about their attitudes towards computers being good for the future of humankind. The results of the ratings for these questions are shown in Figure 6.9. The overall mean rating for this question was 3.66. The most popular ratings were 4 (39.0%, n = 23) and 3 (5.6%, n = 21). Eleven VR design students (18.6%) gave a rating of 5 and two (3.4%) gave a rating of 2 and similarly two students gave a rating of 1.

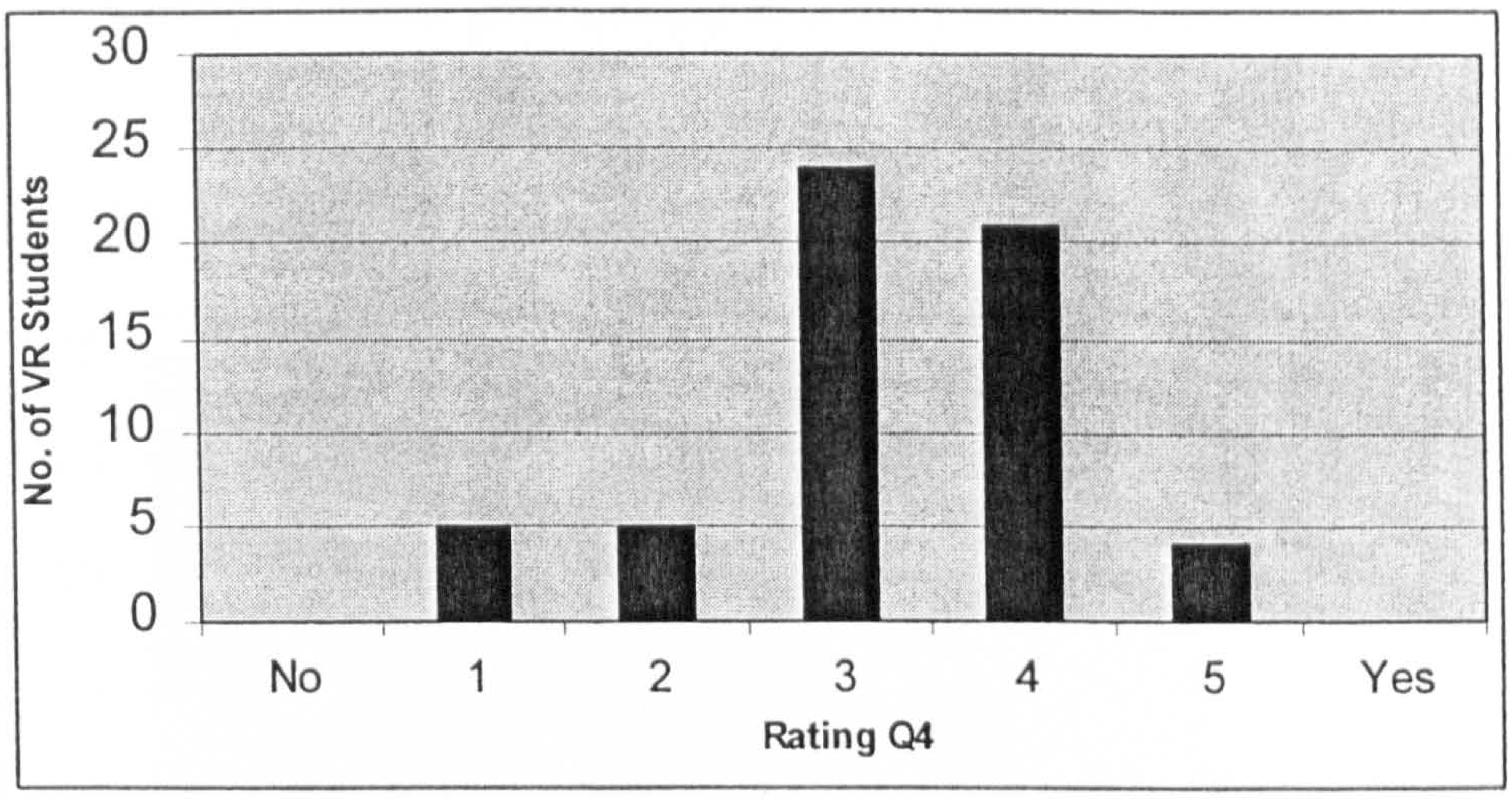

Figure 6.10 Do you think/feel that computer-based software is an effective training medium at present?

The fourth question asked the VR design students about their attitudes towards computer-based software as an effective training medium. The results of the ratings for these questions are shown in Figure 6.10. The overall mean rating for this question was 3.24. The most popular ratings were 3 (40.7%, n = 24) and 4 (35.6%, n = 21). Five students (8.5%) gave a rating of 1 and another five gave a rating of 2. Four VR design students gave a rating of 5 (6.8%).

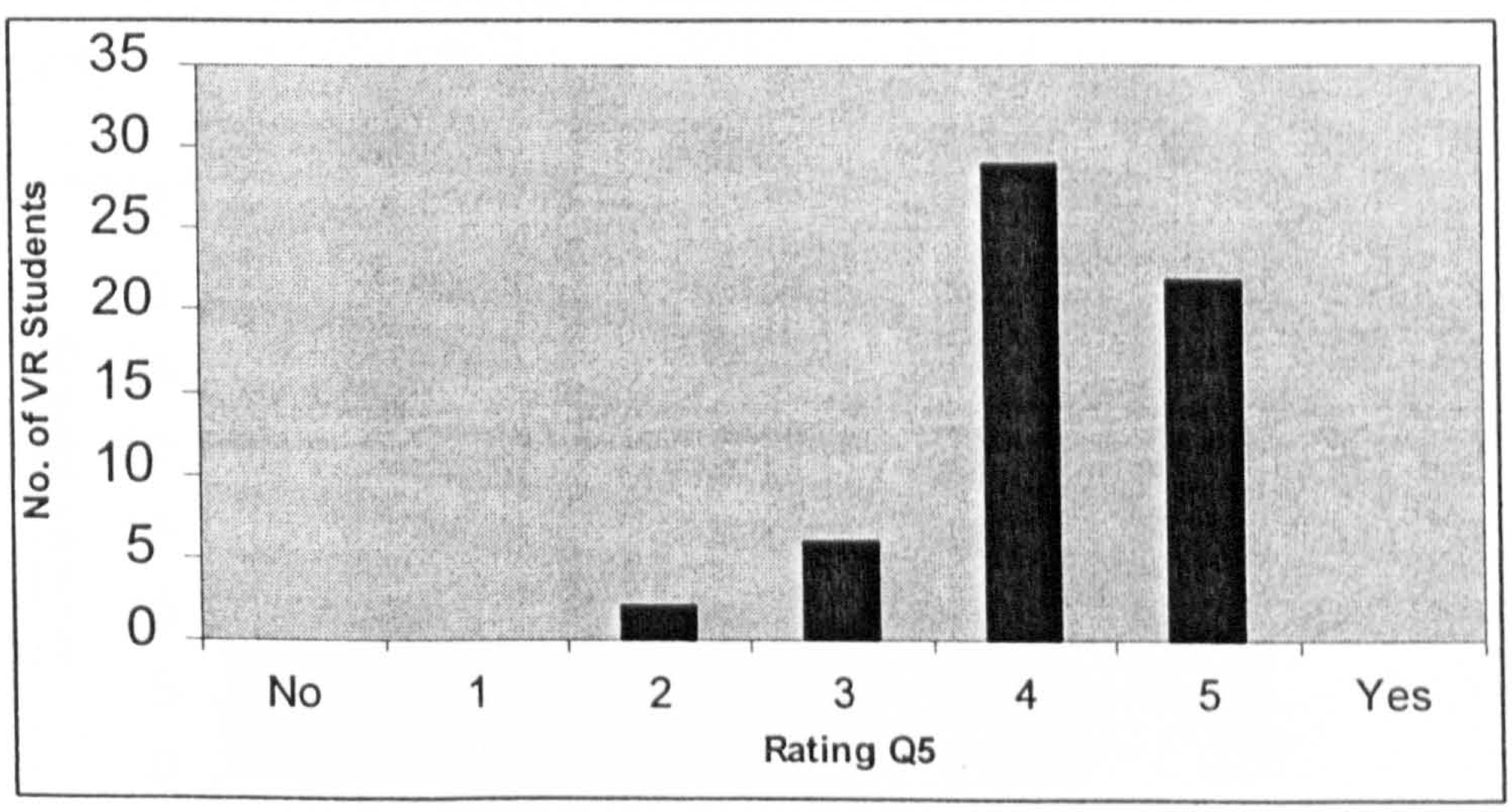

Figure 6.11 Do you think/feel that computer-based software could be an effective training medium in the future?

The fifth question asked about attitudes towards computer-based software as an effective training medium in the future. The results of the ratings for this question can be seen in Figure 6.11. The overall mean rating for this question was 4.2. The most popular ratings were 4 (49.2%, n = 29) and 5 (37.3%, n = 22). Six VR design students (10.2%) gave a rating of 3 and two VR design students gave a rating of 2. No participants gave a rating of 1.

VR and Training

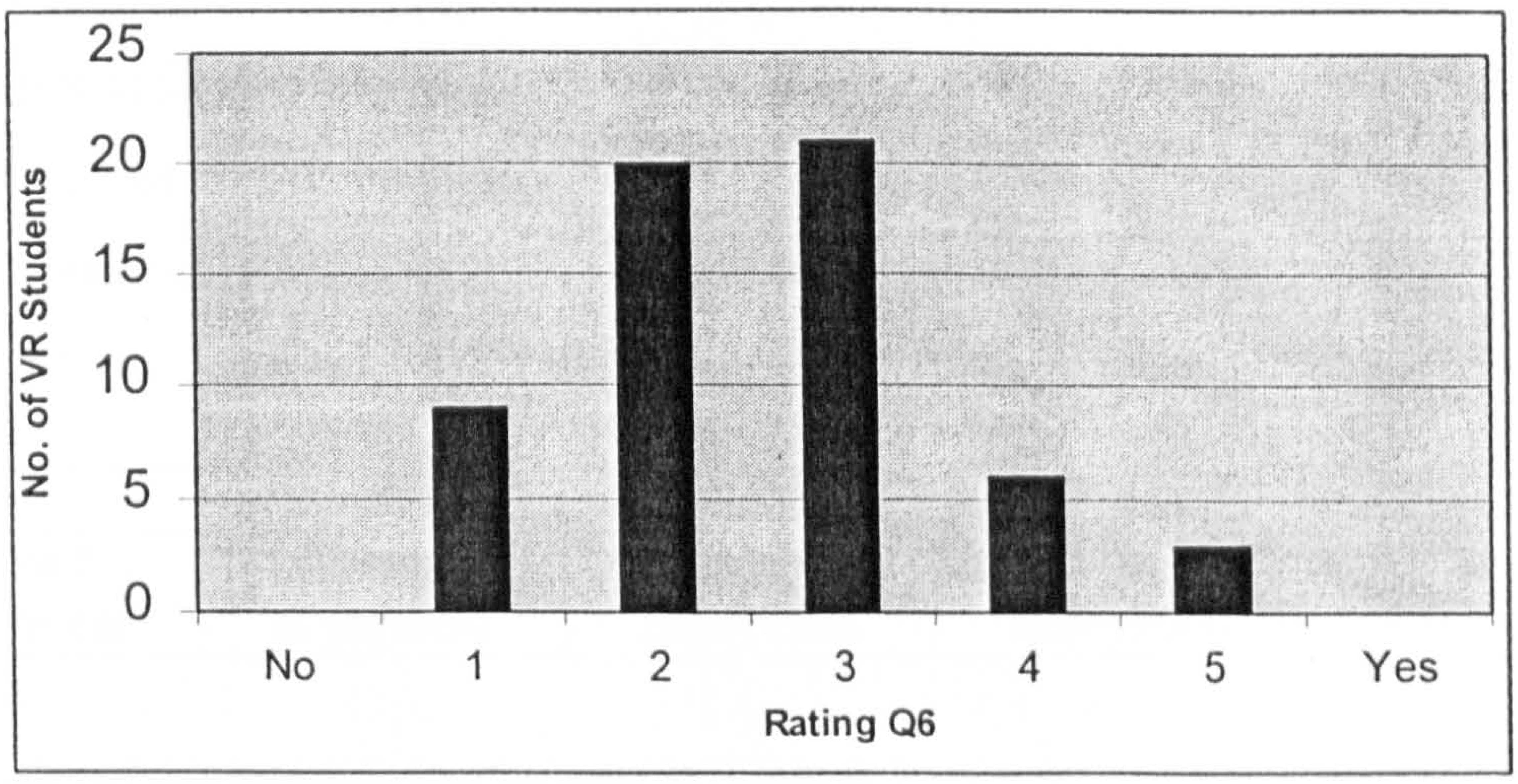

Figure 6.12 Do you think/feel that virtual reality is an effective training medium at present?

The sixth question asked the students about their beliefs about virtual reality being an effective training medium at the moment. The results of the ratings for this question are shown in Figure 6.12 and the mean rating was found to be 2.56. The most popular ratings were 3 (35.6%, n = 21) and 2 (33.9%, n = 20). Nine (10.2%) of the VR design students gave a rating of 1, six (10.2%) students gave a rating of 4 and three (5.1%) of the participants gave a rating of 5.

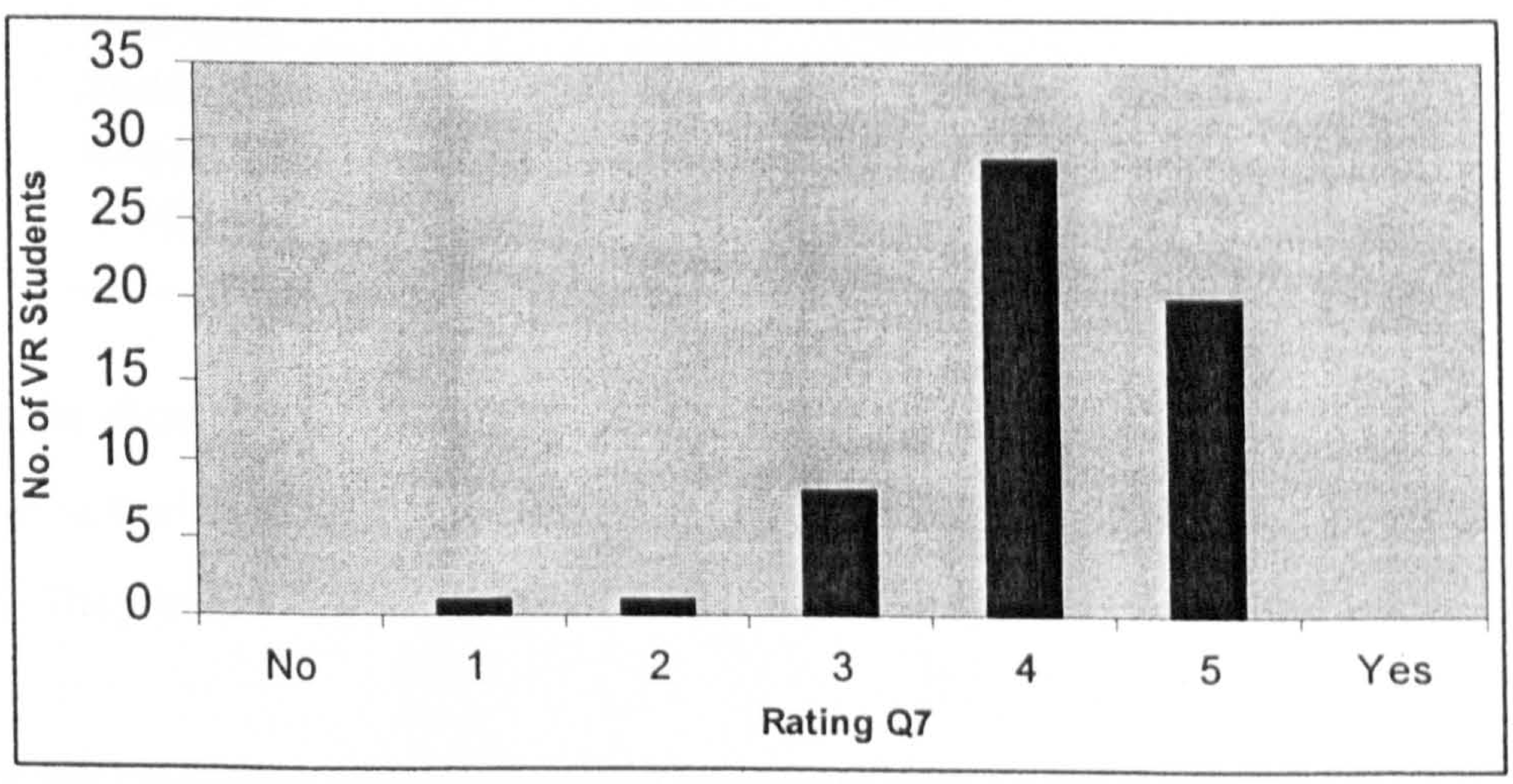

Figure 6.13 Do you think/feel that virtual reality could become an effective training medium in the future?

The seventh question asked about attitudes or beliefs about virtual reality becoming an effective training medium in the future. The results can be seen in Figure 6.13 and the mean rating was found to be 4.12. The most popular ratings were 4 (49.2%, n = 29) and 5 (33.9%, n = 20). 8 (13.6%) of the VR design students gave a rating of 3, and one student gave a rating of 1 and one student gave a rating of 2.

Enjoyment of Computer Software

The next part of the questionnaire explored the issue of enjoyment of using software. The VR students were asked to indicate a rating that related to their enjoyment from one of five categories:

1	2	3	4	5
Little or No Enjoyment	Some Enjoyment	Reasonable Enjoyment	Much Enjoyment	Great Enjoyment

The results of this question can be seen in Table 6.5.

Table 6.5 Ratings for Software used by the design students

Type of Software	*Enjoyment Rating*	*No. of Participants*
Educational Games	2.90	42
Fun Games	4.00	58
Word-processing software	2.49	59
Spreadsheet	2.11	53
Databases	2.08	50
Computer-based training packages	2.49	43
Multimedia	3.85	59
Superscape VR software	3.39	59
Programming languages	2.55	44

The results showed that the VR design students enjoyed using games for entertainment and multimedia packages the most. *Superscape* VR software was their third most enjoyable choice. They least liked using spreadsheets and databases.

Each of the categories of software were compared with *Superscape* VR software to see if the differences in ratings were statistical significant. Mann-Whitney statistical tests were carried out using Minitab software. The results of these tests can be seen in Table 6.6.

Table 6.6 Comparisons of Differences in Ratings for Design Students Using Superscape VR Software and Other Types of Software

Software	*Mean Rating*	*N*	*P*	*Significance*
Superscape	3.39	59	-	-
Educational games	2.90	42	0.013	*
Entertainment games	4.00	58	0.001	**
Word-processing	2.49	59	0.000	**
Spread-sheets	2.11	53	0.000	**
Databases	2.08	50	0.000	**
CBT	2.49	43	0.000	**
Multimedia	3.90	59	0.011	*
Programming	2.55	44	0.001	**

These results show that *Superscape* VR software (mean = 3.39) was found to be rated the second most enjoyable software to use after Multimedia (mean = 3.90). *Superscape* software was found to be significantly more enjoyable than all the other software types. It was found to be significantly less enjoyable than multimedia (p = 0.011).

The ninth question in the VR design student questionnaire asked them to rate those types of software that they had not used for the amount of enjoyment that they would expect if they did use them. A summary of the average ratings for those types of software that had not been used by the participants can be seen in Table 6.7.

Table 6.7 Perceived Ratings for Software not used by the VR design students

Type of Software	*Perceived Enjoyment Rating*	*No. of Participants*
Educational Games	2.82	17
Fun Games	3.00	1
Spreadsheet	1.8	5
Databases	1.33	9
Computer-based training packages	2.44	16
Programming languages	1.6	7

These results show that the VR design students believed that educational games and fun games would be quite enjoyable to create. Computer-based training packages were also considered to be reasonably enjoyable. However, spreadsheets, programming languages and databases were all perceived as not very enjoyable by the students in this study.

Table 6.8 Comparison of Known Enjoyment vs. Expected Enjoyment of Software

Software	Known Mean Rating	N	Expected Mean Rating	N	P	Significance
Educational games	2.90	42	2.82	17	0.909	no
Fun games	4.00	58	3.00	1	-	-
Word-processing	2.49	59	-	0	-	-
Spread-sheets	2.11	53	1.80	6	0.508	no
Databases	2.08	50	1.33	9	0.039	*
CBT	2.49	43	2.44	16	0.922	no
Multimedia	3.90	59	-	0	-	-
Superscape	3.39	59	-	0	-	-
Programming	2.55	44	1.60	15	0.010	**

** = significant at 0.05 level ** = significant at 0.01 level*

A comparison of the enjoyment ratings of the students who had used the different software and the ratings of those who had not is given in Table 6.8. The results of two-sample t-tests showed that students found that spreadsheets, databases and programming languages were significantly more enjoyable by those who had experienced them than those who had not.

The tenth question in this survey asked participants to state some of the reasons why they had enjoyed certain types of software. Participants gave a variety of responses but most related to the use of games or VR software. Reasons given included playing for fun or for relaxation, creating interactive worlds, trying out new software. A few of the students liked programming software in order to achieve something or to solve a problem. Some students suggested that simple and 'good-looking' software was more enjoyable. They did not like complicated software that did not provide proper help facilities.

Use of Multimedia and VR

The eleventh question asked the VR design students to describe the good and bad points of any multimedia software that they had used as a training tool. Twenty-nine students (49.2%) did not answer this question. Of the remaining answers a range of different applications had been used. Most of these related to the learning of new software on their degree courses. They liked the use of animations and graphics to illustrate ideas. They also liked the use of clear structure and step-by-step instructions. Some students had used educational software and found that good points included being fun and entertaining. Poorer points tended to include difficulty in navigating through the information and not being able to get the type of help that they wanted. Some suggested that they found some software difficult to use, as they seem to expect a higher amount of knowledge on the part of the user.

Questions 12, 13 and 14 related to the strengths and weaknesses of using VR software if they had used it, its use as a training tool and feelings about it if they had never experienced it. For question 12 it was found that students liked the ability to create interactive and dynamic worlds with 3D characters. They especially liked to become part of the world being able to move around and control things within the world. They did not like the difficulty of using high resolution textures, learning to code the interactivity, software running slow when world was large, jumping of world when moving around. A few students did not like the time it took to create VR software. Many of VR design students were not impressed with the current state of the graphics. One person had used an immersive head-set and expressed a dislike for this because they had felt dizzy when using it. Two of the students stated that they felt that desktop VR did not represent 'true' virtual reality and believed that immersive VR was a more appropriate concept.

Only three people had indicated that they had experienced VR as a training tool and they both considered it to be very effective because it allowed the user to participate in multiple scenarios without tragic consequences. One had used it as a training tool for other naïve users. They said that it proved to be very enjoyable but needed a lot of instruction for proper use.

Help Systems and VR

Question 15 asked participants about the types of help that they would find effective to use with virtual reality software in a training situation. The question was divided into seven parts. For the first six parts the participants were asked to rate different types of help facilities on a scale of 1 to 5.

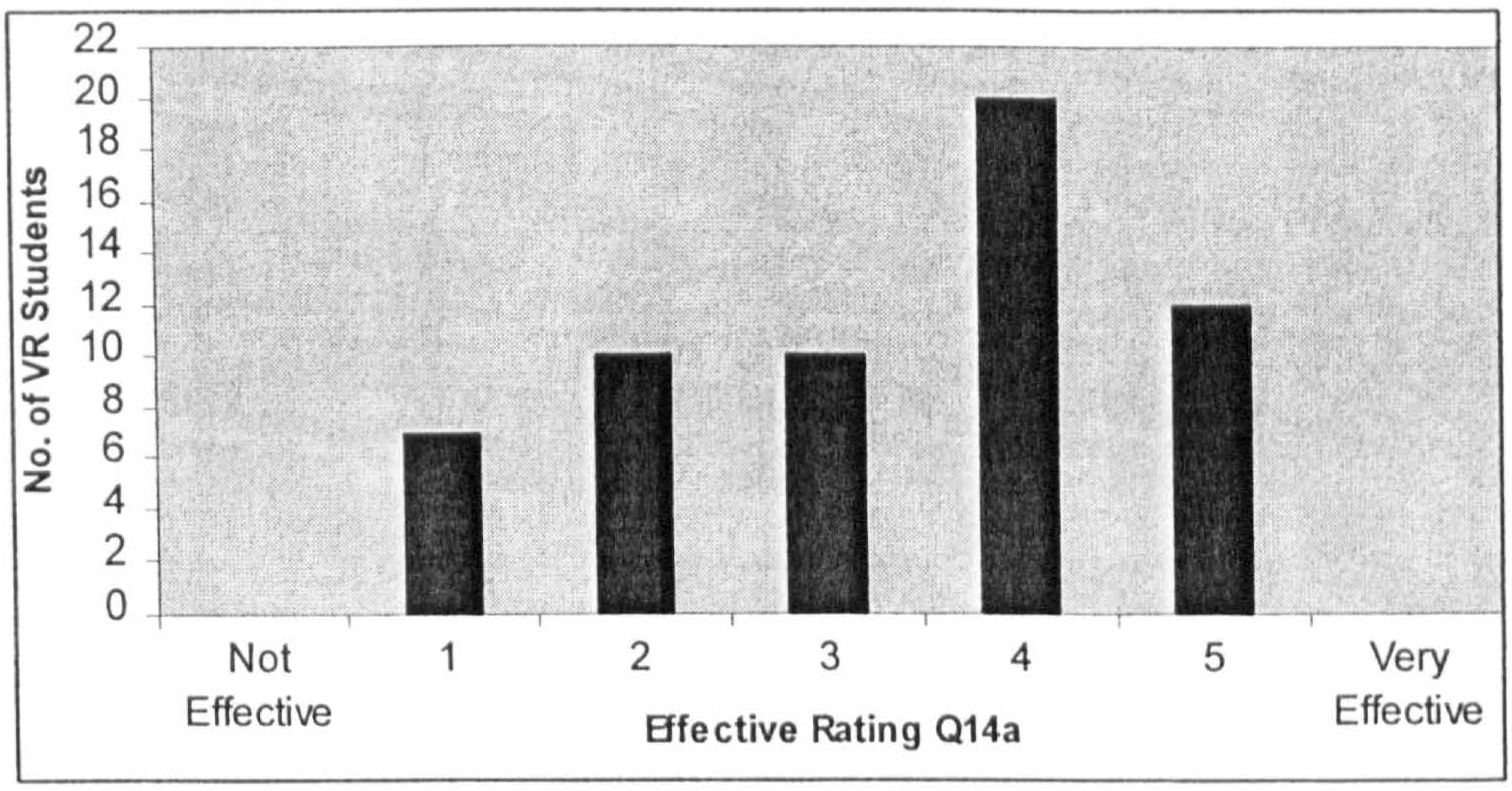

Figure 6.14 Rating for a Well Written Manual

The first question asked participants to rate the effectiveness of a well-written manual. The results are shown in Figure 6.14. The mean rating was found to be 3.34. The most popular rating was 4 (33.9%, n = 20). Twelve students (20.3%) gave a rating of 5 or Very Effective. Ten students (16.9%) gave a rating of 3 and another ten of 2. Five students gave a rating of 1 or Not Effective.

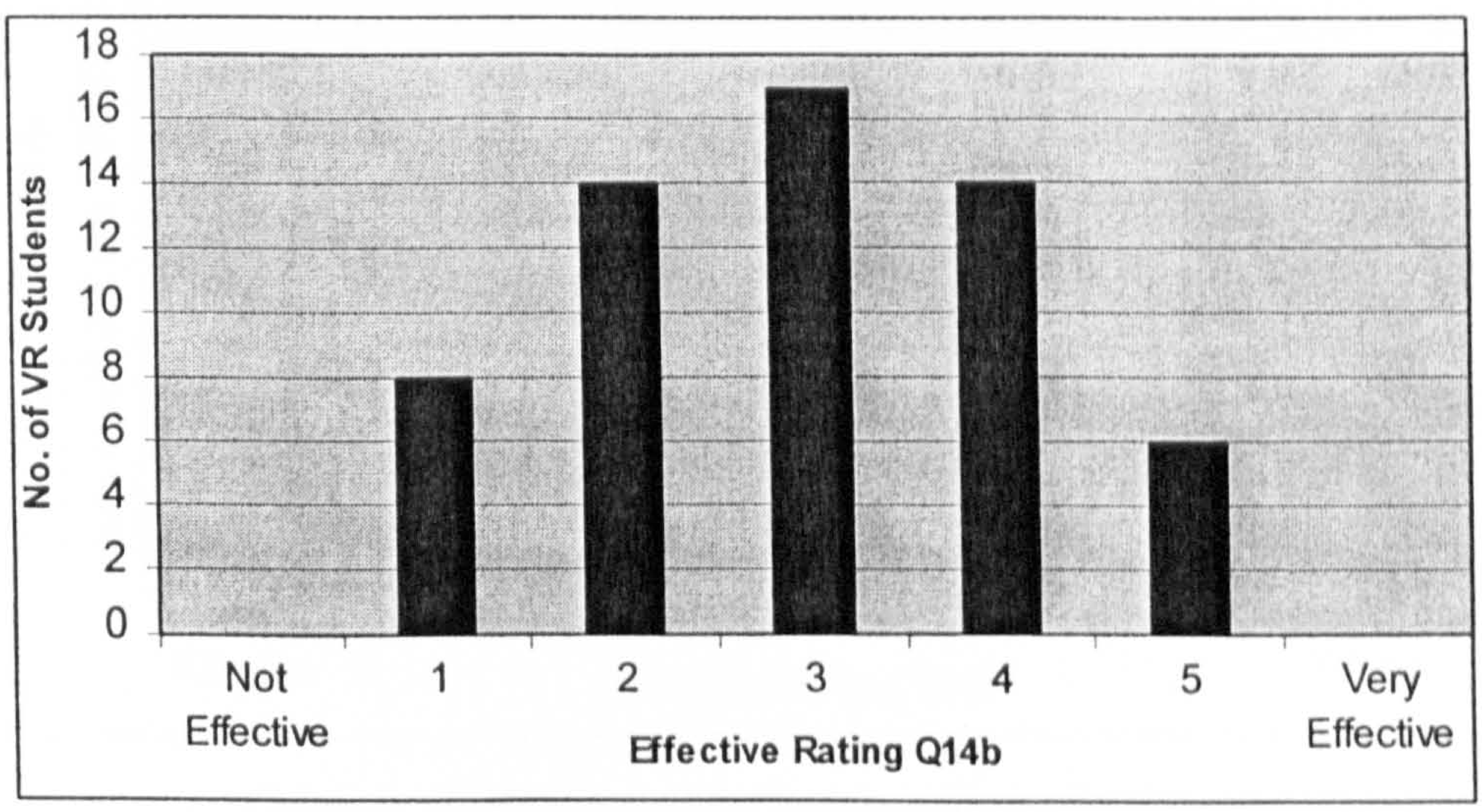

Figure 6.15 Rating for a Good Telephone Support Line

The second part of this question asked participants to rate the effectiveness of a good telephone support line. The results for the ratings can be seen in Figure 6.15. The mean rating was found to be 2.93. The most popular rating was 3 (28.8%, n = 17). Fourteen students (23.7%) gave a rating of 2 and another fourteen a rating of 4. Eight students (13.6%) gave a rating of 1 or Not Effective and six students (10.2%) gave a rating of 5 or Very Effective for a telephone support line.

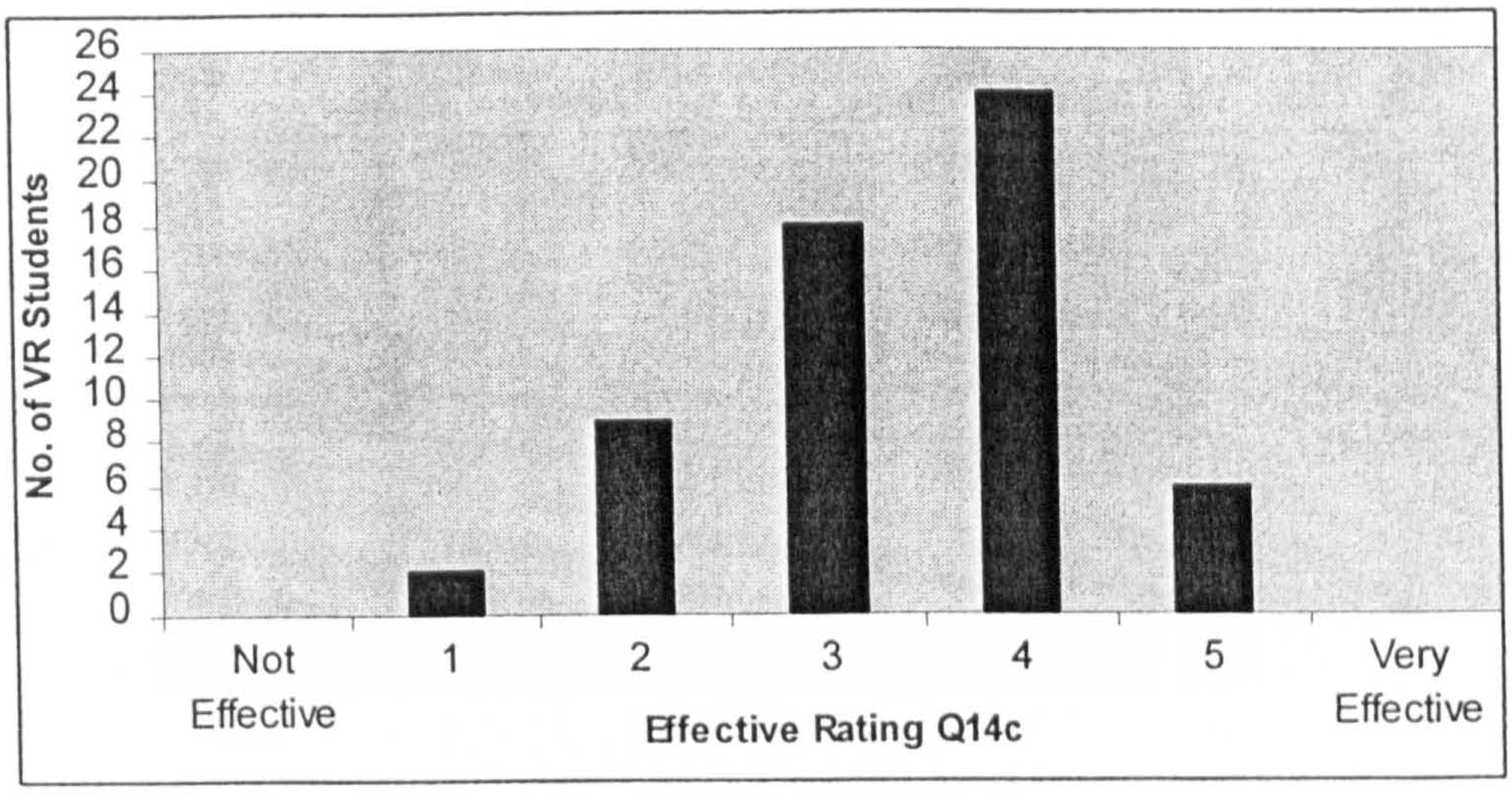

Figure 6.16 Rating for an On-line Text System

The third type of help system was for an on-line text system. The results for the ratings are shown in Figure 6.16. The mean rating was found to be 3.39. The most popular rating was 4 (40.7%, n = 24) and a further 30.5% of the students (n = 18) gave a rating of 3. Nine students (15.3%) gave a rating of 2 and six students (10.2%) gave a rating of 5. Two students rated an on-line text system as 1 or Not Effective.

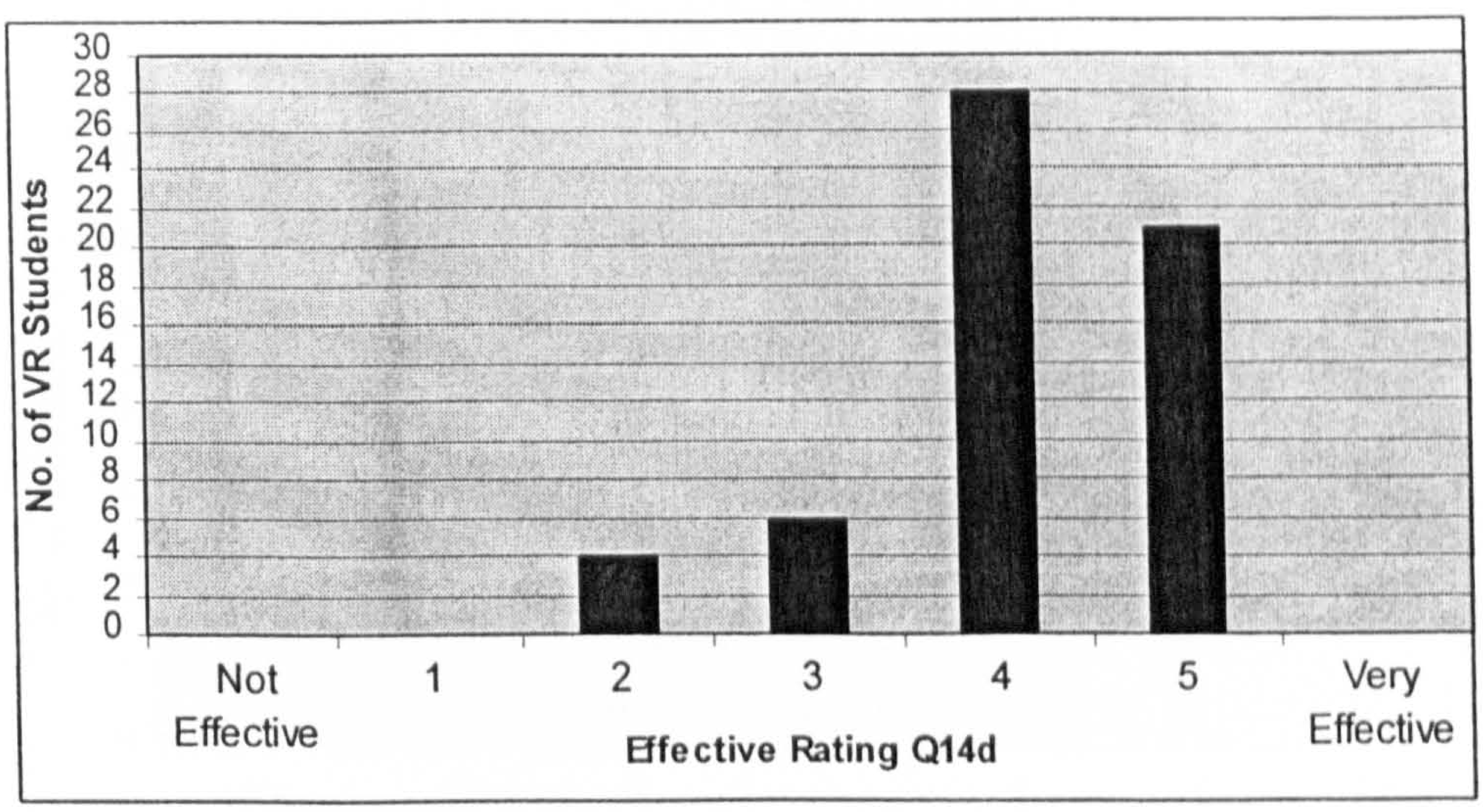

Figure 6.17 Rating for an On-line Multimedia Help System

The fourth type of help system was for an on-line multimedia help system. The results for the ratings are shown in Figure 6.17. The mean rating was found to be 4.12. The most popular rating was 4 (47.5%, n = 28) and a further 35.6% of the students (n = 21) gave a rating of 5 or Very Effective. Six students (10.2%) gave a rating of 3 and 4 students (6.8%) gave a rating of 2. No student rated an on-line multimedia help system as 1 or Not Effective.

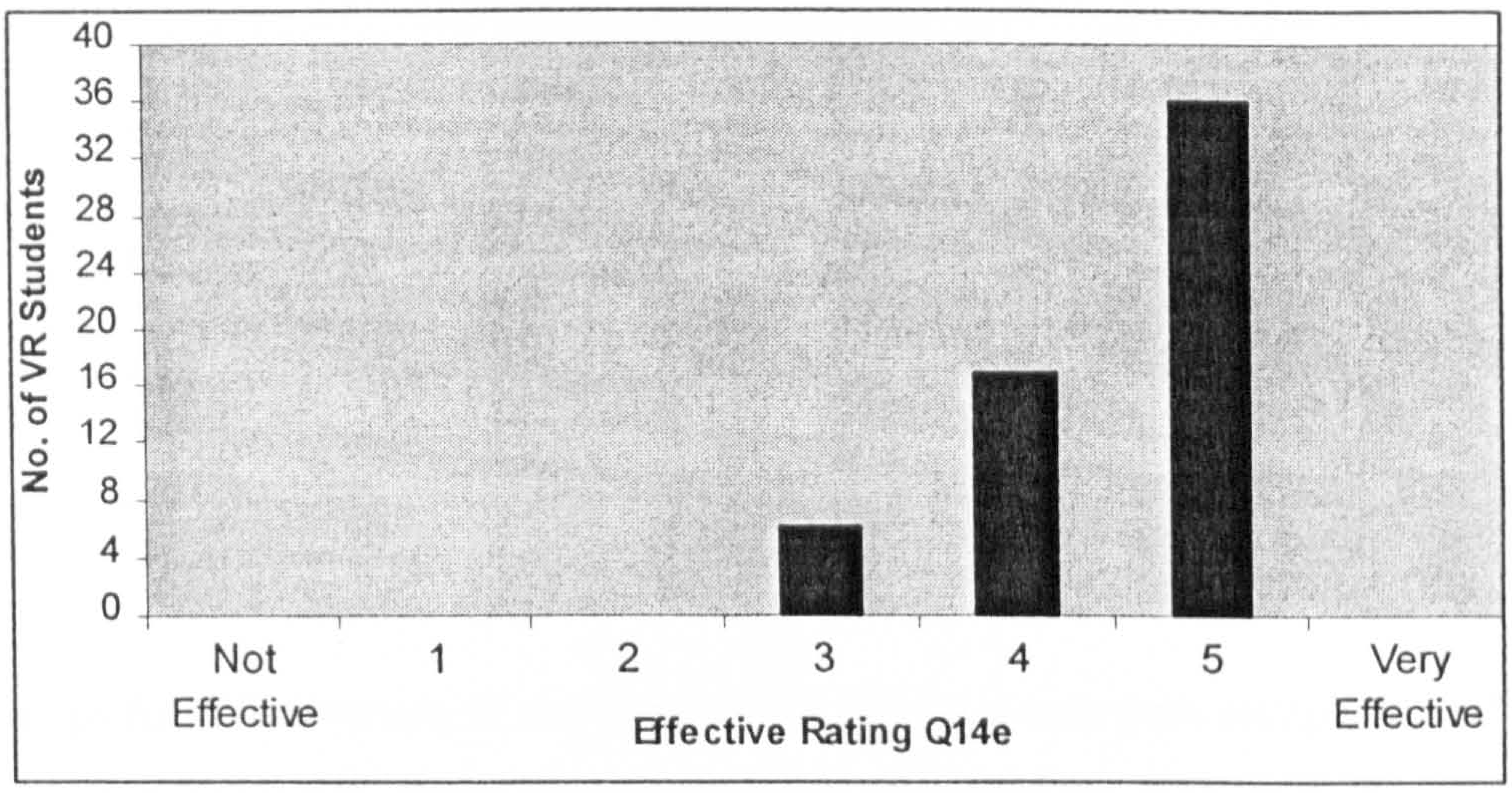

Figure 6.18 Rating for a Real Instructor whom you can ask for Help

The fifth type of help system was for a real instructor who could be asked to help the user. The results for the ratings can be seen in Figure 6.18. The mean rating was found to be 4.51. The most popular rating was 5 or Very Effective (61.0%, n = 36). Six students (10.2%) gave a rating of 3 and four students (6.8%) gave a rating of 2. No student rated an on-line multimedia help system as 1 or Not Effective.

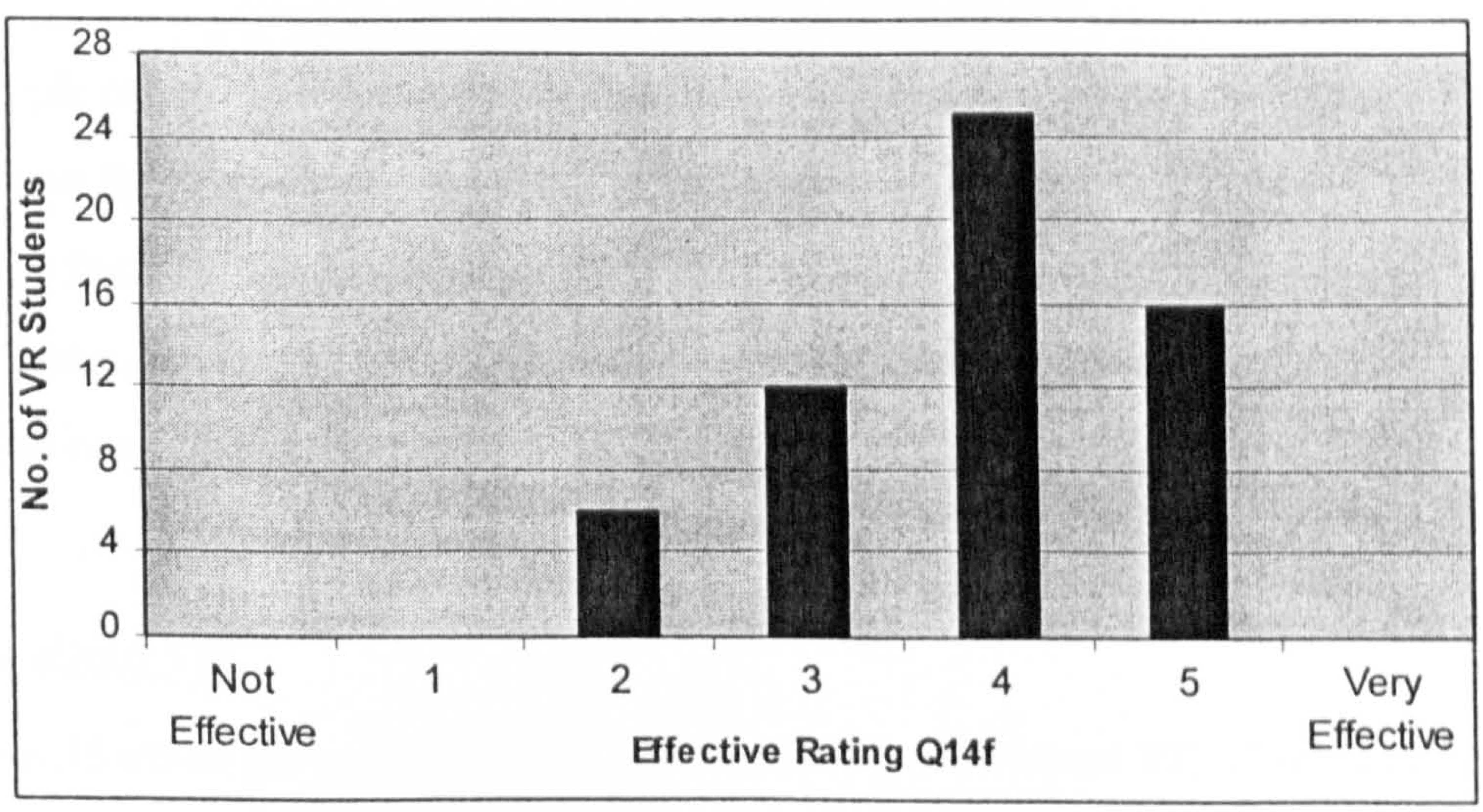

Figure 6.19 Rating for a Virtual Instructor whom you can ask for Help

The sixth type of help system was for a virtual instructor who could be asked to help the user. The results for the ratings can be seen in Figure 6.19. The mean rating was found to be 3.85. The most popular rating was 4 (42.4%, n = 25). Sixteen students (27.1%) gave a rating of 5 or Very Effective and twelve students (20.3%) gave a rating of 3. Six (10.2%) of the students rated a virtual instructor as 2 and no students rated this as 1 or Not Effective.

Table 6.9 Comparisons for Forms of Help in VR

Help System	*Mean Rating*	*N*	*P*	*Significance*
Manual	3.34	59	0.000	**
Telephone	2.93	59	0.000	**
On-line Text	3.39	59	0.000	**
Multimedia	4.12	59	0.007	**
Real Instructor	4.51	59	-	-
Virtual Instructor	3.85	59	0.000	**

** significant at α = 0.05 level   ** significant at α = 0.01 level*

The ratings for effectiveness of six types of VR help systems were compared and the results can be seen in Table 6.9. From these results it is clear that the highest mean rating was found for the Real Instructor option (mean = 4.51), which indicates a high rating of effectiveness. The next most effective help system was an on-line multimedia facility (mean = 4.12) and then a virtual instructor (mean = 3.85). Comparisons for significant differences were carried out to look at the most effective facility (Real Instructor) and other types of help system. The results for Mann-Whitney tests can be seen in the last two columns of the table in Table 6.9. The Real Instructor was found to be significantly considered more effective than all the other types of help at the α = 0.01 level.

Few people answered the last part of this question that was to write about any other methods of help that they would like. One student suggested an intelligent user knowledge base system as found in some performance support systems. One suggested better navigation and screen design, although these are not really help systems. Another suggested a tutorial with mouse pointers and voice talk-throughs but this seems to be a form of multimedia.

Beliefs about VR

Question 15 asked the participants to indicate their beliefs about VR. They were required to tick either Yes, No or Unsure. These were marked as Yes=3, Unsure=2 and No=1.
There were seven different sub-questions to answer.

The first part of this question asked participants the question "Do you believe that VR is the ultimate form of training medium?" The results can be seen in Figure 6.20.

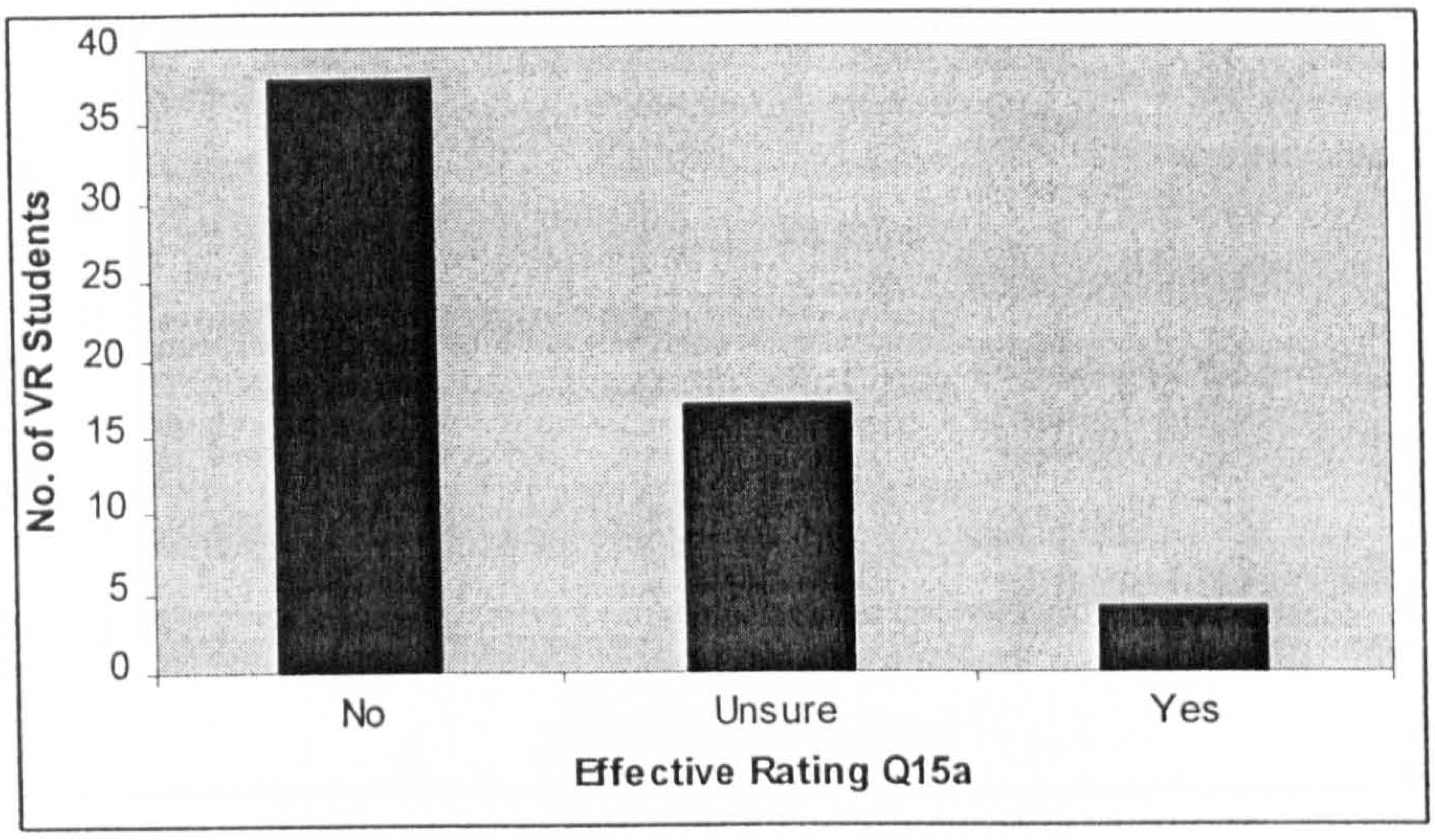

Figure 6.20 Do you believe that VR is the ultimate form of training medium?

The mean of this data was found to be 1.42 and equates to nearly half way between No and Unsure. 28.8% (n = 17) students responded Unsure to this question and 6.8% (n = 4) replied Yes.

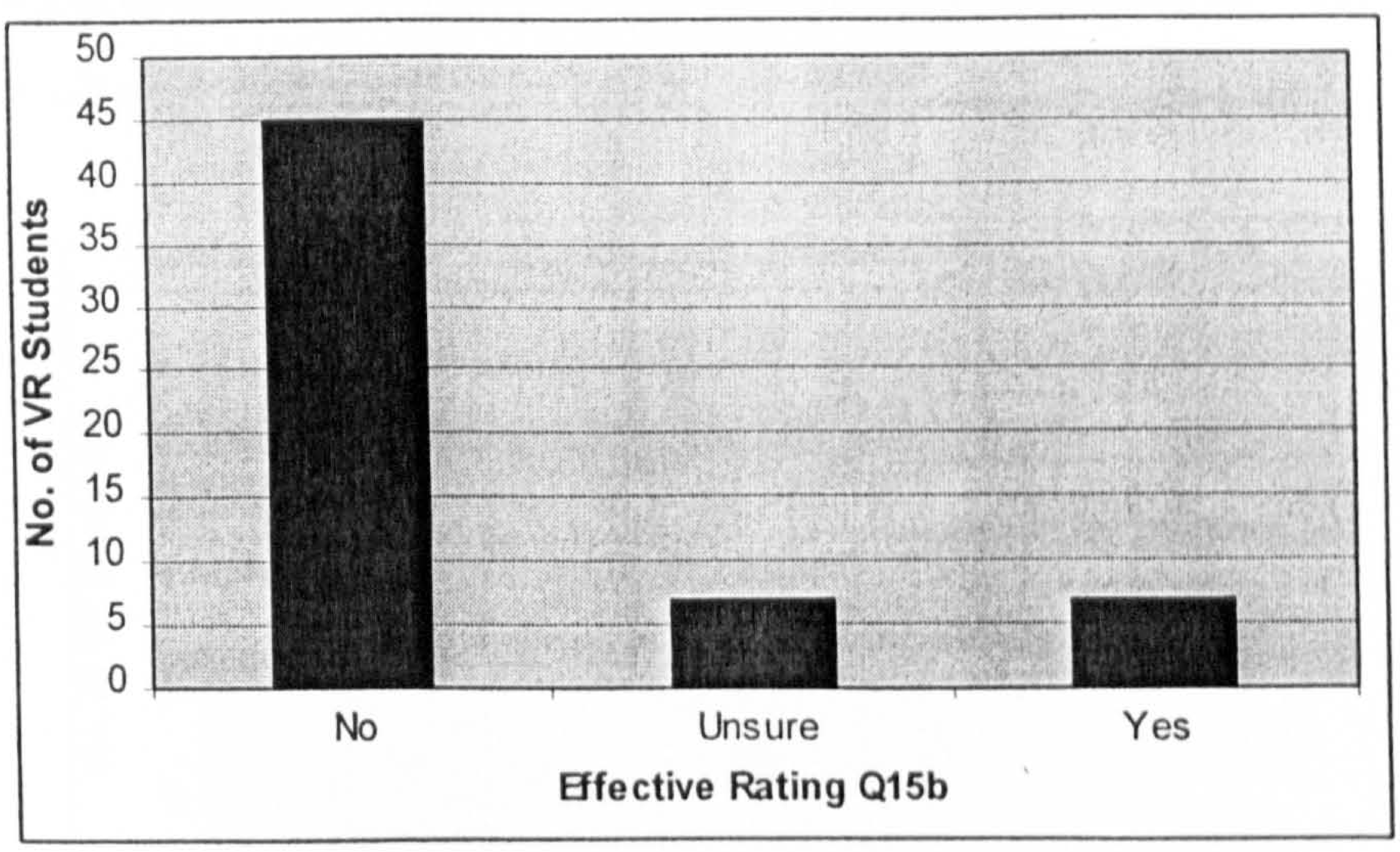

Figure 6.21 Do you believe that VR is only useful for enjoyment purposes?

The second part of this question asked participants the question "Do you believe that VR is only useful for enjoyment purposes?" The results can be seen in Figure 6.21. The mean of this data was found to be 1.36 and equates to mainly No. 76.3% (n = 45) students responded No to this question. 11.9% (n = 7) replied Unsure and also another 11.9% said Yes.

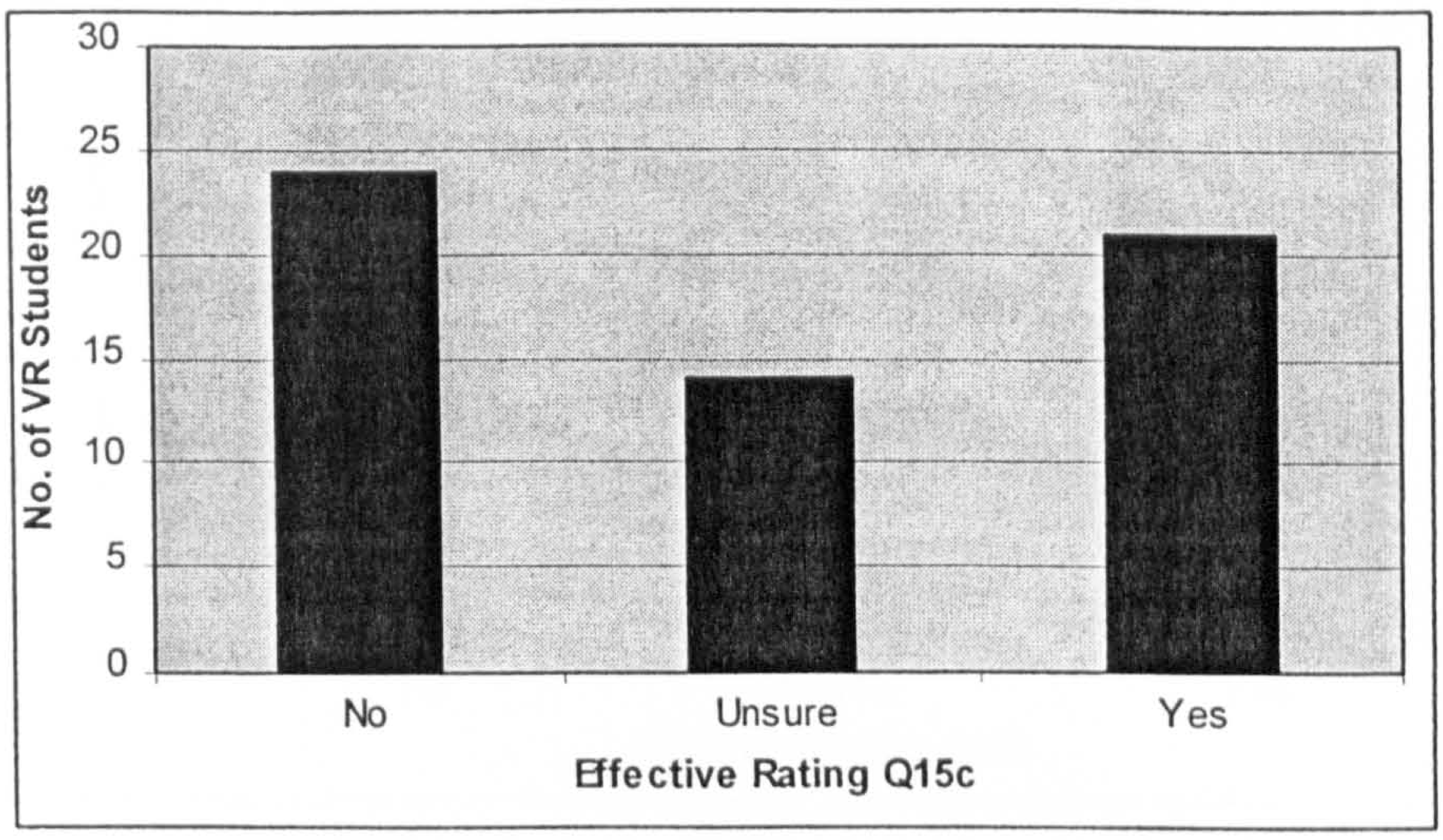

Figure 6.22 Do you believe that social interaction with people will decrease if VR is constantly used?

The third part of this question asked participants the question "Do you believe that social interaction with people will decrease if VR is constantly used?" The results are shown in Figure 6.22. The mean of this data was found to be 1.95 and equates to almost Unsure. 40.7% (n = 24) of the students replied No to this question and 35.6% (n = 21) replied Yes. 23.7% (n = 14) students were Unsure.

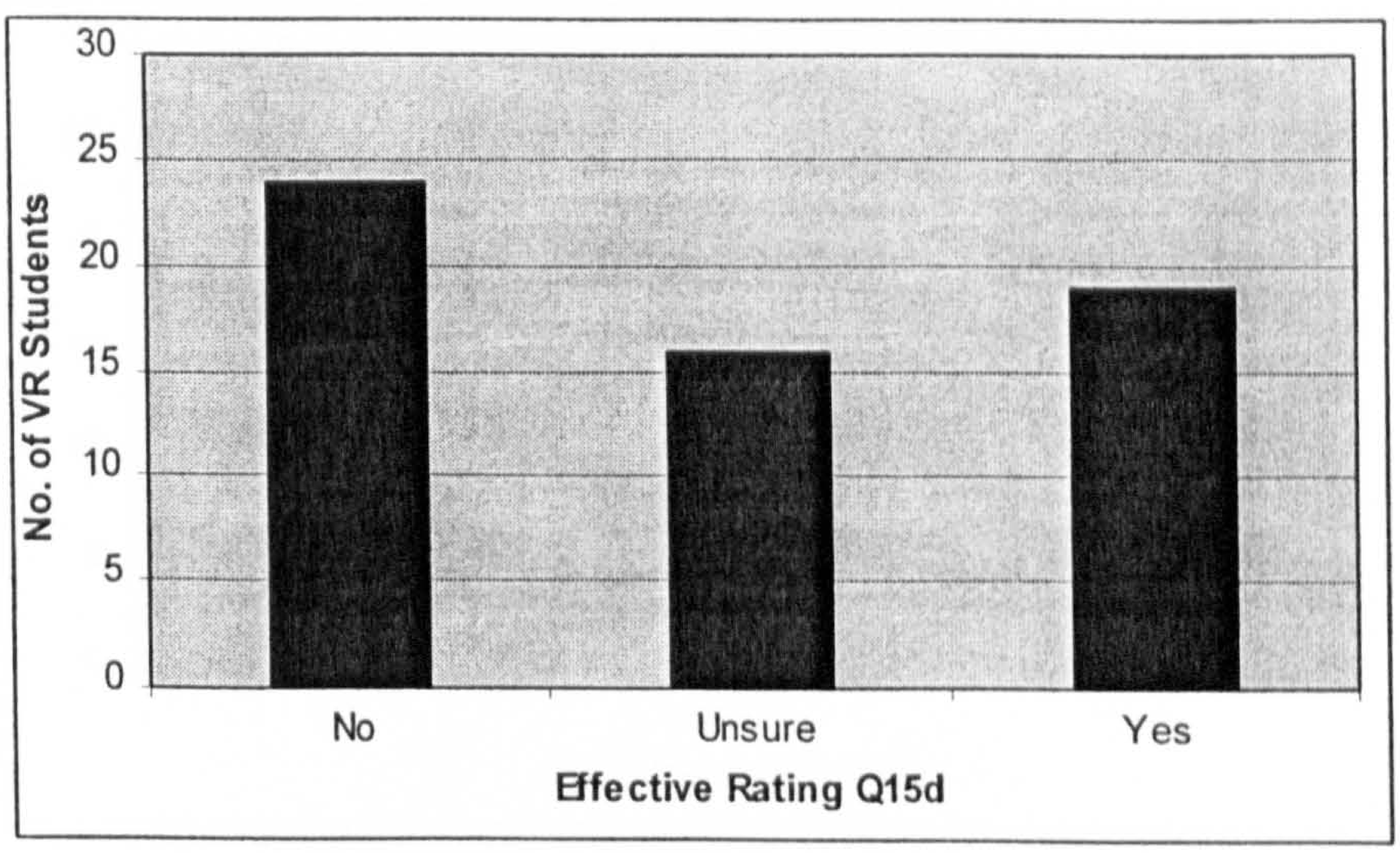

Figure 6.23 Do you believe that VR has to have all the senses including taste, smell and touch?

The fourth part of this question asked participants the question "Do you believe that VR has to have all the senses including taste, smell and touch?" The results can be seen in Figure 6.23. The mean of this data was found to be 1.92 and equates to almost Unsure. 40.7% (n = 24) of the students replied No to this question and 32.2% (n = 19) replied Yes. 27.1% (n = 16) students were Unsure.

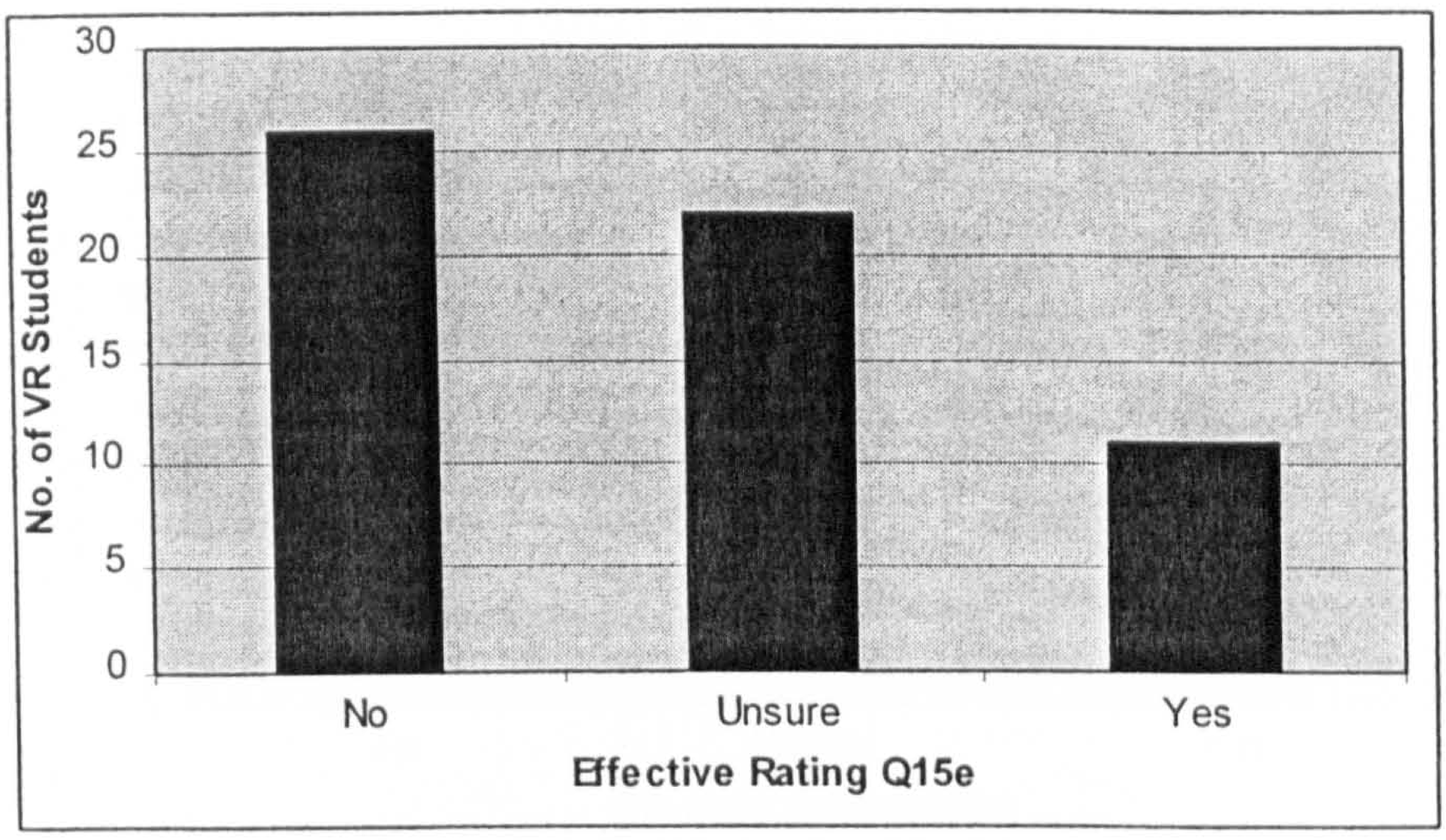

Figure 6.24 Do you have to wear a head-set device to believe that you are part of the VR world?

The fifth part of this question asked participants the question "Do you have to wear a head-set device to believe that you are part of the VR world?" The results can be seen in Figure 6.24. The mean of this data was found to be 1.75 and equates to nearly Unsure. The most popular answer was No to this question (44.1%, n = 26) but 37.3% (n = 22) replied Unsure. 18.6% (n = 11) students replied Yes.

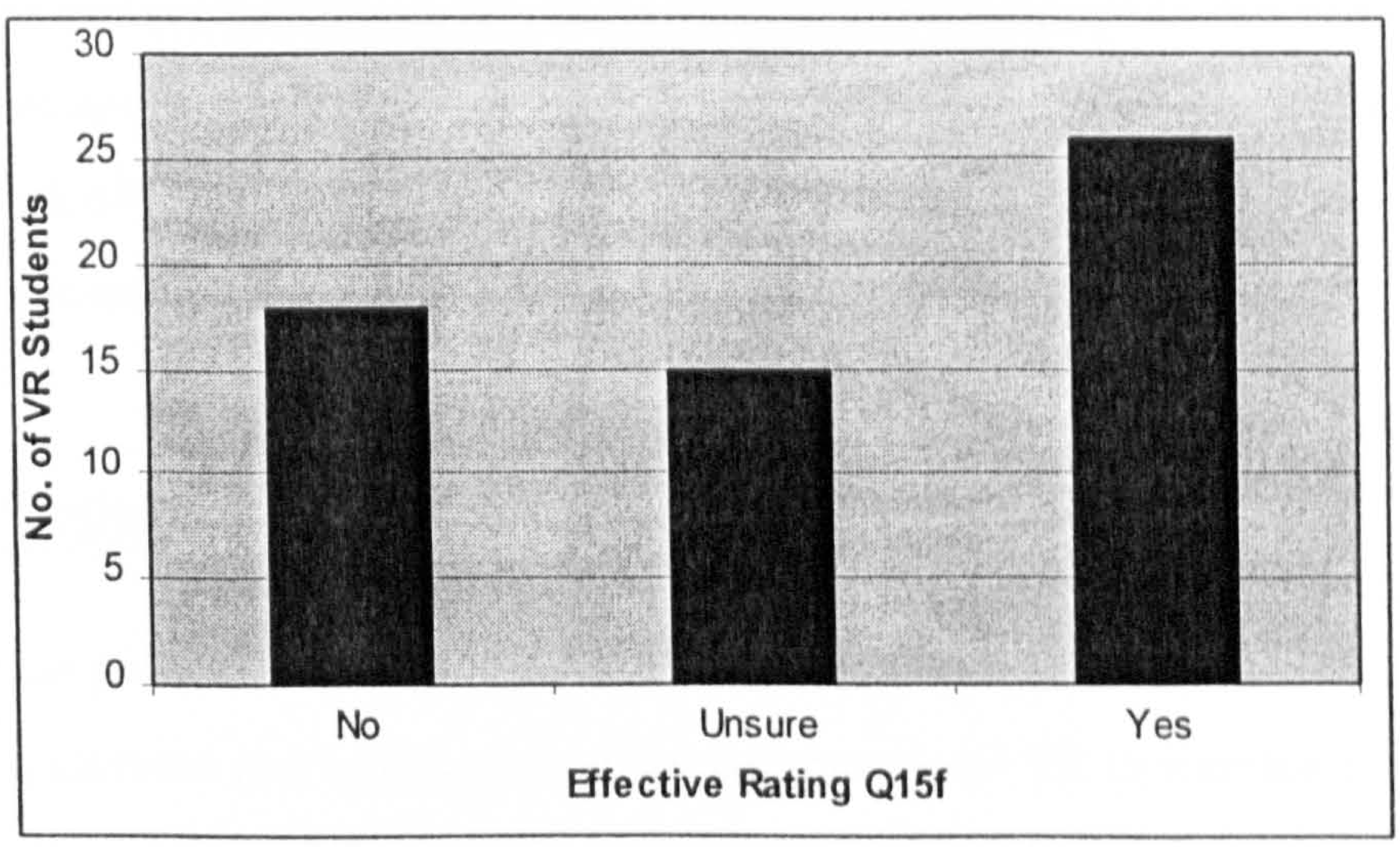

Figure 6.25 Do you believe that realistic 'touch' sensation have to be a part of VR?

The sixth part of this question asked participants the question "Do you believe that realistic 'touch' sensation have to be a part of VR?" The results can be seen in Figure 6.25. The mean of this data was found to be 2.14 and equates to nearly Unsure. The most popular answer was Yes to this question (44.1%, n = 26) but 30.5% (n = 18) replied No and 25.4% (n = 15) students replied Unsure.

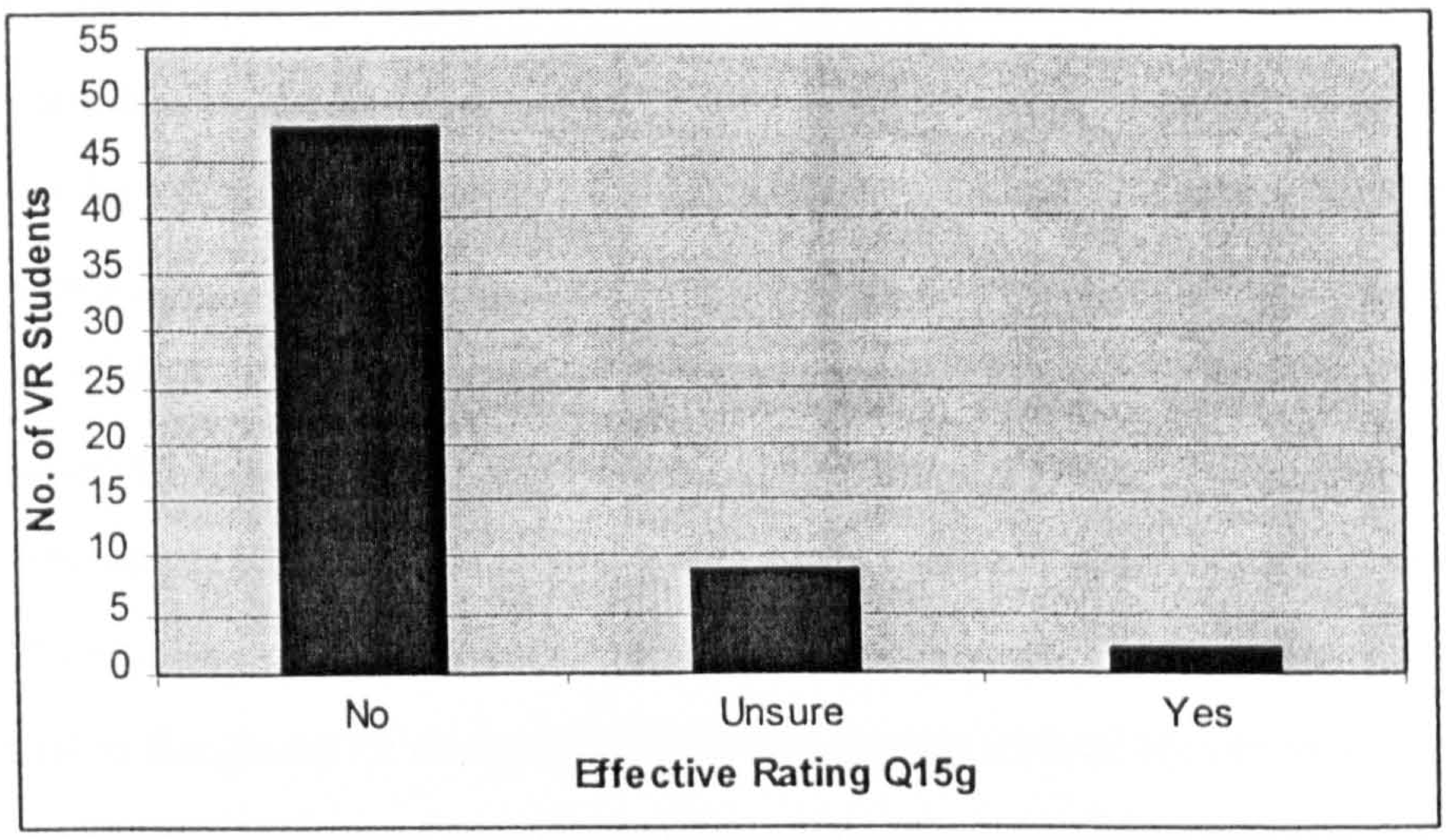

Figure 6.26 Would your prefer a 'virtual world' to the 'real world'?

The seventh part of this question asked participants the question "Would your prefer a 'virtual world' to the 'real world'?" The results can be seen in Figure 6.26. The mean of this data was found to be 1.22 and equates to nearly No. The most popular answer was No to this question (81.4%, n = 48). 15.3% (n = 9) replied Unsure and 3.4% (n = 2) students replied Yes.

The sixteenth and last question in this survey asked the participants to describe any disadvantages or dangers that may result from using VR. Popular replies included possible addiction, lack of social skill development, inability to distinguish between real and virtual life. Other answers included health and safety issues such as disorientation.

6.4 Discussion

This study has presented a number of answers to a series of questions developed to assess the experiences, attitudes and beliefs about using computers and VR in learning situations, the design of help systems in VR and their enjoyment of using VR software. These answers have given an insight into how motivated these participants might be when considering the designing VR learning environments. As two different questionnaires were produced the results will be discussed in two different sections.

6.4.1 VR Designers

The VR designers in this study were involved, as a group, in a variety of work experiences, developing VR applications or software for areas such as training, education, simulation, web development, games, defence simulations, advertising and sales, architecture and product visualisation project. About a third of the sample had had some experience of using VR for training or educational environments. Most designers were enthusiastic about using VR software to create interactive worlds using 3D objects, textures and programmed dynamics. Many of the participants expressed the wonderful opportunity VR software gave them to be more artistic than for other computing software. Overall there seemed to be a very positive attitude towards using VR for a variety of applications including training and education and also for the future of humankind. These results suggest that there is a great deal of motivation within the group of designers towards creating virtual reality worlds. High motivation transferred into good design would certainly enhance the experiences of users of these virtual worlds.

The designers were asked about their attitudes towards use of computers in training or learning situations. The results suggested that many of the designers considered that it was important or very important to use computers in training situations but expressed a particular belief that it be used alongside other media in the classroom. However they did not express the same beliefs about virtual reality, most of them feeling that it was not very important to use it for training, although they believed that when used it should also be used alongside other forms of learning media. These results show that the strong motivation and evidence of positive attitudes amongst the designer group for creating VR worlds did not seem to include use in VR in training situations. This seems to suggest that the designers were not positive about the results of their design, perhaps not feeling that they were adequate enough for training applications. However, this view was contradicted when asked about their beliefs about VR being used for training. For this question there was a strong response that indicated that VR was Effective or Very Effective as a training tool. These beliefs do show some contradiction in attitudes and beliefs about VR as a training tool.

Help Systems

Previous chapters have indicated the importance of using appropriate help systems in VR to help and guide users. The VR designer group was asked about their experiences of creating help facilities and of their thoughts for more effective help systems. The replies to the questions about help systems in this study did not reveal an imaginative set of ideas. Most of the answers were practical ones concerning on-line text help or telephone support. These are the type of help systems that are common in basic software packages (Harrison, 1995) and do not seem like natural and appropriate help systems for users of VR (Mason, 1996; Roussos and Bizri, 1998).

When asked about ideas for better help systems, VR designers' answers suggested that current facilities could be designed better. There seems a lack of knowledge or interest for other types of help system, especially those that could be incorporated into the virtual world to give guidance to the users. There was only one suggestion for friendly characters in the VR that could help the users. All help suggestions seemed to be related to the type of help systems that are available with 2D multimedia and computer-based programs. Very few actually explored the unique nature of the VR software. It was not clear if this was due to the difficulty in creating adventurous help systems with the software or lack of desire on the part of the designers who were used to providing 2D help systems. One possible factor that might underlie this issue is that found in Chapter 7 where the VR designer group had a lack of the F factor or Feeling type. These F types are considered to be more 'friendly' and 'helpful' types who want to communicate with other people (Myers and McCaulley, 1985). Results in Chapter 7 showed that this experimental VR group contains mainly T or Thinking types that prefer logical, thing-centred decision-making processes (Durling, 1996). This could be the reason that the group as a whole did not consider the use of friendly, person-centred help systems as being important. It seems likely that F types might prefer the use of more 'friendly' help systems such as the use of virtual characters rather than the manuals, menus, button clicks and dialogue boxes chosen by this group which seem to be less person-centred.

Enjoyment of Developing or Using Software

A positive attitude has been considered an important aspect of high motivation (Hendrickson, 1997). This study investigated how much the designers enjoyed using VR software and also contrasted their ratings with other software. The results showed that developing with *Superscape* VR software was considered the second most enjoyable type after developing games for entertainment, both being rated high on the enjoyment factor. Compared to other software, *Superscape* was found to be significantly more enjoyable to VR designers than developing databases or computer-based training programs. Although *Superscape* was rated more enjoyable than other VR software this was not found to be significant.

The VR designers were also asked about use of software packages. Ratings of enjoyment showed that of all types of software, the designers enjoyed using *Superscape* VR software the most. *Superscape* was even rated more enjoyable to use than other types of VR and games for entertainment and these results were found to be significant.

These results suggest that VR designers are very positive to both developing and using *Superscape* software. It is also clear that the designers in this study significantly prefer to use or develop with *Superscape* software than other forms of VR. As the group were members of the *Superscape* User Group, this high rating might have been expected from their own personal and professional choice but it was not obvious that their attitudes towards this software would be more favourable than for other VR tools.

Overall the survey of VR designers in this study revealed a positive attitude towards using computers in training which included the use of VR as a training tool alongside other forms of training media. Such a positive attitude suggests a great deal of motivation for the design of VR environments which will prove beneficial in the effort to encourage more establishments to use VR as part of their learning and training plans. However, such a positive view does not ensure that others will appreciate the benefits of VR and produce a demand for more VR applications. In particular, there might need to be a more positive view from designers about the importance of VR in training and learning situations if interest in this field is to be fostered. No other study has looked at VR designer attitudes and beliefs so these results cannot be compared with any other. Not all the designers in this group had used VR in learning situations, but it would be useful to find a large group of designers who had experience of designing VR learning environments to ask them more questions about how they use VR in education in training, the advantages and disadvantages and how they design to encourage successful learning. It was disappointing to see that designers were only considering very basic help systems, which do not seem suitable for VR learning environments and this needs to be investigated further. It does take more time and effort to design interactive and friendly environments, but it seems likely that these would add to the interest and the effectiveness of VR in ways discussed previously in this thesis.

6.4.2 VR Design Students

This study assessed the experiences, attitudes and beliefs about computers, VR and training. The results showed that the participants in this study had much experience in using computers, but not much experience of use of either computers or VR in learning or training environments.

The students' views on the use of computers in training were quite positive although their beliefs about computers being good for humankind were slightly less positive. Many of the students did agree that computers were an effective training tool, but were less positive about the role of VR in training situations. These results were similar to those of the VR designers. Such results are unusual given the number of studies that have suggested that VR is an ideal learning medium (Barker, 1995; Pantelidis, 1993; Rose and Billinghurst, 1995; Standen and Cromby, 1995).

However they were more positive about the potential of VR to become more effective in training and education in the future. They did not believe that VR was the ultimate form of training; however, they strongly agreed that VR was not just useful for enjoyment or entertainment purposes. This suggests that the students are not quite as happy about the current state of VR applications but envisage that improvements will improve matters. It would be interesting to find out more about the reasons why they do not think VR is important given its perceived effectiveness and potential. Further research is needed to investigate these issues.

The group was unclear about whether or not VR should be a truly multi-sensory type of medium with just as many saying 'no' as 'yes'. This is surprising since the literature seems to suggest that this would be both motivating and worthwhile (Brown, 1996; Byrne and Furness 1994; Osberg, 1992) and in studies participants have asked for more sounds and tactile feedback (Hoffman et al, 1999). However, when asked about the sense of touch, the majority of students believed that a realistic touch sensation was a necessary part of the VR experience. Most of the students were unsure or believed that a user did not have to wear a headset to believe that they were part of a VR world which is good for non-immersive types of VR. The group was of mixed opinion about whether or not VR would serve to decrease the social interaction between people. Fortunately a large majority of the students believed that they would not prefer the virtual world to the real world.

Overall the attitudes and beliefs to VR in training are reasonably positive but answers suggest that they are more positive about the potential of VR than about its current state. The students showed that they were a little worried about the possibility of being addicted to using VR and many were concerned with health and safety issues of current technology.

Health and safety issues of using headsets have been given some attention in the media and in the literature (see Chapter 2). Students' replies are obviously a reaction to this as in the classroom very few of these participants had indicated any experience of using headsets themselves.

Help Systems

The VR design students had not had experience of creating help systems themselves so could not be asked about this. Instead they were asked about their ideas for help systems in VR and several were suggested. Students were asked to rate their beliefs about how effective they thought these different help systems might be. The ratings suggested that the VR design students considered that most of these help systems would be effective. Only the telephone support system, which was considered to be the least effective, was rated just below less than effective. Of the six different types of help system the one that was believed to be the most effective was that of a real instructor that could help the user. This seems strange given the difficulty of a real instructor to help someone that is in an immersive VR system, unless they themselves became a part of the virtual world. The second best type of help system was found to be a multimedia facility, which would include graphics and sounds etc as, found in good interactive tutorials. Again this does seem a strange answer, given that multimedia features would not seem very natural in a virtual world. Why have button, icons, video etc when one is in a 3D simulated virtual world? A virtual instructor was considered to be the third most effective method, well ahead of on-line text and a manual. When asked about other forms of help that they might like, few of the students in this study suggested any, perhaps not being able to think of any other types. It seems likely that the students had not really had much experience or knowledge of using different VR systems, which would have shown the disadvantages of some of their answers. More research is needed to find out if users opinions of VR help systems match those that the designers are likely to provide.

Enjoyment of Different Types of Software

In order to assess the attitudes and motivation of the VR design students towards VR software the students were asked to rate their enjoyment for using a number of different software tools. For those tools that had not been used the VR design students had been asked to give their ratings for how enjoyable they thought that they might be. These answers gave some context for comparing their ratings of enjoyment for VR.

In comparisons of the use of different types of software for development purposes, the VR design students in this study rated games for entertainment as the most enjoyable but only slightly above the second choice of multimedia. As many of the students were taking a multimedia degree course this result seems to support their chosen option. *Superscape* was the software package that was being taught on the module and this was considered to be the third most enjoyable package with its mean ratings still above the halfway point on the scale. The other six types of software, educational games, word-processing, spreadsheets, databases, computer-based training packages and programming languages were considered to be less favourable to use.

Most of the students had used the nine types of software and a comparison between the ratings of those who had used it and those who had not, their expected ratings of enjoyment, showed that in all cases, the expected enjoyment ratings were lower than for those who had actually used the software. However only the differences for using databases and programming languages were significant. The most plausible reason for this is that those who had not tried these types of software had not done so because they did not expect them to be very enjoyable. In particular those who had enjoyed using computer-programming languages stated that they enjoyed solving problems with their own code. Most of the students discussed their enjoyment of using games for fun or using VR because of its interactive nature.

In discussing the negative aspects of software especially VR, most students wrote about bad navigation, complex interfaces, and lack of appropriate help. Several students expressed a dislike of using textures with *Superscape* because of the unrealistic graphics and slowness of the worlds refresh rate. Whilst those that could learn to use the VR programming language enjoyed using it to create interactive worlds, it was also given as the main reason why others did not like using VR software as much. They disliked the length of time it took to create the worlds and all the dynamics, although they seemed to enjoy the results.

The students seemed to be less positive about using *Superscape* software than the VR designers, but it is likely that the VR designers had better programming skills and more technical support in their jobs for creating VR worlds than the students who had to produce the worlds on their own as part of the course requirement. The VR designers, of course, have chosen to use this software in their professions and therefore may be expected to have very positive beliefs about the software. The students, however, seem to have more positive views about the potential of VR in the future with the advance of technology.

The literature has argued that high motivation along with positive beliefs and attitudes are good for learning performance of students (Hendrickson, 1997; Loomis, 2000; Shih and Gamon, 2001). There has been little evidence in the literature about attitudes of designers of software and the effect this might have on their work, although some studies have suggested that there is an association between motivation with job satisfaction (Herzberg et al, 1959) and job performance (Pascoe et al, 2002).

Overall this study suggested that there was a high degree of motivation and positive attitude amongst both the designers and the design students. Most participants gave a high rating for the enjoyment of using VR when compared to other forms of software. Participants had positive beliefs about the use of computers in training and learning situations and considered VR to be an effective learning tool, although some participants were less sure about the role of VR in training. A number of help systems have been considered for use in VR, but designers tended to favour on-line text help systems and VR design students favoured the use of a real life teacher.

The results of this study do not directly apply to the general design model in terms of providing data for practical guidelines; however, they do serve to provide evidence that VR designers generally have a positive attitude towards designing VR worlds, which is one of the elements of the design model that is considered important for learning. Questions relating to the design of help systems provide a basis upon which to explore further the issue of help systems (see Chapter 9).

CHAPTER 7: STUDY 2 - LEARNING STYLES

7.1 Introduction

It has been argued that learners tend to do better when the teaching style matches their own learning style (Henson and Borthwick, 1984), but there is little in the literature, to suggest the type of teaching style that VR can offer. From information presented in Chapter 4, there appears to be a strong argument for VR to favour an active, experiential teaching style. Kolb, and Honey and Mumford (see Chapters 4 and 6) have proposed theories and questionnaires that incorporate the idea of active, experiential learning but no researcher has yet investigated its association with VR.

7.1.1 Aims of this Study

The study aims to determine the learning styles of VR designers and VR design students and relate this to the general model of design outlined in Chapter 5. Four questions formed the basis of the study:

(1) Question 1: If VR is an active learning medium does it attract designers and students who have a dominant Activist learning style?

(2) Question 2: If VR is an active learning medium does it attract designers and students who have higher Activist learning style scores?

(3) Question 3: Do VR designers and VR design students have the same learning styles?

(4) Question 4: Do VR designers and VR design students have learning styles representative of the general student population?

This investigation will determine the learning styles of both current VR designers and VR design students in order to answer these hypotheses. The Honey and Mumford Learning Style Questionnaire (LSQ) was considered the most appropriate tool for investigation (see Chapter 4) as it identified the active learning style that may relate to the concept of active participation in VR. VR design students were included in the study because the population of VR designers was quite small and because these adults had chosen to take a VR course and may well become VR designers in the future. The study will also investigate any differences due to age, as there may be a difference in age between the two groups. Honey and

Mumford (1992) suggest that learning styles are not constant and can be developed over time, so age may be a factor that could affect the results.

7.2 Method

7.2.1 Participants

All participants had volunteered to take the LSQ. They were informed of the aims of this study and were assured that results would be kept confidential. A large number of LSQ were handed out to participants; only those that were completed and returned were used in this study.

VR Designers

The participants were 5 females and 19 males who were all VR designers, mainly of desktop VR systems. The age of the group ranged from 22 to 47 years old with a mean age of 35 years and a standard deviation of 8 years.

VR Design Students

The participants were 16 females and 58 males who were higher education students taking either the Virtual Reality third year Module or the MSc Virtual Reality Module. They were of mixed age, ranging from 21 to 55 years old. The average or mean age was 26 years with a standard deviation of 8 years.

7.2.2 Materials

The Honey and Mumford Learning Style Inventory (LSQ) was used in the written format, in the 1986 revised version (see Appendix 5). The 1986 LSQ (Honey and Mumford, 1992) was a self-report questionnaire consisting of 80 questions to which people answered 'yes' or 'no' by entering a tick or a cross against each question.

7.2.3 Procedure

A small pilot study was carried out with a group of university students to ascertain what problems may occur in doing the main study and to adjust verbal instructions to ensure that participants understood what needed to be done. Verbal pre-study information and written instructions on the inventory were found to be clear and understandable and no problems were found. All returned questionnaires were correctly filled in and all participants stated that they had fully understood what to do with the questionnaire.

The experiment consisted of administering LSQ to two groups of participants (independent variable): current VR designers and VR design students. The questionnaire was a self-report instrument and participants were able to calculate their own scores in order to determine their learning style profile and particular dominant learning style - four categories (dependent variable). Analyses were carried out within groups (1 x 4 design) and also between groups (2 x 4 design).

LSQs were handed out to VR designers at several *Superscape* User Group meetings and to VR design students at lectures during the university semesters. Participants were asked if they could complete the questionnaire and hand or post it back to the experimenter, but were not forced to do so. Participants were given full instructions on how to complete the questionnaire and were told to do the questionnaire in their own time and to record their age. They were told that all personal data was confidential. Ethical guidelines were followed; subjects did not have to give their name, but were asked to give some code so that data could be compared for those who wished to take part in the other studies.

7.2.4 Data Analysis

Learning style preferences and the order of preferences were recorded for each participant. Percentages and means were calculated using *Excel* software and t-tests were calculated using *Minitab* statistical software. Tables and bar-charts were produced to highlight differences between the four learning styles for each of the two groups. Scores for each learning style were taken and adjusted in order to compare means and analysed for significance using t-tests and ANOVAs. A correlation analysis was carried out to determine relationships between the four learning styles. Scores were also grouped together to form norms in order to compare with other population norms given by Honey and Mumford (1992). Age differences were also discussed as possible factors influencing the results.

7.3 Results

7.3.1 Predominant Learning Style

The raw data can be seen in Appendix 6 and summaries can be seen in Table 7.1 and Figure

7.1.

Table 7.1 Learning Types for Designers and Students

	Activist	*Pragmatist*	*Reflector*	*Theorist*
Designers	9	1	11	5
n=26	35%	4%	42%	19%
Students	38	6	26	4
n=74	52%	8%	35%	5%
Overall	47	7	37	9
n=100	47%	7%	37%	9%

The results in Table 7.1 showed that the predominant learning style for VR designers was Reflector (42.3%) and the second style was Activist (34.6%). They also showed that the predominant learning style for VR design students was Activist (51.4%) and the second style was Reflector (35.1%). For both groups there had less than 10% of either Pragmatists or Theorists.

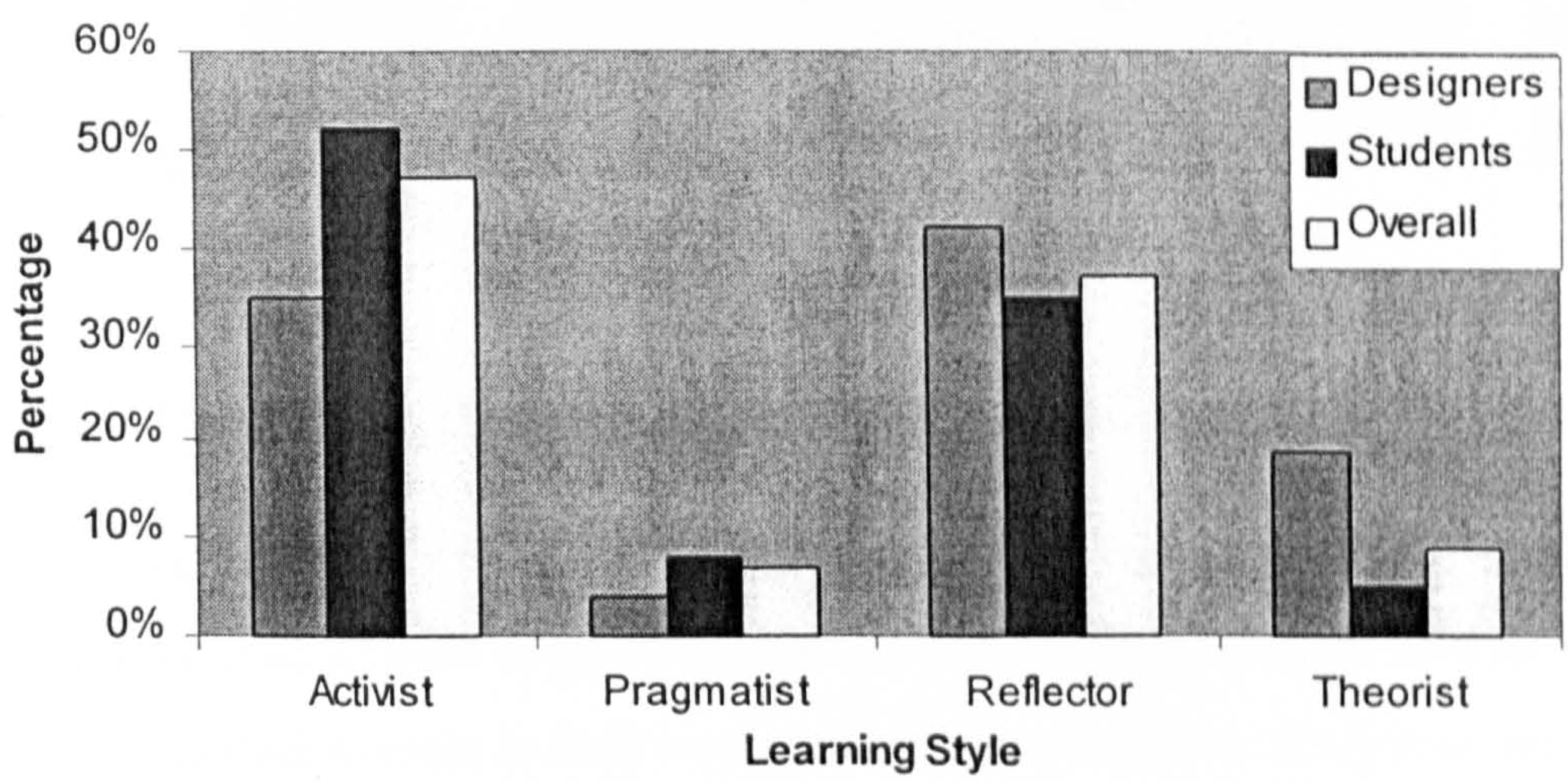

Figure 7.1 Percentage of Learner Types

The results showed that overall both groups consisted mainly of Activists and Reflectors; Activists were 47% of the whole sample and Reflectors were 37% of the sample. Pragmatists and theorists were both only 8% of the whole sample. There were fewer Activists and more Theorists in the designer group than in the student group.

7.3.2 Activist Learning Preferences

The previous section described the predominant learning for each participant. This section investigates the position of the Activist learning style preference.

Table 7.2 Position of Activist Learning Style For Designers, Students

	1st	*2nd*	*3rd*	*4th*
Designers *n=26*	9 35%	2 8%	2 8%	13 50%
Students *n=74*	38 51%	13 18%	13 18%	10 14%
Overall *n=100*	47 47%	15 15%	15 15%	23 23%

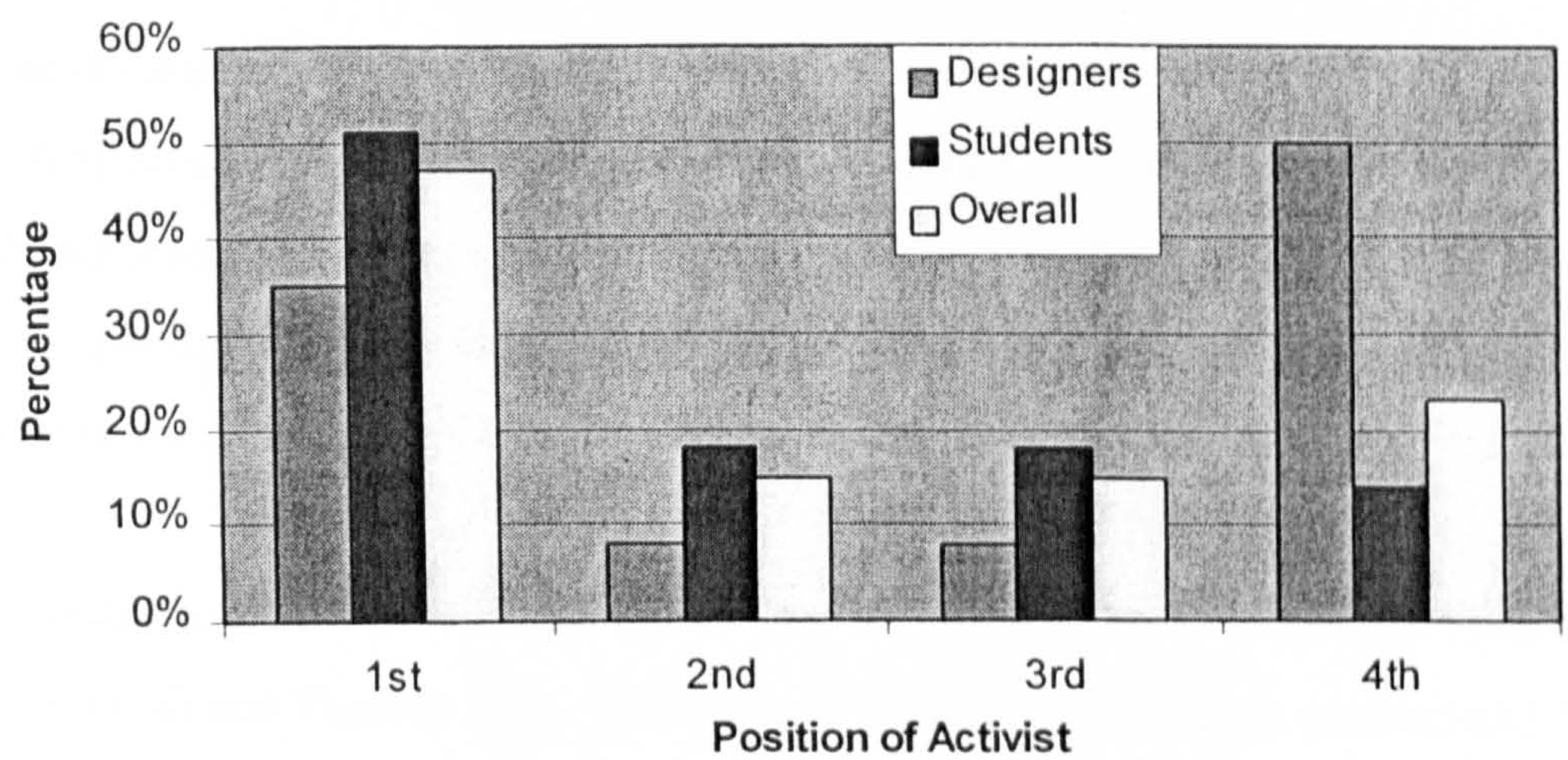

Figure 7.2 Position of Activist Learning Style for Designers and Students

The results in Table 7.2 and Figure 7.2 showed that whilst there were nine (35%) VR designers who had Activist as their predominant learning style, a larger number of the VR designers (13) had Activist as their weakest learning style (50%). Only four designers (16%) had Activist as either their second and third preferences. Only 43% of designers had Activist as their first or second preference. The results from the sample of VR design students showed that few students had Activist as their weakest learning type (ten students or 14%). Twenty-six students (36%) had Activist as their second and third preferences. 69% of students had Activist as their first or second choice.

7.3.3 Differences in Learning Style Scores

Scores were obtained from the LSQ by adding up the number of ticked questions for each type of learning style. The scores were then matched using the Honey and Mumford (1992) scoring grid (see Appendix 5) and the results can be seen in Table 7.3.

Table 7.3 Original (Non-adjusted) Scores for the Four Learning Styles

		Activist	Pragmatist	Reflector	Theorist
Designers	Total	241	350	408	347
n=26	Mean	9	13	16	13
	SD	4	2	3	4
Students	Total	757	813	1003	744
n=74	Mean	10	11	14	10
	SD	4	3	4	4
Overall	Total	998	1163	1411	1091
n=100	Mean	10	12	14	11
	SD	4	3	3	4

The results showed that the means (rounded to nearest whole figure) for the designer group were Activist (9), Pragmatist (13), Reflector (16) and Theorist (13). This equates to Activist (moderate preference), Pragmatist (moderate preference), Reflector (strong preference) and Theorist (moderate preference). These results showed that the designer group had a strong preference for Reflector learning style and only moderate preferences for other styles.

The results showed that the means for the student group were Activist (10), Pragmatist (11), Reflector (14) and Theorist (10). This equates to Activist (moderate preference), Pragmatist (low preference), Reflector (moderate preference) and Theorist (low preference). The student group showed moderate preferences for Activist and Reflector learning styles and low preferences for Pragmatist and Theorist. Overall means for each learning style were Activist (10), Pragmatist (12), Reflector (14) and Theorist (11). The overall type would equate to Activist (moderate preference), Pragmatist (moderate preference), Reflector (moderate preference) and Theorist (low preference).

Scores across learning styles cannot be compared directly as equal scores do not mean equal strengths of preferences as. In order to compare differences between scores, a fifth column of scores was produced containing all values in the grid (see Appendix 7). Scores in columns were then adjusted using the equivalent value in Column 5. Thus all adjusted scores would equate to the same amount of preference as indicated in Column 6. A summary of the results can be seen in Table 7.4 and Figure 7.3.

Table 7.4 Adjusted Scores for the Four Learning Styles (Minitab)

		Activist	*Pragmatist*	*Reflector*	*Theorist*
Designers	Total	355	372	458	409
n=26	Mean	13.65	14.31	17.62	15.73
	SD	5.08	3.15	4.42	5.1
Students	Total	1148	841	1063	842
n=74	Mean	15.51	11.37	14.37	11.38
	SD	4.56	3.98	4.44	4.47
Overall	Total	1503	1213	1521	1251
n=100	Mean	15.46	11.88	14.7	11.83
	SD	4.54	4.0	4.45	4.67

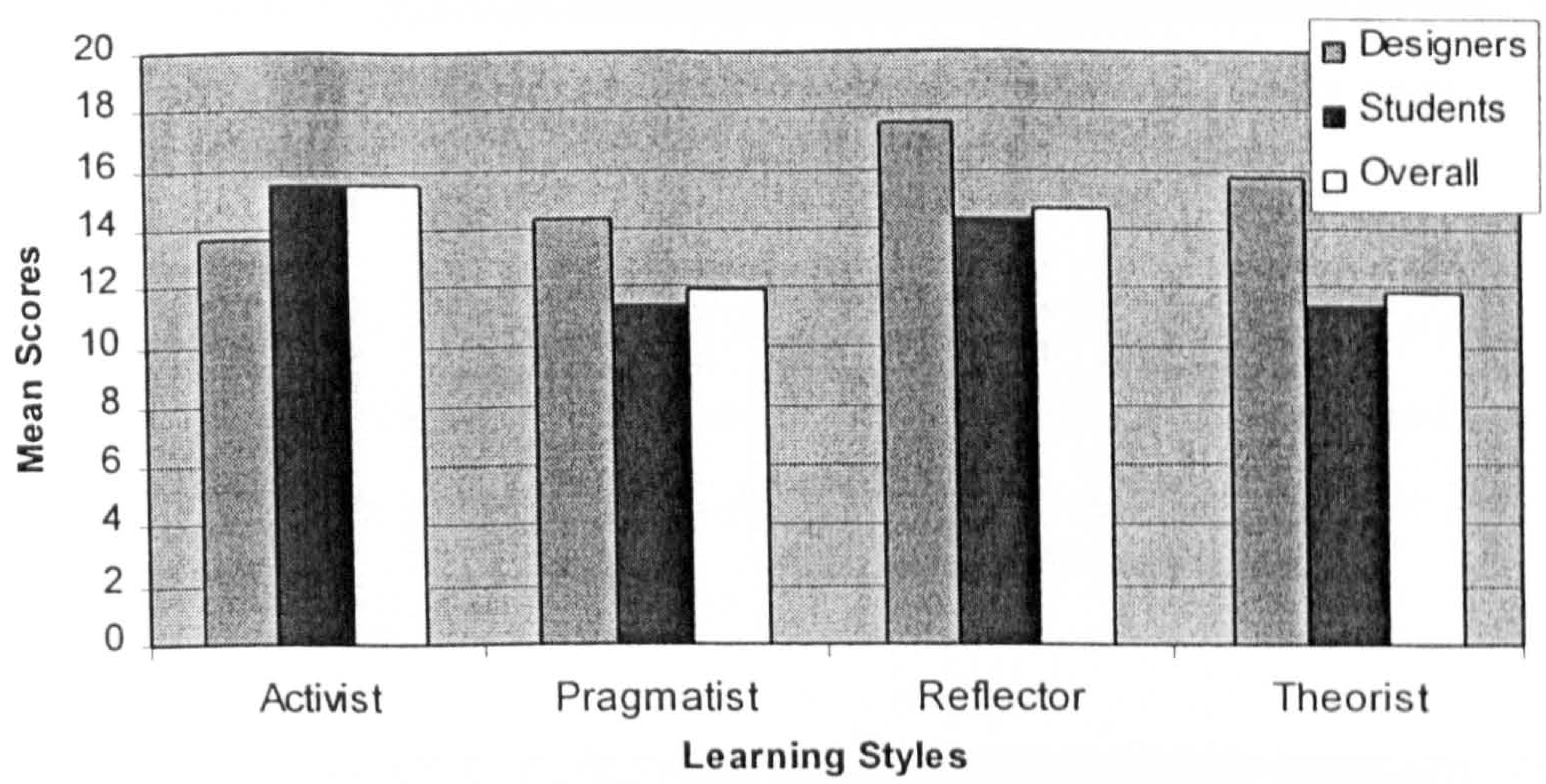

Figure 7.3 Mean Adjusted Scores for each Learning Style

Adjusted scores can now be compared directly. Table 7.4 and Figure 7.3 show that Reflector was the dominant learning style for the Designer group (mean = 17.62) and Theorist was the second preferred learning style (mean = 15.73). Activist was the weakest learning style (mean = 13.65). This does not support the initial analysis that showed that Activist was the second strongest learning style for the VR designers from previous count data. Further investigation revealed the reason for this contradiction. The VR designer group consisted of a large number of Activists in first position but also in fourth position. The data suggests a bi-modal group of scores. The data was further analysed for distribution to see if this was true and the results can be seen in Figure 7.4.

Figure 7.4 shows that there were three groups of scores. Six designers had mean Activist above 19. However ten designers had scores below 10. The shape of this distribution shows that the means are low because although there were some designers who had very strong preferences for the Activist learning style, there were more designers who had a low preference for the Activist learning style.

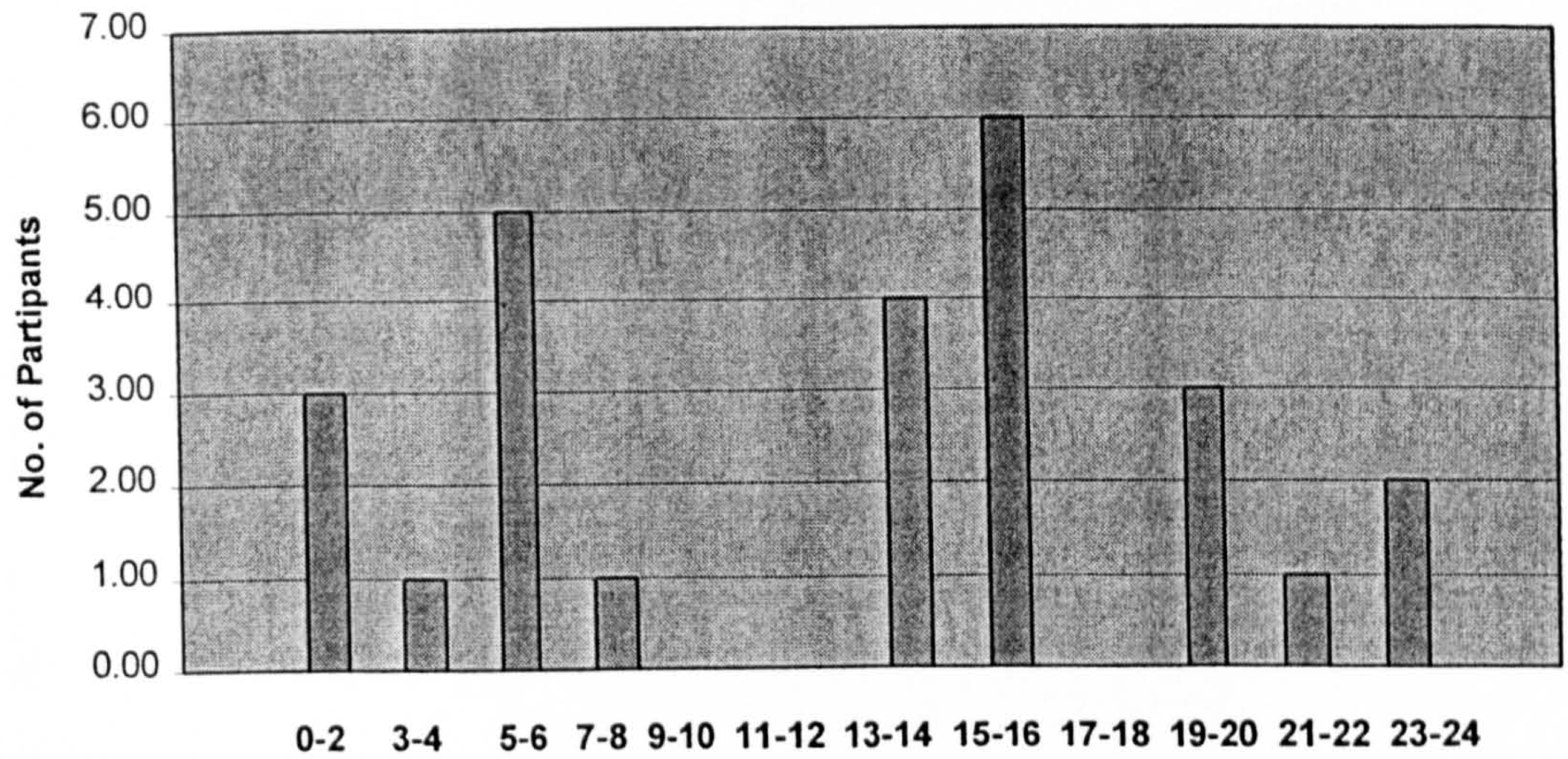

Figure 7.4 Distribution of Activist Scores (designers)

For the student group, the results in Table 7.4 and Figure 7.3 showed that Activist was the dominant learning style (mean = 15.51), and Reflector as the second preferred learning style (mean = 14.34). This supported the analysis from previous data. Overall the dominant learning style was Activist (mean = 15.46).

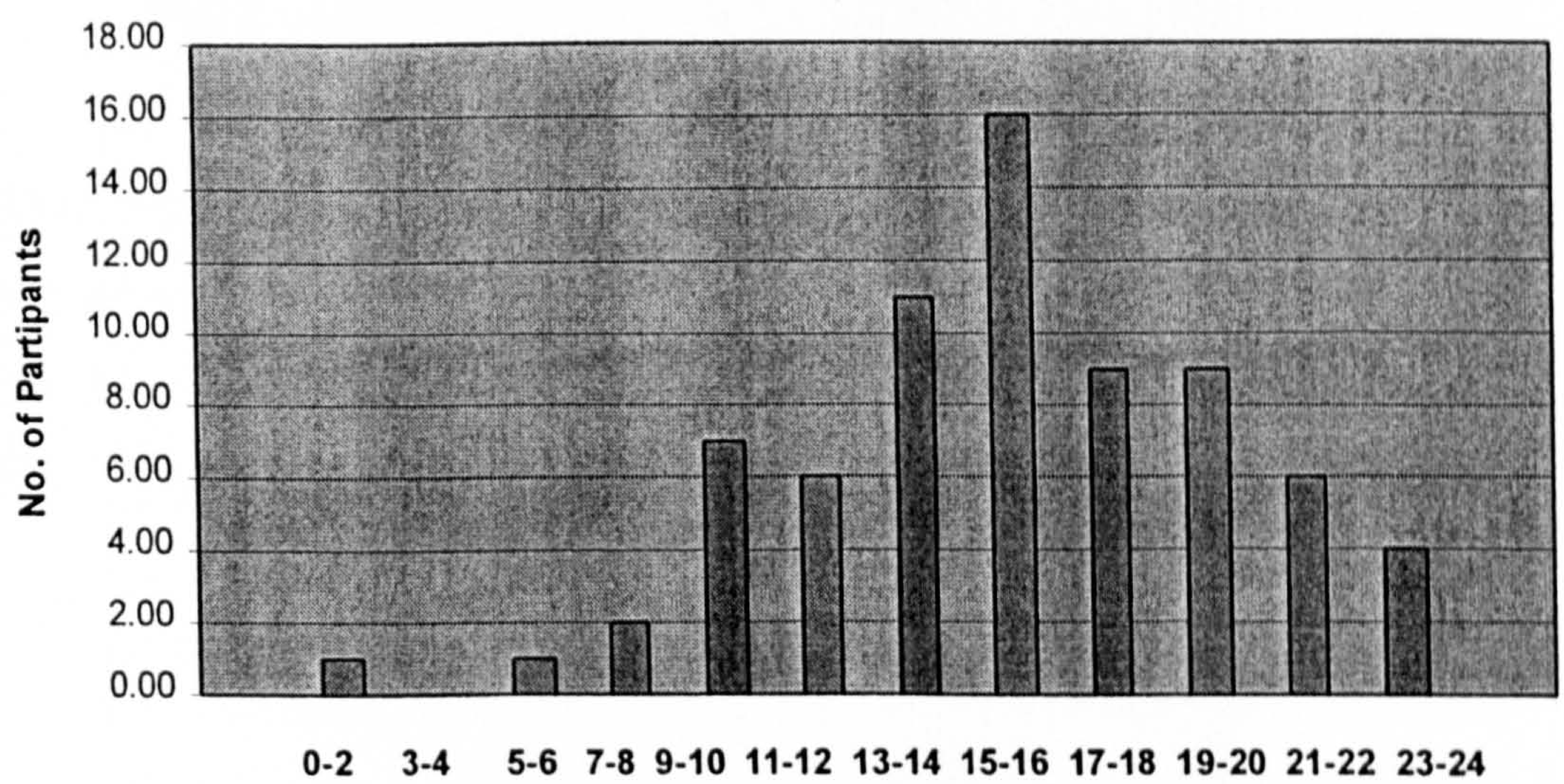

Figure 7.5 Distribution of Activist Scores (students)

The distribution of VR design students' scores was more typical of a normal distribution as can be seen in Figure 7.5. This contrasts greatly to the distribution of VR designers' scores.

A correlation analysis was carried out on the VR designer group data. The results are shown in Table 7.5. There was only a significant positive correlation, which was between Reflector and Theorist (p = 0.000) at the $\alpha = 0.01$ level.

Table 7.5 Correlations for Designers Learning Style Scores (n=26)

		Activist	Pragmatist	Reflector
Pragmatist	Pearson Correlation	0.110	1	.052
	p-value	.595		.801
Reflector	Pearson Correlation	-0.397	.052	1
	p-value	.45	.801	
Theorist	Pearson Correlation	-.362	.274	.593(**)
	p-value	.069	.175	.000

** correlation is significant at the 0.01 level * correlation is significant at the 0.05 level

A correlation analysis was carried out on the VR student group data. The results are shown in Table 7.6.

Table 7.6 Correlations for Students Learning Style Scores (n=74)

		Activist	Pragmatist	Reflector
Pragmatist	Pearson Correlation	-0.049	1.000	.142
	p-value	.679	.	.228
Reflector	Pearson Correlation	-0.534 (**)	.142	1.000
	p-value	.000	.228	.
Theorist	Pearson Correlation	-.385(**)	.463(**)	.558(**)
	p-value	.001	.000	.000

** correlation is significant at the 0.01 level * correlation is significant at the 0.05 level

There were significant negative correlations between Activist and Reflector (p = .000) and Activist and Theorist (p = .001) at the $\alpha = 0.01$ level. There were significant positive correlations between Reflector and Theorist (p = .000) and Pragmatist and Theorist (p = .000) at the $\alpha = 0.01$ level.

Table 7.7 Correlations for Overall Learning Style Scores (n=100)

		Activist	Pragmatist	Reflector
Pragmatist	Pearson Correlation	-0.068	1.000	.211 (*)
	p-value	.504	.	.035
Reflector	Pearson Correlation	-0.520 (**)	.211 (*)	1.000
	p-value	.000	.035	.
Theorist	Pearson Correlation	-.410(**)	.486(**)	.616(**)
	p-value	.000	.000	.000

** correlation is significant at the 0.01 level * correlation is significant at the 0.05 level

A correlation analysis was carried out on the combined groups' data. The results are shown in Table 7.7. There were significant negative correlations between Activist and Reflector (p = .000) and Activist and Theorist (p = .000) at the $\alpha = 0.01$ level. There were significant positive correlations between Reflector and Theorist (p = .000) and Pragmatist and Theorist (p=0.000) at the $\alpha = 0.01$ level.

7.3.4 Differences between Learning Styles

A one-way analysis of variance (ANOVA; 1 x 4) was used to investigate differences between the scores for each learning style in each of the two different dependent groups. Significant differences were found in the scores for learning styles in the VR designer group (F = 3.94, p-value = 0.011, d.f. = 103) at the α level = 0.05 and for the VR student group (F = 17.3, p-value = 0.000, d.f. = 295) at the $\alpha = 0.01$ level.

In order to investigate the differences between the independent variables (learning styles) further, t-tests were used out to find out which scores were different. Paired t-tests were used to compare within-subjects scores for each of the two groups.

Differences in Designers' Learning Style Scores

Earlier results for the VR designer group presented the mean scores for each of the four learning styles (see Table 7.4). Paired t-tests were used out to look at the scores and see if there were any differences. The results can be seen in Table 7.8.

Table 7.8 Paired t-tests for Designers (n=26)

	Mean Difference	*Standard Deviation*	*Mean Error*	*T-Value*	*p-value*	*Significance*
Activist-Pragmatist	-0.650	5.670	1.110	-0.59	0.562	no
Activist-Reflector	-3.960	7.940	1.56	-2.54	0.018	$\alpha = 0.05$ *
Activist-Theorist	-2.08	8.40	1.65	-1.26	0.219	no
Pragmatist-Reflector	-3.310	5.29	1.04	-3.19	0.004	$\alpha = 0.01$ **
Pragmatist-Theorist	-1.42	5.21	1.02	-1.39	0.176	no
Reflector-Theorist	1.885	4.339	0.851	2.21	0.036	$\alpha = 0.05$ *

The paired t-tests showed that there were significant differences in scores between Pragmatist and Reflector scores at $\alpha = 0.01$ level, indicating that the scores for Reflector learning style (mean = 17.62) were significantly greater than for the Pragmatist learning style (mean = 14.31). They were also found to be significantly greater ($\alpha = 0.05$ level) than for Activist (mean = 13.65) and for Theorist (mean = 15.73). There were no significant differences between Activist and Pragmatist, Activist and Theorist and Pragmatist and Theorist learning styles.

Differences in Students' Learning Style Scores

The results for the VR student group means were presented earlier in this thesis (see Table 7.4). Paired t-tests were carried out to look at the scores and see if there were any differences. The results can be seen in Table 7.9. The results of the paired t-tests showed that there were four significant results for the VR design students, all at the $\alpha = 0.01$ level. The results suggested that the scores for the Activist learning style (mean = 15.51) was significantly greater than for the Pragmatist learning style (mean = 11.37) and for the Theorist learning style (mean = 11.38). The results also showed that the Reflector learning style scores (mean = 14.37) were significantly greater than those of the Pragmatist learning style (mean = 11.37) and the Theorist learning style (mean = 11.38).

Table 7.9 Paired t-tests for Student Scores (n=74)

	Mean Difference	*Standard Deviation*	*Mean Error*	*T-Value*	*p-value*	*Significance*
Activist-Pragmatist	4.149	6.199	0.721	5.76	0.000	$\alpha = 0.01$ **
Activist-Reflector	1.149	7.898	0.918	1.25	0.215	no
Activist-Theorist	4.135	7.513	0.873	4.73	0.000	$\alpha = 0.01$ **
Pragmatist-Reflector	-3.0	5.527	0.643	-4.67	0.000	$\alpha = 0.01$ **
Pragmatist-Theorist	-0.014	5.21	1.02	-1.39	0.176	no
Reflector-Theorist	2.986	4.189	0.487	6.13	0.000	$\alpha = 0.01$ **

Differences in Overall Learning Style Scores

Earlier results for the overall group mean scores were presented for each of the four learning styles (see Table 7.4). Paired t-tests were used out to look at the scores and see if there were any differences. The results can be seen in Table 7.10.

Table 7.10 Paired t-tests for Overall Scores (n=100)

	Mean Difference	*Standard Deviation*	*Standard Mean Error*	*T-Value*	*p-value*	*Significance*
Activist-Pragmatist	2.9	6.398	0.64	4.53	0.000	$\alpha = 0.01$ **
Activist-Reflector	-0.180	8.185	0.819	-0.22	0.826	no
Activist-Theorist	2.52	8.182	0.818	3.08	0.003	$\alpha = 0.01$ **
Pragmatist-Reflector	-3.080	5.441	0.544	-5.66	0.000	$\alpha = 0.01$ **
Pragmatist-Theorist	-0.380	4.634	0.463	-0.82	0.414	no
Reflector-Theorist	2. 7	4.234	0.423	6.38	0.000	$\alpha = 0.01$ **

The results of the overall paired t-tests showed that there were four significant results, all at the $\alpha = 0.01$ level. The results suggested that the scores for the Activist learning style (mean = 15.46) was significantly greater than for the Pragmatist learning style (mean = 11.88) and for the Theorist learning style (mean = 11.83). The results also showed that the Reflector learning style scores (mean = 14.7) were significantly greater than those of the Pragmatist learning style (mean = 11.88) and the Theorist learning style (mean = 11.83). These are similar to the student group and perhaps reflect the fact that there were many more student participants than designer participants and thus they would have a greater impact on the overall results.

7.3.5 Differences between Designer and VR Design Student Scores

A number of 2 sample t-tests were carried out in order to investigate any significant differences between the dependent variables. The results, so far, suggest that Activist was the dominant learning style for the VR design student group, but was the weakest learning style for the VR designer group in terms of scores, although it was the second strongest style in terms of dominant styles.

Paired t-tests could not be used out, as the groups were not of equal size. Instead two-sample t-tests were used out on each of the four learning styles to find out if there were any significant differences between the two groups (see Table 7.11).

Table 7.11 Results of 2-sample t-tests

	95% CI for difference		*T-Value*	*p-value*	*d.f.*	*Significance*
Activist	-4.14	0.42	-1.65	0.107	40	no
Pragmatist	1.397	4.488	3.82	0.000	65	α = 0.01 **
Reflector	1.227	5.28	3.22	0.002	44	α = 0.01 **
Theorist	2. 07	6.63	3.86	0.000	39	α = 0.01 **

The results showed that there were significant differences in the scores for Pragmatist ($mean_d$ = 14.31, $mean_s$ = 11.37), Reflector ($mean_d$ = 17.62, $mean_s$ = 14.37) and Theorist ($mean_d$ = 15.73, $mean_s$ = 11.38) at the $\alpha = 0.01$ level. There were no differences between the designer Activist scores ($mean_d$ = 13.56) and the student Activist scores ($mean_s$ = 15.51). The results were all significant at the $\alpha = 0.01$ level; and indicated that the designer scores for Pragmatist (p = 0.000), Reflector (p = 0.002) and Theorist (p = 0.000) were all greater than for the students' scores.

7.3.6 General Norms

The results so far do suggest some significant differences between dependent and independent conditions. The next stage is to compare the results to other population results to find out if these results are unusual.

Forming bands for the top 10%, the next 20%, the middle 40%, the next 20% and the lowest 10% of weighted scores, creates general norms. This procedure was described by Honey and Mumford (1992). Norms for different populations of professional groups are given in their manual and are used by the authors to compare results. Honey and Mumford do not give norms for VR designers, graphics designers or computer programmers. It was decided that it was inappropriate to compare these results with any of the other populations but Honey and Mumford's norms for the general UK population can be seen in Table 7.12 and for the general UK student population in Table 7.13. These were used to compare differences between the designers and the possible users of VR systems.

Table 7.12 Norms for General Population (Honey and Mumford, 1992)

	Band A	*Band B*	*Band C*	*Band D*	*Band E*
Activist	13-20	11-12	7-10	4-6	0-3
Reflector	18-20	15-17	12-14	9-11	0-8
Theorist	16-20	14-15	11-13	8-10	0-7
Pragmatist	17-20	15-16	12-14	9-11	0-8

Table 7.13 Norms for Student Population (Honey and Mumford, 1984)

	Band A	*Band B*	*Band C*	*Band D*	*Band E*
Activist	17-20	15-16	10-14	7-9	0-6
Reflector	19-20	17-18	13-16	10-12	0-9
Theorist	16-20	14-15	9-13	6-8	0-5
Pragmatist	16-20	14-15	10-13	8-9	0-7

One of the main differences in these norms is the obvious contrast in scores for the Activist learning style. The general student population seems to have higher Activist scores, across all bands, than the general population.

Designers

Norms were created for results of this study using non-adjusted scores. Norms for the VR designer group can be found in Table 7.14

Table 7.14 Norms for VR Designer Group (in this study)

	Band A	*Band B*	*Band C*	*Band D*	*Band E*
Activist	15-20	11-14	8-11	5-7	0-4
Reflector	19-20	18-18	15-17	12-15	0-12
Theorist	18-20	16-17	13-15	9-12	0-8
Pragmatist	16-20	15-15	14-15	11-13	0-10

A comparison of norms for the VR designer group (Table 7.14) and the general population (Table 7.12) showed that the designers had slightly higher bands than the general population, across all four learning styles. The only lower band was for the Pragmatist Band, A which was slightly lower for the designers than the general population.

A similar comparison of norms for the designers and the general student population (see Table 7.13) showed that VR designers had lower score bands for the Activist learning style than other students. They had similar scores at the top bands for the Reflector learning style but lower scores for the lower bands. They had higher scores for Pragmatist and Theorist for most of the bands.

Students

Norms were created for results of this study using non-adjusted scores. Norms for the VR designer group can be found in Table 7.15.

Table 7.15 Norms for VR Student Group (in this study)

	Band A	*Band B*	*Band C*	*Band D*	*Band E*
Activist	16-20	13-15	10-12	5-9	0-4
Reflector	18-20	16-17	13-15	10-12	0-9
Theorist	15-20	12-14	9-11	6-8	0-5
Pragmatist	15-20	13-14	9-12	7-8	0-6

A comparison of norms for the VR student and the general population (Table 7.12) show that the students had higher bands for all learning styles, except the top band of Reflector, which was the same. A similar comparison of norms for the students and the general student population (see Table 7.13) showed that VR design students had lower score bands for many of the learning styles across the top bands, but higher scores for the lower bands.

7.3.7 Age

The VR designer sample had a mean age that was higher than the VR student sample. It is possible, therefore, that the Activist style is linked not with VR but with age. The results for learning type, therefore, could have been due to an age factor. Honey and Mumford (1992) suggest that learning styles can change through various factors and developing learning strategies over time may be reflected in the two samples. Results were therefore analysed to investigate if the learning styles were affected by the age factor.

Table 7.16 Mean Age and Sample Size for Designers and Students

	Mean Age Designers	*Sample Size*	*Mean Age Students*	*Sample Size*
Activist	31	9	25	38
Pragmatist	23	1	32	6
Reflector	35	11	25	26
Theorist	44	5	30	4
Overall Mean Age	35		26	
St. Deviation	8		9	

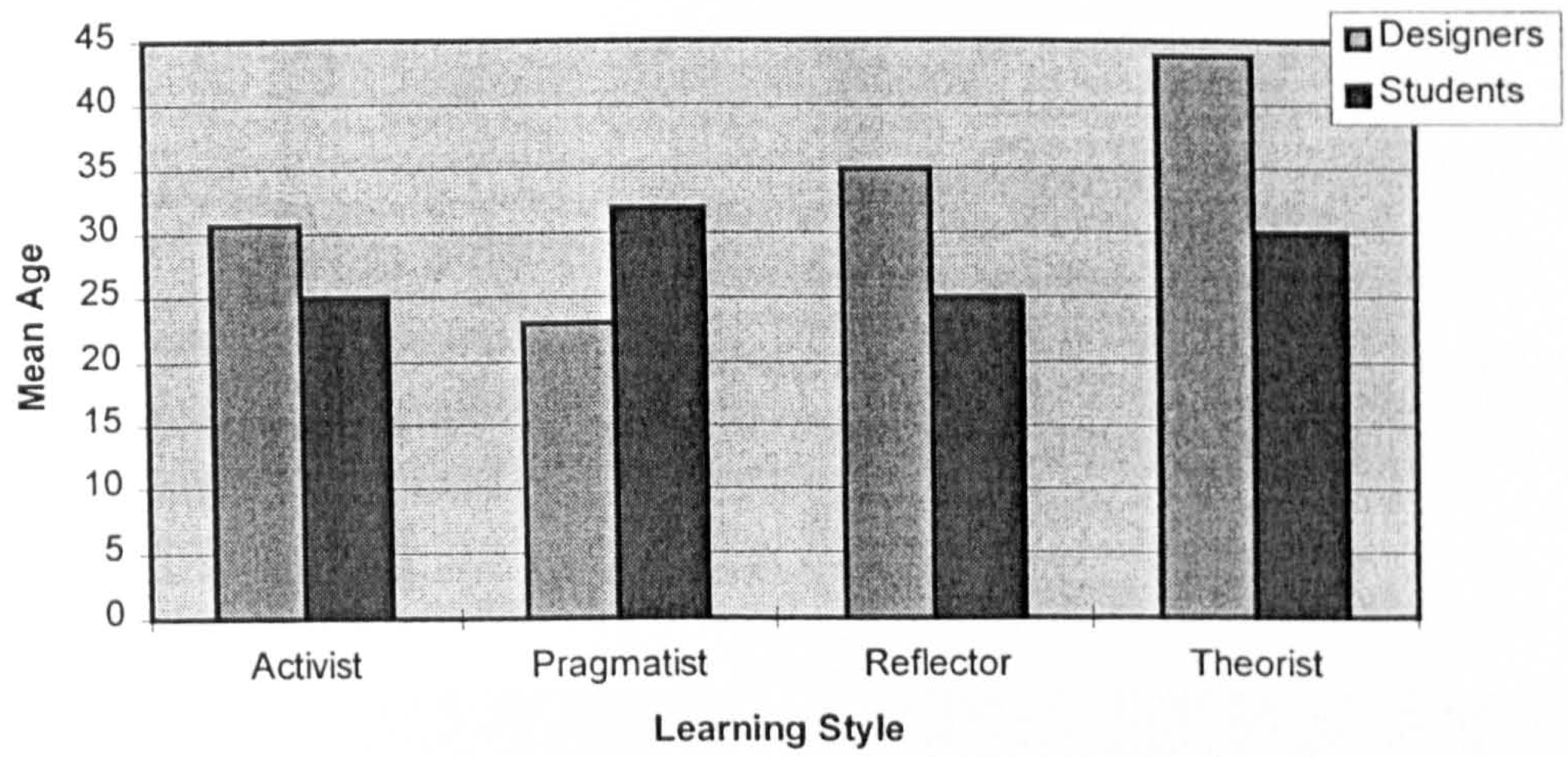

Figure 7.6 Mean Age of Designers and Students for Each Learning Style

The overall mean ages and standard deviation for each group of participants was calculated and the results can be seen in Table 7.16 and Figure 7.6. The results clearly show that the VR designer group tended to have older members (mean age of 35) when compared to the VR student group (mean of 26).

The results also showed within the VR designer group, the oldest members tended to show a Theorist learning style. Within the VR student group, the oldest members tended to show a Pragmatist learning style. The Activist group showed the least variance in that its members' ages were between 25 and 31 years.

Table 7.17 Correlations for Age and Learning Styles

		Activist	*Pragmatist*	*Reflector*	*Theorist*
Age	Pearson correlation	-0.234	0.286	0.195	0.481
	p-value	0.019	0.004	0.052	0.000

A correlation analysis was carried out on the adjusted scores to look for significant relationships between age and learning style. The results are shown in Table 7.17. There were highly significant positive correlations between age and Theorist learning styles ($p = 0.000$) and between age and Pragmatism ($p = 0.004$) at the $\alpha = 0.01$ level. There was also a significant negative correlation between age Activism ($p = 0.019$) at the $\alpha = 0.05$ level.

7.4 Discussion

The VR designers in this study were found to compose of 42% Reflectors, 35% Activists, 19% Theorists and 4% Pragmatists. The VR design students were found to comprise of 52% Activists, 35% Reflectors, 8% Pragmatists and 5% Theorists. This data is presented visually in Figure 7.7. Combined they comprised of 47% Activists; 37% Reflectors; 9% Theorists and 7% Pragmatists.

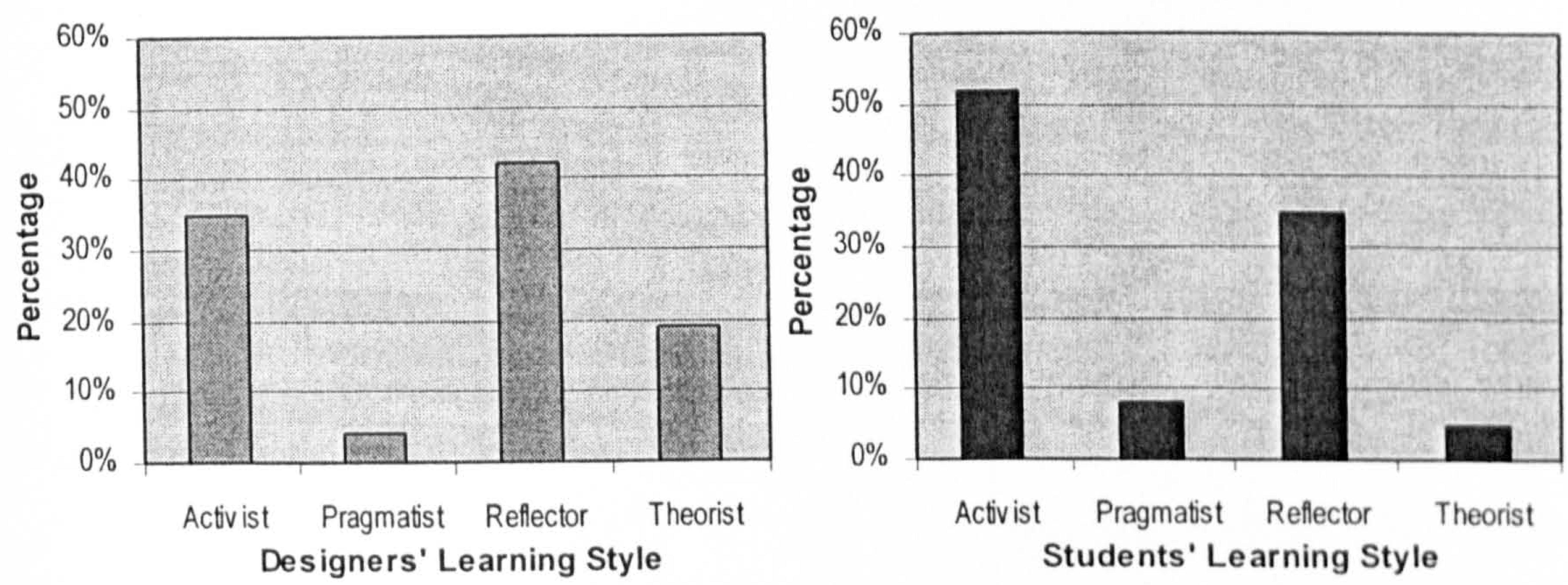

Figure 7.7 Overall Learning Styles for this Study

The main objectives of this study were to investigate the learning style preferences of VR designers and VR design students. Four specific questions were asked and these will now be addressed.

If VR is an active learning medium does it attract designers and students who have a dominant active learning style?

The results showed that there were dominant styles in both of the two groups and that Activist was the dominant learning style overall. It was the dominant style for VR design students and the second dominant style for VR designers. This seems to suggest that an Activist learning preference could be an important factor amongst those people attracted to the designing of VR worlds. However, Reflector was the dominant style for the VR designer group and the second dominant style for the VR design student group. Thus Reflector could also be an important learning style for VR software designers. Very few participants had either Pragmatist or Theorist learning styles.

If VR is an active learning medium does it attract designers and students who have higher Activist learning style scores?

Further analysis on the actual scores produced by the LSQ, also showed Activist was the highest scoring preference for both groups combined. However, these were probably influenced by the results of the VR design student group as there were far more students than designers in this study.

The results for the VR design students showed that they produced the highest LSQ scores for the Activist learning style. Reflector was the second highest scoring learning style. Statistical t-tests showed that the results for Activist were not significantly higher than for Reflector but they were significantly higher than for Pragmatist and Theorist learning styles. However, a slightly different picture for the VR designer group was found. Although this Activist was the second dominant learning style for this group, i.e. there a large number of designers who had Activist as their first preference, the individual scores showed that the Activist learning style was the weakest scoring learning style. The reason for this is because whilst there were quite a few Activists (first position), there were many non-Activists (fourth position) with very low scores. The data seemed to be skewed and a distribution chart verified this. Thus the results for VR designers show mixed results; a number of designers have high scores for the Activist learning style, but a larger number do not.

Do VR designers and VR design students have the same learning styles?

The overall learning style patterns suggest some similarity in learning styles for both groups in that Reflector and Activist were the top two dominant learning styles for both groups and Theorist and Pragmatist were the least dominant learning styles. However, there were significant differences between the groups when the learning style scores were compared. The learning style scores showed that VR designers had the following order of preference; Reflector, Theorist, Pragmatist and Activist. The order for the VR design students was Activist, Reflector, Theorist and Pragmatist. The VR student group had higher scores for the Activist learning style than the other three styles, and were significantly higher than for Theorist or Pragmatist. The VR designer group had the highest scores for the Reflector learning style and the lowest scores for the Activist learning style. The VR designers' scores were significantly lower than for the Reflector or the Theorist learning styles, although not for the Pragmatist learning style. Distributions of scores were very different for VR designers and VR design students. A distribution of the VR design students' scores gave a normal type of distribution whereas the distribution of VR designers' scores gave three distinct groupings, one in the top range, one in the middle and one in the lower end of the range.

Do VR designers and students have learning styles representative of the general student population?

The designer data was also compared with appropriate population norms. Honey and Mumford (1992) have published a number of such norms for different occupations. This data is now quite old, but more recent data was not available for comparison. General population norms were used for comparison as there are no norms for designers or computer programmers,. These are likely to represent those who might become users of VR as part of a training programme at work.

Interestingly, the data showed that the VR designer group were quite similar in most styles except that for Activist. The results in this study showed that VR designers had slightly higher scores in the top bands and slightly lower scores in the bottom bands. This supports the idea that the VR designer group consisted of participants who had some very high Activist preferences or very low Activist preferences. A comparison of VR design students with the general population shows that the VR design students have higher scores across nearly all the bands, only the top band of the Reflector learning style was not higher and this was the same as the general population.

The norms for VR designers and VR design students were also compared to the general student population. It is not clear in the literature as to how the data was compiled and the age range of the participants; therefore it is an assumption that this data represents a typical higher education population, similar to that of the VR design students. Differences were found in the data for the general student norms and for both the VR designers and VR design students in this study. VR designers' scores were higher for both Pragmatist and Theorist for most of the bands. They were more similar for the Reflector learning style but were much lower for the Activist learning style than the general student population. VR design students' scores were found to be lower across all bands, perhaps with the exception of the top bands for Reflector, which were about the same. This indicates that whilst the VR design students had Activist as their dominant learning style and also had the highest learning scores for the Activist learning style, when compared with the general student population, there norm bands were slightly lower.

The data suggests that whilst the data, at first, seemed to suggest that the Activist learning style was a dominant learning style for the participants in this group, their scores were found to be mostly lower than for those of the general student population, although higher for the general population.

Since there are differences in scores between VR designers, VR design students, the general population and the general student population, this may cause problems in the design of learning media, as the literature suggests that learning occurs best when the learning styles of the teacher/designer match those of the student (Cordell, 1991; Felder, 1993). The mismatch is especially problematical for young pupils and those of low ability who are finding the task difficult to understand (Atkinson, 2001). Overall it seems that the Honey and Mumford norms showed that the general population is less Activist than the participants in this study, but the general student population is more Activist. If VR is an active type of learning environment then it may well appeal to the general student population more than the general population. There are enough participants in this study to show that Activist and Reflector learning styles will be matched, but there may be a problem for Theorists and Pragmatists. These styles do not seem to be evident in either of the groups. VR does not seem to cater for the Theorist learning style, but might suit a Pragmatist learning style if there were practical problems to carry out within its design. More research is needed in this area to clarify these issues further, as also suggested by Mills and de Araújo (1998).

VR learning media, designed for older student populations, is likely to match the learning styles of the VR designers than the VR design students. On the other hand, the VR design students were more likely to match those of the traditional student population. One of the possibilities for this may be the fact that the ages within each group were different. The VR designer group had a mean age that was higher than that of the VR student group and it is likely that the general population would have a similar higher mean age. The differences in the results may be explained by age rather than any preference for VR design.

Age Differences

The literature research supports the view that traditional (younger) student populations tend to be more Activist than other populations. Shelbourn et al (1998) claimed that many young people come out strongly as Activists. There was a range of ages within each of the two groups although the VR designer group was clearly an older group. One study (Cameron and Treagust, 1997) showed similar results amongst a group of occupational therapy students who had a strong preference for the activist learning style with reflector learning style being second preference. Reflector was similarly the second preferred learning style for VR design students. Another study (Penn-Edwards, 1999) looked at learning styles of 49 students and found that the group consisted of mainly activists (49%) and reflectors (27%).

It is possible therefore, that the Activist style is linked, not with VR, but with age, the young VR designers being more Activist than the older designers. This seems to be confirmed by the analysis of the mean ages for each learning style, which suggested that the Activist learners were slightly younger than for the other learning styles. In this study the youngest mean was for Pragmatist but the data may not be reliable as there was only one Pragmatist and it may have been a coincidence that this person was the youngest member of the group. Within the VR student group, the youngest members were either Activist or Reflector. A correlation analysis supports this view in that it showed that there was a significant negative correlation between age and the Activist learning style. There were also significant positive correlations between age and the Pragmatist and Theorist learning styles. In both samples the older participants tended to have a Theorist learning style. It is not clear from this study if older VR designers and VR design students tend to have a Theorist learning style; or perhaps Theorists might get attracted to VR as they get older.

Learning Media Design

In a preliminary study cited by O'Conner (1997), the results had suggested that both traditional (25 years and below) and non-traditional students (aged over 25 years preferred hands-on learning activities (a form of active learning) as their favourite teaching tool. VR as an active type of learning media would be considered a suitable tool to use, therefore, for both traditional and non-traditional types of learners. This study has shown that VR does attract designers with slightly higher Activist scores than the general population although not as high as younger students. These designers would be able to understand the needs of Activist learners and develop truly interactive and participatory VR learning environments. However, this study shows that VR designers and students also have a large number of Reflector types which are considered the opposite to Activist in that they are the passive, sit back and reflect learners. It is likely they will be able to design active worlds that enable learners to do this. One of the ways is to build a world with little interactivity and pre-programmed fly-throughs. The learner sits back and watches the VR world unfold. This is more like a 3D visualisation. Another method would be to let Reflectors watch the Activists and learn from their actions.

The Pragmatist and Theorist learning styles are not really dominant within either sample and learners with these styles may have problems using virtual reality, as their needs might not be met. The Theorist tends to prefer to make conclusions from observations about principles and concepts (Honey and Mumford, 1992) and again this may be possible if they VR is used as a 3D visualisation tool, which provides information that can be observed by the theorists. However, these theorists might not be persuaded to take part in the experiential activities.. Pragmatists tend to like job-related activities and like to draw up plans of action (Honey and Mumford, 1992). Pragmatists may benefit from trying out new ideas to see if they work in practice. This could be done by using VR as a simulation tool which incorporates 'what if' scenarios or more practical problems that can be related to a real-world situation. However, there needs to be more research to investigate this further.

One negative possibility from the Reflective results is that this may be the reason why some of the VR worlds seem to be lacking in interactivity. It may be that the Reflective types are not interested in programming for interaction and tend to prefer designing the 3D objects and worlds to look realistic and maybe include some movement, but without full interactive participation for users. Reflector type designers are probably more likely to produce programmed 'fly-throughs' where the viewpoint is pre-programmed to move along a certain path, and the user is not active. This technique would not really suit the Activist types who want to be able to explore and manipulate the VR world in order to learn from their experiences. Ideally both options should be available within the software in order for it to appeal to both Activist and Reflector learning types.

The literature seems to suggest that VR can appeal to a large group of students, who have different learning styles. Studies carried out by Byrne (1993) have shown that whilst the literature suggest a difference in computer usage for groups of students with different learning styles, this has not been the case and she summarises that whilst it cannot be expected that VR would be liked by everyone, experience suggests that a very high percentage of learners do like to use it. However, the students had not used VR before and found it a novelty. They also did not use it for long periods of time. This is an interesting area of research and more studies need to be carried out to ensure that VR is really suitable for different types of learners. The results of this study need to be incorporated into the general design model presented in Chapter 5 and this will be discussed in Chapter 10 of this thesis.

CHAPTER 8: STUDY 3 – COMMUNICATION/LEARNING STYLES

8.1 Introduction

In the field of VR, Ellis (1995) suggested that VR could only become a successful learning interface if it was designed to provide an effective communication channel between the simulation and the user. This means that VR has to match the different ways that the user communicates with information or else it is likely only to meet the needs of those users who have matching preferences. There is no literature to indicate how VR is likely to communicate with the users and more information is needed to consider the ways that people perceive and process information in VR worlds. Jung's theoretical ideas seems to suggest that individuals have preferences in the way that they communicate and Myers and Briggs have developed a questionnaire that can determine these preferences. Chapter 4 of this thesis discussed the use of this questionnaire with learning. Howe and Sharkey (1998) used this questionnaire with virtual reality learning environments. They suggested that Introvert, Intuition and Perception were the most favourable types for VR learning (see Chapter 4). However, if VR is an active type of learning environment, then Extraverts may be more suited to its use, because extraversion has been linked with active learning (Schroeder, 1993)

8.1.1 Aims of this Study

This study aims to use the Myers-Briggs Type Indicator (MBTI), to investigate the communication styles and learning preferences of VR designers and VR design students. In order to structure the study and the results, the following questions are asked:

(1) Question 1: Is there a dominant MBTI type, overall and for each preference, for VR designers and VR design students?

(2) Question 2: Do VR designers and VR design students have similar communication preferences?

(3) Question 3: Do VR designers and VR design students have similar preferences to other similar occupations or populations?

(4) Question 4: Is there a correlation between any of the Honey and Mumford learning styles and the MBTI types?

8.2 Method

8.2.1 Participants

All participants had volunteered to take the MBTI. They were informed of the aims of this study and were assured that results would be kept confidential. A large number of MBTI questionnaires were handed out to participants; only those that were completed and returned were used in this study.

VR Designers

The participants were 5 females and 19 males who were all VR designers, mainly of desktop VR systems. The age of the group ranged from 22 to 47 years old with a mean age of 35 years and a standard deviation of 8 years.

VR Design Students

The participants were 9 females and 26 males who were higher education students taking either the Virtual Reality third year Module or the MSc Virtual Reality Module. They were of mixed age, ranging from 21 to 55 years old. The average or mean age was 30 years with a standard deviation of 10 years.

8.2.2 Materials

The Myers-Briggs Type Indicator (MBTI) was used in the written self-score format and in the 1987 revised Form G version (Myers and McCaulley, 1985). Copyright laws do not permit a copy to be presented in this thesis.

8.2.3 Procedure

A small pilot study was carried out on a group of 10 multimedia degree students to ensure that the test was being completed correctly. Full instructions were given to all participants. The initial analysis of this sample did not reveal any problems in the administration and was too small to anticipate any outcomes in the results.

The experiment consisted of administering the Myers-Briggs Type Indicator to two groups of participants (independent variable): current VR designers and future VR design students. The questionnaire was a self-report, self-scoring instrument and participants were able to calculate their own scores in order to determine their communication style preferences for each of four bi-polar dimensions (dependent variable). The four preferences combined to produce one of 16 Myers-Briggs Types (independent variable).

Questionnaires were handed out to designers at VR user group meetings and to students in VR module classes. Both groups of participants were given a short introduction about the nature of this research. Participants were asked if they could complete the questionnaire and hand in or post back to the experimenter. Participants were told to complete the questionnaire in their own time and to record their initials or a personal code, age and gender. Full instructions for completing the test were given to the designers and students. All subjects were volunteers and were not forced to complete the questionnaire.

8.2.4 Data Analysis

Learning style preferences and the order of preferences were recorded for each participant. Percentages and means were calculated using *Excel* software and t-tests were carried out using *Minitab* statistical software. Tables and bar-charts, produced in *Excel*, are used to highlight differences between the four communication styles for each group and for MBTI types and patterns. Scores for each learning style were taken and compared directly for differences between groups (dependent measure) for each preference. Percentages of types and various combinations of preferences were compared with general population data given by Myers and McCaulley (1985) and Durling (1996). Scores were then adjusted to take into account the score maxima and compared using paired t-tests to investigate differences within subjects on the independent measure. Age differences in the groups were also discussed as possible factors influencing the results. Correlations were carried out to look at possible associations between the MBTI styles and the Honey and Mumford Learning styles where participants had completed both questionnaires.

8.3 Results

8.3.1 Dominant MBTI Types

The number of designers and students were recorded for each of the 16 types and the percentages of each type were calculated and can be seen in Table 8.1. General UK population figures are taken from Durling (1996).

Table 8.1 Percentages for each MBTI Type

3 samples	*16 MBTI Types*			
	ISTJ	**ISFJ**	**INFJ**	**INTJ**
	19.1%	15.6%	3.0%	3.3%
UK Population	26.9%	0%	3.8%	26.9%
n=1105	8.6%	2.9%	2.9%	11.4%
Designers	**ISTP**	**ISFP**	**INFP**	**INTP**
n=26	5.0%	6.7%	3.8%	2.1%
VR design students	0.0%	0.0%	7.7%	3.8%
n=35	8.6%	0.0%	5.7%	2.9%
(different font sizes n=	**ESTP**	**ESFP**	**ENFP**	**ENTP**
are used to	4.0%	5.4%	3.7%	3.7%
represent each	0.0%	0.0%	7.7%	3.8%
population)	8.6%	2.9%	14.3%	14.3%
	ESTJ	**ESFJ**	**ENFJ**	**ENTJ**
	9.9%	9.1%	2.3%	3.9%
	11.5%	0.0%	3.8%	0.0%
	5.7%	0.0%	2.9%	8.6%

The UK general population figures showed a predominance of ISTJ types (19.9%) and ISFJ (15.6%). The VR designer sample showed a majority of ISTJ and INTJ types (26.9% for each). The VR design student sample showed a majority of ENFP and ENTP types (14.3% for each). Thus there are possible differences between VR designers and VR design students and between VR design students and the general population. The results will now be analysed in more detail.

8.3.2 Dominant MBTI Preferences

Table 8.2 Percentages for each the 4 MBTI Preferences

	4 MBTI bi-polar preferences			
	I	N	F	P
General	58.6%	25.8%	50.0%	34.4%
Designers	73.1%	57.7%	26.9%	26.9%
Students	42.9%	62.9%	31.4%	57.1%
	E	S	T	J
General	42.0%	74.8%	50.0%	66.2%
Designers	26.9%	42.3%	73.1%	73.1%
Students	57.1%	37.1%	68.6%	42.9%

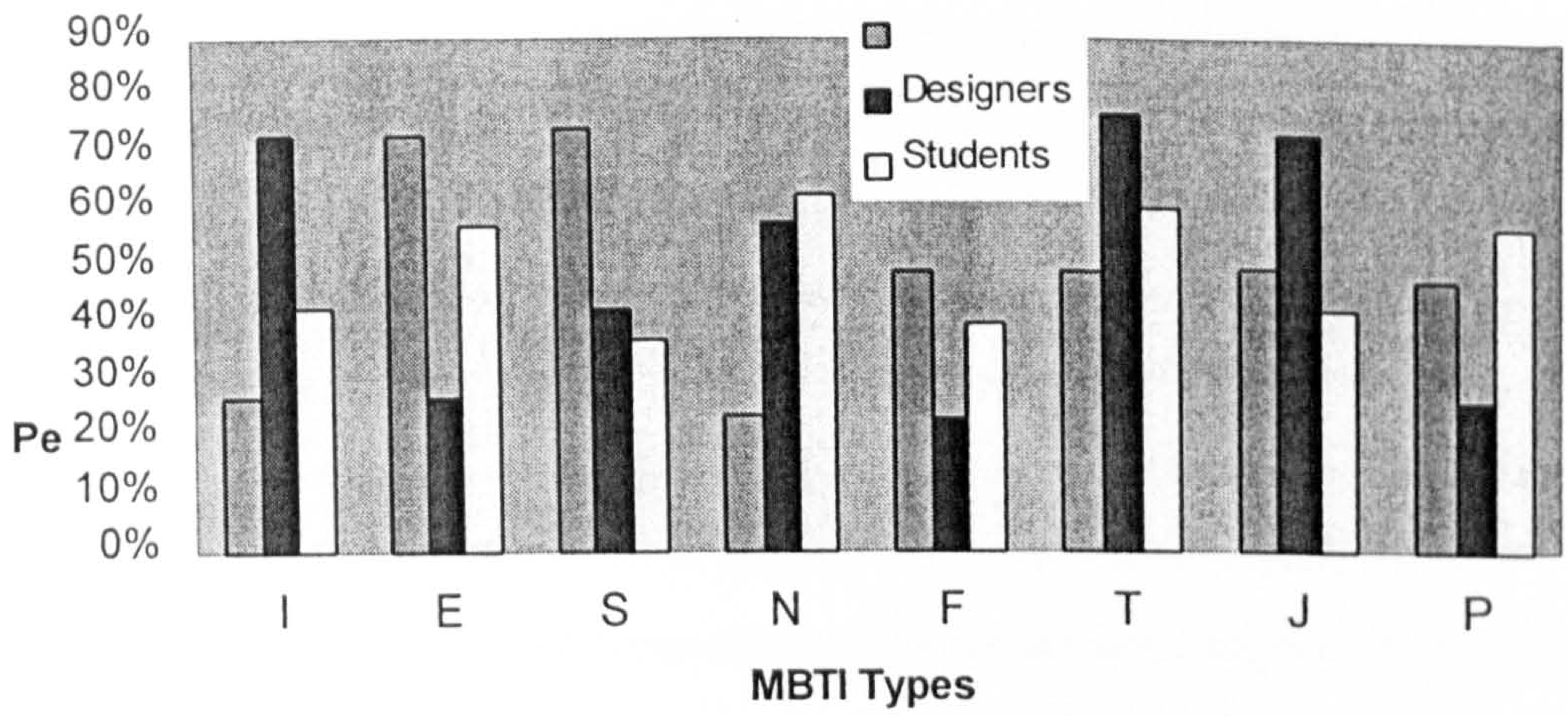

Figure 8.1 Percentage of General Population, Designers and Students for each of the 4 MBTI Preferences

Percentages of participants for each of the four dimensions (I-E, N-S, F-T, and P-J) are shown above in Table 8.2 and visually in Figure 8.1.

The general population results showed a slight predominance of Introversion types (58.6%) rather than Extraversion types (42.0%). The VR designer sample in this study also showed a majority of Introversion types (73.1%); however, the VR design student sample showed a dominance of Extraversion types (57.1%).

The results of the general population showed that there was a clear dominance of Sensing types (74.8%) amongst the general public. Both VR designer and VR design student samples did not show this trend. The designer sample showed a slight predominance of Intuitive types (57.7%) and the student sample showed an even greater majority of Intuitive types (62.9%).

There were equal numbers of Feeling and Thinking types (50%) in the general population results. This is not echoed by the designer group which showed a clear dominance of Thinking types (73.1%) nor the student sample, which had 68.6% of Thinking types.

The general population percentages showed that there were more Judging types (66.2%). This dominance was even more pronounced in the VR designer group (73.1%) but not in the VR design student group (only 42.9%). The VR design student group were mainly Perceiving types.

Overall the majority types for the general population are ISJ with equal T and Fs. The VR designer group were found to be INTJ and the VR design student group were found to be ENTP. These results suggest that VR designers are similar to the general population in that they both have a majority of Introversion and Judging types but are different in that they have iNtuitive types rather than Sensing types. There were also more Thinking types. The VR design student sample was similar to the general population only in that they both had more Judging types. The students were different in that they had more Extraverts, more Perceivers and more Thinkers. The students were also different from the VR designers on two dimensions; they were Extraverts not Introverts and Perceivers not Judgers. They were also similar on two dimensions; they were both iNtuitive and Thinking. These results suggest that iNtuitive and Thinking are the most likely preferences for those individuals who are attracted to VR design.

Statistical analysis was not possible on this type of data; however, by adjusting the scores across the types analysis was possible and this will be discussed later.

Comparison with Howe and Sharkey's Model

Table 8.3 Weightings for the 16 MBTI types (Howe and Sharkey, 1998)

	S		N		
I	ISTJ (5)	ISFJ (4)	INFJ (5)	INTJ (6)	J
I	ISTP (6)	ISFP (5)	INFP (6)	INTP (7)	P
E	ESTP (5)	ESFP (4)	ENFP (5)	ENTP (6)	P
E	ESTJ (4)	ESFJ (3)	ENFJ (4)	ENTJ (5)	J
	T	F	F	T	

Howe and Sharkey (1998) weighted the MBTI types for likely suitability with VR (see Chapter 4 and Table 8.3). The types that were weighted as highly suitable for VR were Introvert, iNtuitive and Perceptive. The type that was weighted as least likely to be suitable for VR was the Feeling preference.

The VR designers in this group were found to be mainly Introverted, iNtuitive, Thinking and Judging types. This suggests that except for the Judging-Perceiving dimension the VR designers are reasonably suited to VR.

The VR design students in this group were found to be mainly Extraverted, iNtuitive, Thinking and Perceiving types. Interestingly this also suggests that the students, whilst not a perfect match, are equally reasonably suited for VR. In this case they do have the Perception preference but do not have the Introversion preference.

The general UK population (Durling, 1996) is Introverted, Sensing, and Judging with equal numbers of Thinkers and Feelers. As a group they are less likely to be suited to VR as they only have suitability in one dimension, that of Introversion.

8.3.3 Dominant MBTI Patterns

The percentages for each pair of dimensions or patterns (Lawrence, 1995) were calculated and are shown in Table 8.4.

Table 8.4 Percentages for each Pair of Dimensions

	16 different pairs of dimensions							
	IN	IS	NF	SF	FJ	TJ	IJ	IP
general	12.2%	46.4%	12.8%	36.8%	30.0%	36.2%	41.0%	17.6%
designers	47.3%	26.9%	23.1%	0.0%	7.7%	65.4%	57.7%	11.5%
students	22.9%	20.1%	25.7%	5.7%	8.6%	34.3%	25.7%	17.1%
	EN	ES	NT	ST	FP	TP	EJ	EP
general	13.6%	28.4%	13.0%	38.0%	19.6%	14.8%	25.2%	16.8%
designers	15.4%	11.5%	38.5%	38.5%	15.4%	7.7%	15.4%	11.5%
students	40.1%	17.2%	37.1%	31.4%	22.9%	34.3%	17.1%	40.0%

The results showed that in the general population there were no strongly dominant (over 50%) paired types or patterns. The most popular were the Introverted-Sensing (IS) patterns with 44.1% approximately of the population and Introverted-Judging (IJ) with 41% of the population. The results of this study showed that there were few of the IS patterns in the designer sample (26.9%) and the student sample (22.9%).

The VR designers exhibited a majority of individuals who exhibited the Introverted-Judging (IJ) pattern (57.7%) although the most popular pattern was TJ or Thinking-Judging (65.4%).

The most popular pattern for the VR design student group was EP or Extraversion-Perceiving (40%), which was not matched by the other populations. They also had a reasonable number of Thinking-Judging (TJ) individuals (34.4%). There was a lack of Sensing-Feeling (SF) types (0%) in the designer group and few Thinking-Perceiving (TP) types (7.7%) and Feeling-Judging (FJ) types (7.7%) when compared to the general population.

The student sample showed no clear predominance (over 50%) of any paired types. The most popular pattern was the Extravert-iNtuition (EN) type (40%) and Extravert-Perceiving (EP) type (40%). There was a lack of Sensing-Feeling (SF) types (5.7%) and Feeling-Judging (FJ) types (8.6%) when compared to the general population (30%).

Overall the main patterns for the designer group were TJ (65.4%) and IJ (57.7%). The main pairs for the student group were EN (40%) and EP (40%). There were some strong differences in percentages between the VR designers and VR design students on the IN, TJ, IJ, EN, TP and EP pair types.

Comparison of Patterns with Schroeder's Model

Using Schroeder's learning model/grid (see Chapter 4) as a basis of analysis, the patterns of ES (concrete active), IS (concrete reflective), EN (abstract active) and IN (abstract reflective) were compared for VR designers and VR design students were compared with each other and the general population. These results can be seen in Figure 8.2.

VR Designers

ES 11%	IS 27%
EN 15%	IN 47%

VR design students

ES 17%	IS 20%
EN 40%	IN 23%

UK Population

ES 28%	IS 46%
EN 14%	IN 12%

Figure 8.2 VR Designers, VR Design Students and UK Population

The results showed that the majority of VR designers are IN types or Abstractive Reflectors. The VR design students are EN types or Abstractive Activists. This contrasts with the UK general population, which is mainly, IS types or Concrete Reflectors. Interestingly, there is some support here for results in the previous study (see Chapter 7), which showed that the VR designers were mainly Reflectors and the VR design students were mainly Activists.

8.3.4 Relationships between MBTI Dimensions

This section looks at the data produced in this study to determine if there are any significant relationships between the different MBTI dimensions. This was done by carrying out a correlation analysis on the adjusted scores.

The MBTI employs weightings and has different score maxima, which means that scores cannot be directly compared with each other. For example, the largest score possible was for Sensing which enabled a maximum score of 34. A maximum of 26 is only possible for females for Extraversion. In order to compare like with like, the scores were adjusted to take into account the different maximums for each type. There is no literature to suggest how this can be done so a pragmatic approach was taken to provide a suitable method. Adjustment of the scores was done by taking the largest maximum and using this as the baseline. Then other scores are adjusted by find their equivalent value on this baseline scale, using simultaneous equations. For example, an Extraversion score of 10 would be equal to 13.077 on the baseline scale:

```
10 / 26 = Y /34      Y = 10/26 * 34       Y or new score = 13.077
```

Adjusted scores were calculated for all individuals (see Appendix 9) and a correlation analysis was carried out to find any significant differences for each group between the MBTI scores.

VR Designers

Table 8.5 Correlations between MBTI Preferences for VR Designers

TYPE	E	I	S	N	T	F	J
I	-0.967** 0.000						
S	-0.483 0.012	0.409 0.038					
N	0.187 0.359	-0.135 0.512	-0.839** 0.000				
T	-0.162 0.431	0.148 0.471	0.265 0.191	-0.367 0.065			
F	0.019 0.927	-0.077 0.708	0.059 0.775	0.122 0.554	-0.781** 0.000		
J	-0.404 0.041	0.325 0.105	0.607** 0.001	-0.676** 0.000	0.583** 0.002	-0.360 0.070	
P	0.264 0.192	-0.198 0.333	-0535** 0.005	0.635** 0.000	-0.538** 0.005	0.374 0.060	-0.940** 0.000

Cell Contents: Pearson correlation
P-Value
** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

A correlation analysis was carried out on the adjusted scores for the VR designer group and the results can be seen in Table 8.5. The results showed that there were highly significant negative correlations between E and I, between S and N, between T and F and between J and P. Since these dimensions were bi-polar opposites of the same dimensions, these results were expected as part of the inherent nature of the MBTI.

The results, however, showed that there were also significant differences between some of the dimensions. Highly significant ($\alpha = 0.01$) positive correlations were found between Judgement and Sensing (p=0.001), between Judgement and Thinking (p=0.002) and between Perception and iNtuition (p=0.000)). This was supported by the highly significant ($\alpha = 0.01$) negative correlations between Judgment and iNtuition (p=0.000), between Perception and Sensing (p=0.005) and between Perception and Thinking (p=0.005).

This suggests that the Judging types also tended to be Sensors and Thinkers rather than iNtuitives and Feelers. Perceptive types tended to be iNtuitives and Feelers.

VR Design Students

Table 8.6 Correlations between MBTI Preferences for VR Design Students

TYPE	E	I	S	N	T	F	J
I	-0.928** 0.000						
S	-0.518** 0.001	0.547** 0.001					
N	0.459** 0.006	-0.529** 0.001	-0.932** 0.000				
T	-0.312 0.068	0.406* 0.016	0.341* 0.045	-0.408* 0.015			
F	0.265 0.124	-0.352 0.038	-0.177 0.308	0.193 0.267	-0.819** 0.000		
J	-0.245 0.157	0.253 0.143	0.079 0.651	-0.133 0.446	0.270 0.117	-0.329 0.053	
P	0.289 0.093	-0.286 0.095	-0.175 0.315	0.195 0.261	-0.400* 0.017	0.471** 0.004	-0.955** 0.000

Cell Contents: Pearson correlation
P-Value
** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

A similar correlation analysis was carried out on the adjusted scores for the VR design student group. There results can be seen in Table 8.6. The results for VR design students showed that there were also several significant differences between different dimensions. Highly significant ($\alpha = 0.01$) positive correlations were found between Extraversion and iNtuition (p = 0.006) and between Introversion and Sensing (p = 0.001). In support of this there were significant negative correlations between Extraversion and Sensing (p = 0.001) and Introversion and iNtuition (p = 0.001). There were also significant (α = 0.05) positive correlations between Introversion and Thinking (p = 0.016) and between Sensing and Thinking (p = 0.045). There was only one support significant negative correlation Thinking and iNtuition (p = 0.015). A significant positive correlation (α = 0.01) was also found for Perception and Feeling (p = 0.004) and a corresponding negative correlation (α = 0.05) for Perception and Thinking (p = 0.017).

These results indicate that VR design students who are Extraverts are more likely to be iNtuitives than Sensors. The Introverts are more likely to be Thinkers. Perceptive types are more likely to be Feelers than Thinkers.

8.3.5 Differences between MBTI Dimensions

The previous sections have shown that there were a number of differences in preferences, and patterns and types of the VR designers and VR design students. This section presents the results of several t-tests, which were used to determine if any of these differences were significant. Because the two groups had unequal numbers of participants, 2-sample t-tests were used.

Table 8.7 Results of 2-sample t-tests (d.f. = 54)

	95% CI for difference		*T-Value*	*p-value*	*d.f.*	*Significance*
Extraversion	-2.99	3.24	0.08	0.937	54	no
Introversion	-2.6	4.32	0.5	0.620	54	no
Sensing	-3.9	2.67	0.38	0.708	54	no
iNtuition	-4.24	2.24	-0.62	0.538	54	no
Thinking	3.72	9.66	0.455	0.000	54	α = 0.01
Feeling	-4.12	0.89	-1.3	0.200	54	No
Judgement	2.31	9.28	3.34	0.002	54	α = 0.01
Perception	-7.88	-1.43	-2.90	0.006	54	α = 0.01

The results showed that there were significant differences (α = 0.01) in the scores for Thinking ($mean_d$ = 15.35, $mean_s$ = 8.66), Judgement ($mean_d$ = 18.31, $mean_s$ = 12.51) and Perception ($mean_d$ = 10.46, $mean_s$ = 15.11) at the α = 0.01 level. This means that the designers had higher scores for Thinking and lower scores for Perception when compared with the students.

8.3.6 Comparing Data using the CAIUS Model

The results in this study were then summarised and laid out using the CAIUS model type grid or matrix developed by Durling (1996) and discussed in Chapter 4. Shading of the cells represents the percentage of types in that cell, the darker the shading the higher the percentage. Results for the VR designers and VR design students were compared to results given by Durling for the general UK population, for fine artists and for computer programmers. These populations were chosen as possibly being the most likely to be associated with the design of VR software.

<u>VR Designers</u>

ESTJ 11.5%	ISTP 0%	ENTJ 0%	INTP 3.8%
ISTJ 26.9%	ESTP 0%	INTJ 26.9%	ENTP 3.8%
ISFJ 0%	ESFP 0%	INFJ 3.8%	ENFP 7.7%
ESFJ 0%	ISFP 0%	ENFJ 3.8%	INFP 7.7%

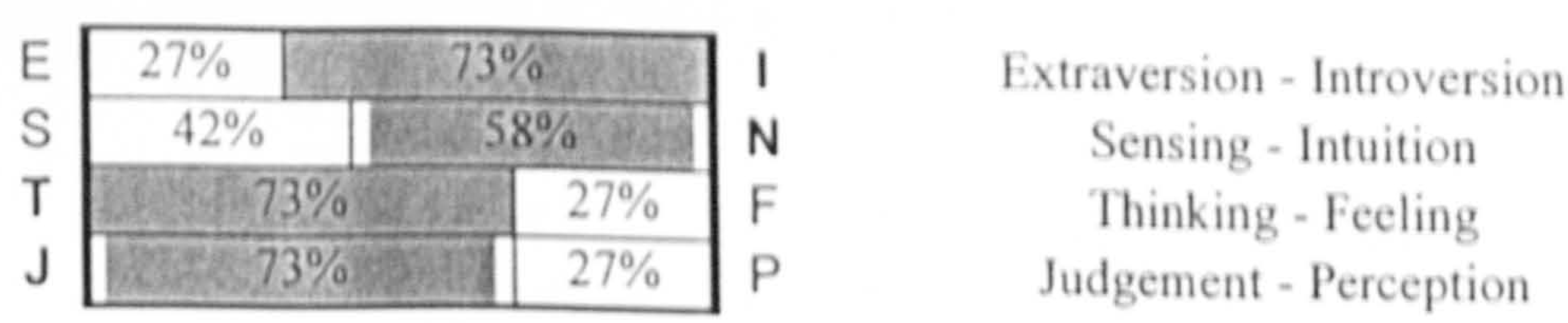

Figure 8.3 Summary Data for VR Designers

The data for VR designers was presented in the form used by Durling and can be seen in Figure 8.3. The results showed that the VR designers tended to consist of types found in the first, second and third column with no types in the second column, which represented a lack of SP types (0%). Two types in particular were strongly represented in this sample, ISTJ (26.9%) and INTJ (26.9%). There were more types in the top half of the grid than the bottom half. The preference data showed that VR designers were strongly Introverted (73%), iNtuitive (58%), Thinking (73%) and Judgemental (73%) types.

VR Design Students

ESTJ 5.7%	ISTP 8.6%	ENTJ 8.6%	INTP 2.9%
ISTJ 8.6%	ESTP 8.6%	INTJ 11.4%	ENTP 14.3%
ISFJ 2.9%	ESFP 2.9%	INFJ 2.9%	ENFP 14.3%
ESFJ 0%	ISFP 0%	ENFJ 2.9%	INFP 5.7%

E	57%	43%	I	Extraversion - Introversion
S	37%	63%	N	Sensing - Intuition
T	69%	31%	F	Thinking - Feeling
J	43%	57%	P	Judgement - Perception

Figure 8.4 Summary Data for VR Design Students

The results for VR design students were similarly presented and can be seen in Figure 8.4. The data showed that there is a more even distribution of types than for the VR designers. The VR design students had a dominance of two types ENTP (14.3%) and ENFP (14.3%) with some INTJ types (11.4%). VR design students tended to consist of Extraverted (57%), iNtuitive (63%), Thinking (Thinking) and Perceptive (57%) types.

General UK Population

ESTJ 9.9%	ISTP 6.0%	ENTJ 3.9%	INTP 2.1%
ISTJ 19.1%	ESTP 4.0%	INTJ 3.3%	ENTP 2.1%
ISFJ 15.6%	ESFP 5.4%	INPJ 3.0%	ENFP 3.7%
ESFJ 9.1%	ISFP 6.7%	ENFJ 2.3%	INFP 3.8%

E	40%	60%	I	Extraversion - Introversion
S	76%	24%	N	Sensing - Intuition
T	50%	50%	F	Thinking - Feeling
J	66%	34%	P	Judgement - Perception

Figure 8.5 Summary Data for General Population (Durling, 1996)

The results in Figure 8.5 show that the general UK population tends to consist of types that are positioned mainly at the left side of the grid. The preference data shows that the popular types are Introverted (60%), Sensing (76%)and Judgement (66%) types. This contrasts with the VR designers who are not Sensing but iNtuitive and with the VR design students who are Extraverted and iNtuitive.

Fine Artists

ESTJ 0.8%	ISTP 0%	ENTJ 8.8%	INTP 10.5%
ISTJ 1.7%	ESTP 0.8%	INTJ 7.0%	ENTP 0%
ISFJ 2.6%	ESFP 0%	INFJ 16.7%	ENFP 14.0%
ESFJ 1.7%	ISFP 0.8%	ENFJ 12.3%	INFP 21.9%

E	34%	66%	I	Extraversion - Introversion
S	8%	92%	N	Sensing - Intuition
T	30%	70%	F	Thinking - Feeling
J	52%	48%	P	Judgement - Perception

Figure 8.6 Summary Data for Fine Artists (Durling, 1996)

Data for Fine Artists was presented by Durling (1996) and can be seen in Figure 8.6 below. There is a strongly uneven distribution of types with most of them in the bottom right quadrant of the grip. The Fine Arts students tended to consist of INFP types (21.9%) with INFJ the second popular type (16.7%). This data also shows that Fine Artists tend to consist of Introverted, iNtuition, Feeling types. Fine artists show some similarity to VR designers and VR design students in that they both have preferences for iNtuition. They are also different in that they are Feelers rather than Thinkers. Fine Artists and VR designers also share a preference for Introversion.

Computer Professionals

Computer Professionals data was presented by Durling (1996) and can be in Figure 8.7.

ESTJ 9.2%	ISTP 5.2%	ENTJ 8.4%	INTP 12.1%
ISTJ 22.6%	ESTP 2.1%	INTJ 15.5%	ENTP 5.6%
ISFJ 3.9%	ESFP 0.7%	INFJ 2.7%	ENFP 3.4%
ESFJ 1%	ISFP 1.6%	ENFJ 2.4%	INFP 3.6%

E	43%	57%	I	Extraversion - Introversion
S	46%	54%	N	Sensing - Intuition
T	81%	19%	F	Thinking - Feeling
J	66%	34%	P	Judgement - Perception

Figure 8.7 Summary Data for Computer Professionals (Durling, 1996)

These figures show that Computer Professionals tend to consist of Introverted (57%), iNtuition (54%), Thinking (81%) and Judgement (66%) types. These results are extremely similar to the VR designer group, but not the VR design student group. There is an uneven distribution of types with most types being situated at the top of the grid. The computer professionals had a clear dominance of ISTJ types (22.6%) with INTJ types coming second (15.5%).

Design Students

ESTJ 4.2%	ISTP 2.8%	ENTJ 9.9%	INTP 5.4%
ISTJ 1.4%	ESTP 2.8%	INTJ 5.6%	ENTP 26.8%
ISFJ 1.4%	ESFP 7%	INFJ 2.8%	ENFP 15.5%
ESFJ 0%	ISFP 1.4%	ENFJ 5.6%	INFP 7%

E	72%	28%	I	Extraversion - Introversion
S	21%	79%	N	Sensing - Intuition
T	59%	41%	F	Thinking - Feeling
J	31%	69%	P	Judgement - Perception

Figure 8.8 Summary Data for Design Students (Durling, 1996)

The results shown in Figure 8.8 show that design students tend to consist of Extraverted, iNtuition, Thinking and Perception types. This is exactly the same as for the VR design students in this study. There is an uneven distribution of types with most types being situated at the right of the grid similar to the Fine Artists. The design students had a clear dominance of ENTP types (26.8%) with ENFP types coming second (15.5%). This data suggests that VR design students and design students are similar in preferences.

High School Students

As the data for VR design students and design students were similar, there was a possibility that this might represent the fact that both were student populations rather than VR or design students. Unfortunately data for general student populations could not be found. Data was available for general High School Students and this was used to see if there were also similarities between the designers, students and a possible younger VR user group

ESTJ 15.7%	ISTP 5.1%	ENTJ 6.7%	INTP 6.0%
ISTJ 8.2%	ESTP 7.7%	INTJ 4.7%	ENTP 7.9%
ISFJ 4.0%	ESFP 6.4%	INFJ 2.1%	ENFP 7.1%
ESFJ 6.5%	ISFP 4.4%	ENFJ 3.5%	INFP 4.2%

E	62%	38%	I	Extraversion - Introversion
S	58%	42%	N	Sensing - Intuition
T	62%	41%	F	Thinking - Feeling
J	65%	35%	P	Judgement - Perception

Figure 8.9 Summary Data for High School Students

The results shown in Figure 8.9 show that college students tend to consist of Extraverted, Sensing, Thinking and Judgement (ESTJ) types. This is different from both VR design students (ENTP) and design students (ENTP). The student populations all shared a preference for Extraversion and for Thinking. They differed in that the design and VR design students were both mainly iNtuitive and Perceiving whereas the High School students were mainly Sensing and Judging.

8.3.7 Correlation with Honey and Mumford Learning Styles

Data for Honey and Mumford Learning styles in the previous study was compared with the data for VR designers and VR design students from this study for those participants who had completed both questionnaires. All of the twenty-six VR designers had completed both questionnaires. Only twenty-seven VR design students had done so.

The correlation analyses were divided into two parts for easier presentation. The four Honey and Mumford learning styles, Activist, Pragmatist, Reflector and Theorist were correlated with the first four MBTI preferences, E (Extraversion), I (Introversion), S (Sensing) and N (iNtuition) and then with the second MBTI preferences T (Thinking), F (Feeling), J (Judgement) and P (Perception).

VR Designers

Table 8.8 Correlations for Honey & Mumford and first 4 MBTI Styles (designers)

TYPE	Activist	Pragmatist	Reflector	Theorist
E	0.457 0.019*	0.054 0.793	-0.314 0.118	-0.422 0.032*
I	-0.514 0.007**	-0.024 0.906	0.250 0.218	0.375 0.059
S	-0.391 0.048*	-0.003 0.988	0.616 0.001**	0.397 0.045*
N	0.360 0.071	0.098 0.635	-0.658 0.000**	-0.375 0.059

Cell Contents: Pearson correlation
P-Value
*** correlation is significant at the 0.01 level(two-tailed)*
** correlation is significant at the 0.05 level(two-tailed)*

The first part of the correlation analysis results for the twenty-six VR designers who completed both questionnaires can be seen in Table 8.8. These results showed several significant correlations. There was a positive correlation (0.457) between Activist and Extraversion ($p = 0.019$) which was significant at the $\alpha = 0.05$ level and a corresponding negative correlation (-0.514) between Activist and Introversion ($p = .007$) which was significant at the $\alpha = 0.01$ level.

There was a significant ($\alpha = 0.05$) negative correlation between Theorist and Extraversion (-0.422, p=0.032) although no significant corresponding correlation between Introversion and Theorist. There were no significant correlations between Reflector and Extraversion or Introversion or Pragmatist or and either Extraversion or Introversion.

The Activist learning style was also significantly ($\alpha = 0.05$) correlated in a negative direction (-0.391, $p = 0.048$) with the Sensing style but there was no significant correlation with the corresponding iNtuition style. There were significant positive correlations ($\alpha = 0.01$) for both the Sensing and the Reflector styles and the iNtuition and Reflector styles. There was also a significant (α = 0.05) positive correlation between Sensing and Theorist (0.397, p = 0.045) but the corresponding negative correlation between iNtuition and Theorist was not quite significant (p = 0.059). There were no significant correlations between Sensing or iNtuition and the Pragmatist learning style.

Table 8.9 Correlations for Honey & Mumford and second 4 MBTI Styles (designers)

TYPE	Activist	Pragmatist	Reflector	Theorist
T	-0.402 0.042*	0.064 0.756	0.229 0.260	0.450 0.021
F	0.466 0.016*	-0.074 0.719	-0.179 0.381	-0.339 0.090
J	-0.476 0.014*	0.116 0.572	0.742 0.000**	0.822 0.000**
P	0.426 0.030*	-0.019 0.927	-0.771 0.000**	-0.812 0.000**

Cell Contents: Pearson correlation
P-Value
** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

The second correlation analysis results for the twenty-six VR designers can be seen in Table 8.9. These results also showed several significant correlations. There was a negative correlation (-0.402) between Activist and Thinking (p = 0.042) which was significant at the alpha = 0.5 level. There was a corresponding positive correlation 0.466) between Activist and Feeling (p = 0.016) which was significant at the α = 0.05. There were no other significant correlation between Thinking and Feeling and any other Honey and Mumford leaning style.

There were also significant correlations for Judgement and Perception and for all Honey and Mumford learning styles except for Pragmatist. There was a significant negative correlation (-0.476) between Activist and Judgement (p = 0.014, α = 0.05) and a corresponding positive correlation (0.426) between Activist and Perception (p = 0.03, α = 0.05). There was also a very significant positive correlation (0.742) between Reflector and Judgment (p = 0.000, α = 0.01) and a corresponding negative correlation (-0.771) between Reflector and Perception (p = 000, α = 0.01). There was also a very significant positive correlation (0.822) between Judgement and Theorist (p = 0.000, α = 0.01) and a corresponding negative correlation (-0.812) between Perception and Theorist (p=.000, α = 0.01).

Overall the results for the VR designers suggested that Extraversion was positively correlated with the Activist (significant) and the Pragmatist (not significant) and negatively correlated with Theorist (significant) and Reflector (not significant). The opposite results were found for Introversion with the negative correlation between Introversion and Activist being significant.

The Sensing preference was positively correlated with the Reflector (significant) and Theorist (significant) learning styles but negatively correlated with the Activist (significant) and Pragmatist (not significant) learning styles. The iNtuition preference was associated in the opposite direction, with the negative correlation between iNtuition and Reflector being significant.

The Thinking preference was found to be positively correlated with Pragmatist (not significant), Reflector (not significant) and Theorist (not significant). It was found to be significantly negatively correlated with the Activist learning style. The opposite was found for Feeling with the positive correlation with the Activist learning style also being significant.

The Judging preference was found to be positively correlated with the Pragmatist, Reflector and Theorist learning styles with only the Pragmatist relationship not being significant. There was a significant negative correlation between Judging and the Activist learning style. Corresponding correlations were found for Perception with only the Pragmatist – Perception correlation being not significant.

VR Design Students

Table 8.10 Correlations for Honey & Mumford and first 4 MBTI Styles (students)

TYPE	Activist	Pragmatist	Reflector	Theorist
E	0.564 0.002**	0.144 0.473	-0.487 0.010**	-0.315 0.110
I	-0.539 0.004**	-0.102 0.614	0.379 0.051	0.291 0.141
S	-0.442 0.021*	-0.131 0.513	0.209 0.296	0.170 0.397
N	0.444 0.020*	0.025 0.902	-0.180 0.370	-0.249 0.210

Cell Contents: Pearson correlation
P-Value
** correlation is significant at the 0.01 level(two-tailed)
* correlation is significant at the 0.05 level(two-tailed)

The first part of the correlation analysis results for the 27 VR design students who completed both questionnaires can be seen in Table 8.10. These results showed several significant correlations. There was a positive correlation (0.564) between Activist and Extraversion (p = 0.002) which was significant at the α = 0.01 level. There was a corresponding negative correlation (-0.539) between Activist and Introversion (p=0.004) which was significant at the α = 0.01 level. There was a significant (α = 0.01) negative correlation between Reflector and Extraversion and a positive correlation between Reflector and Introversion although this was just not quite significant (p = 0.051). There were no significant correlations between Extraversion, Introversion, Pragmatist and Theorist. The Activist learning style was also significantly (α = 0.05) correlated in a negative direction (-0.391, p = 0.048) with the Sensing style and there was a significant positive correlation (p = 0.020, α = 0.05) with the corresponding iNtuition style. There were no significant correlations between Sensing or iNtuition and the Pragmatist, Reflector or Theorist learning styles.

Table 8.11 Correlations for Honey & Mumford and second 4 MBTI Styles (students)

TYPE	Activist	Pragmatist	Reflector	Theorist
T	-0.133 0.508	0.410 0.034*	-0.009 0.965	0.347 0.076
F	0.195 0.330	-0.267 0.179	0.015 0.381	-0.313 0.112
J	-0.431 0.025*	0.355 0.069	0.462 0.015*	0.642 0.000**
P	0.393 0.043*	-0.378 0.052	-0.408 0.035*	-0.611 0.001**

Cell Contents: Pearson correlation
P-Value
** correlation is significant at the 0.01 level
* correlation is significant at the 0.05 level

The second part of the correlation analysis results for the VR design students can be seen in Table 8.11. These results also showed several significant correlations. There was a positive correlation (0.410) between Thinking and Pragmatist (p = 0.034) which was significant at the α = 0.5 level. There were no significant correlations between Thinking and Sensing and Activist, Reflector and Theorist learning styles.

There were significant correlations for Judgement and Perception for all learning styles except for Pragmatist. There was a significant negative correlation (-0.431) between Activist and Judgement (p = 0.025, α = 0.05) and a corresponding positive correlation (0.393) between Activist and Perception ($p = 0.043$, $\alpha = 0.05$). There was also a significant positive correlation (0.462) between Reflector and Judgement ($p = 0.015$, $\alpha = 0.05$) and a corresponding negative correlation (-0.408) between Reflector and Perception ($p = 0.035$, $\alpha = 0.05$). There was also a very significant positive correlation (0.642) between Judgement and Theorist ($p = 0.000$, $\alpha = 0.01$) and a corresponding negative correlation (-0.611) between Perception and Theorist ($p = 0.001$, $\alpha = 0.01$).

Overall the results for the VR design students suggest that Extraversion was positively correlated (significant) with the Activist learning style and the Pragmatist learning style (not significant). Extraversion was negatively correlated with Theorist and Reflector. The opposite results were found for the Introversion with the negative correlation between Introversion and Activist being the only significant one.

The Sensing preference was found to be positively correlated with Reflector and Theorist and negatively correlated with Activist (significant) and Pragmatist. Opposite correlations were found for Introversion with the positive correlation between Activist and Introversion being significant.

The results showed that the Thinking preference was positively correlated with Pragmatist (significant) and Theorist and negatively correlated with Activist and Reflector. Opposite correlations were found for Feeling but none was significant.

The Judging preference was found to be positively correlated with Pragmatist, Reflector (significant) and Theorist and negatively correlated with Activist (significant). Opposite correlations were found for the Perception preference and all were significant except for Pragmatist.

Interestingly the direction of all but one of the correlations was found to be identical for both groups in all correlations. That is, if a particular correlation was positive for one group, it was also positive for the other group and vice versa. The only difference was that for VR designers the Thinking preference was positively correlated with Reflector but for VR design students it was a negative correlation. However, neither of these results was significant.

8.4 Discussion

The VR designers in this study were found to comprise of Introverted (73%), iNtuitive (57.7%), Thinking (73%), Judging (73%) or INTJ types. The VR design students comprised of Extravered (57%), iNtuitive (63%), Thinking (69%), Perceiving (57%) or ENTP types. This data is represented visually in Figure 8.10.

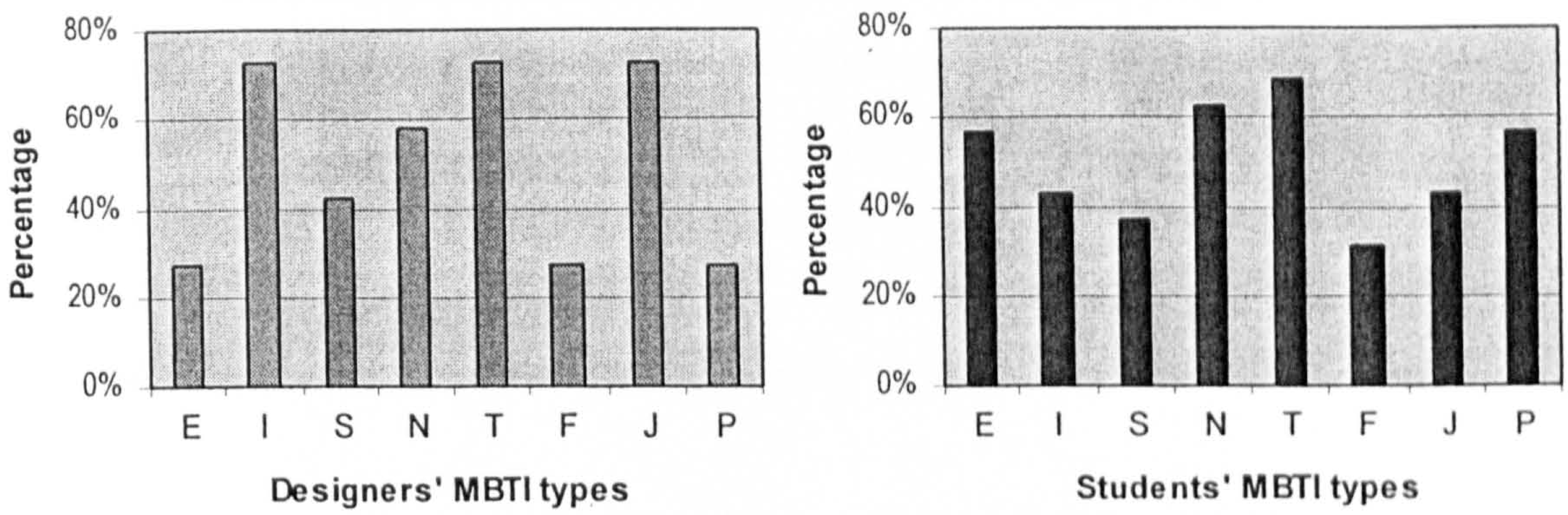

Figure 8.10 MBTI types for VR Designers and VR Design Students

The main objectives of this study were to investigate the communication/learning style preferences of VR designers and VR design students. Four specific questions were asked and these will now be addressed.

Is there a dominant MBTI type, overall and for each preference, for VR designers or VR design students?

The results discussed in this chapter suggested that VR designers tended to consist of two main MBTI types, ISTJ and INTJ. This contrasted with the VR design student sample, which showed that the two main types were ENTP and ENFP. The UK general population was shown to have ISTJ and ISFJ as its two most popular types.

ISTJ and INTJ types are considered to the types more representative of computer programming professionals (Myers and McCaulley, 1985; Tognazzini, 1992) and it reflects the fact that many of the VR designers are programmers or need computer-programming skills in order to create interactivity in the worlds. The ENTP types are more likely to be photographers but can be computer personnel although the ENFP are more likely to be counsellors than programmers (Myers and McCaulley, 1985). The students seem to suggest a more artistic and human-oriented group than the VR designers.

In considering the individual MBTI preferences, both groups scored high on iNtuition and Thinking or the NT pattern. They were different for Introversion-Extraversion and Judging-Perceiving dimensions. This suggests that iNtuition and Thinking might be important learning styles for designing VR software. This combination of attitudes or pattern is known as the logical and ingenious type (Myers and McCaulley, 1985). They tend to prefer intuition for perception and objective thinking for making decisions. They are described as focussing "on possibilities, theoretical relationships and abstract patterns but judge these with impersonal analysis.... They tend to be logical and ingenious. They are best in solving problems within their field of special interest, whether scientific research, mathematics, the more intricate aspects of finance, or any sort of development or pioneering in technical or administrative areas" (Myers and McCaulley, 1985, p 35). As VR could be considered technical and pioneering, there is some possibility that these traits are useful for VR.

Durling replied to an email sent by the author in a discussion at the CYBERG conference in 1996 (on-line email not currently available). He highlighted the fact that in terms of learning preferences, Introversion seemed to suit those who like privacy, working alone, reading books and for whom a capacity to concentrate over long periods is natural. CAL was a perfect type of learning medium for Introverts. However, he admitted that the CAIUS model did not address adequately the design of CAL for Extraverts and suggested that VR had the potential to provide these needs. This is only likely, however, if the worlds are created to allow for users to discuss their thoughts with other people.

Both groups had the TJ pattern or Thinking-Judging. Amongst the MBTI patterns TJ and IJ were the most popular for the VR designer group and NT TJ and TP were the most favoured in the VR design student group. This suggests that a mixture of Thinking and Judging might be important learning styles to have for the design of VR software. Individuals with the TJ pattern are described as the logical decision makers. "They are tough-minded, executive, analytical, and instrumental leaders" (Myers and McCaulley, 1985, p 36). However, this does not really describe the type of person that seems suitable for the design of VR.

Do VR designers and VR design students have similar communication preferences?

As just discussed, there were some strong similarities and some differences between the VR designers and the VR design students. The main similarity is that both groups have the NT pattern. This means that both groups like to deal with abstract concepts and make decisions in a logical and impersonal manner (Myers and McCaulley, 1985). Interestingly this pattern includes, photographers, computer analysts, computer programmers and artists in its top ten of likely careers (Myers and McCaulley, 1985). The main differences in MBTI preferences were that the VR designer group was Introverted and Judging whereas the VR design student group was more Extraverted and Perceiving. The IJ pattern is described as the Decisive Introverts and the EP pattern as the Adaptable Extraverts. They do suggest that the designers are more likely to work and make quick decisions independently of others (Myers and McCaulley, 1985). The students are more likely to discuss issues with others and want to work in groups, taking a long time to come to a decision.

Overall the VR designer group was INTJ and overall the VR design student group was ENTP. Lawrence (1995, p 69) suggests that INTJ types related well to learning strategies such as "Can be global or linear learners (NJ), wants to consider theory first, then applications (N), enjoys working alone (I), prefers open-ended instruction (N) and were good at paper-and-pencil tests (NT). This contrasts with the kind of instructional strategies preferred by the VR design student group. Lawrence (1995, p 69) suggests that ENTP types are " global learners needing choices and deadlines (NP), like autonomy (NP), like seminars (EN), like reading and listening (N), want to consider theory, then applications (N), are good at paper-and-pencil tests (NT) and prefer open-end instructions (N)".

Do VR designers and VR design students have similar preferences to other similar occupations or populations?

The VR designer group had a strong preference for Introversion rather than Extraversion which was similar to the UK general population, however to a much larger extent. This contrasted with the VR design student group, which consisted of slightly more Extraverts than Introverts. The results suggest that the VR designers are less likely to consider the multi-user aspects of VR, as they prefer to be independent learners. Whilst this might be suitable for a UK population who do tend to be more introverted, it is a problem for Extravert people who wish to discuss ideas when learning. Interestingly it has been found that the US population and school children tend to be more Extravert (Myers and McCaulley, 19985) and these types would prefer to have communication with other users.

The VR designer group also showed a strong preference for iNtuition rather than Sensing, which is totally opposite to the general population, which has a majority of Sensing types.

The VR design student group showed a tendency to be slightly more iNtuitive than the general population but less than the VR designers. This suggests that both groups were more interested in finding meanings and relationships in information and are not always good at memorising facts or concerned with details. This may cause a problem for Sensing types who might need more details in the VR worlds in order to learn successfully.

The general population tends to have equal numbers of Feeling and Thinking types but this balance was not shown in either of the groups in this study. Both VR designers and VR design students were found to have a large majority of Thinking types. Feeling types are more subjective in decision-making and tend to prefer people-centred learning environments (Durling, 1996). There may be a problem in teaching Feeling types if Thinking types design the material. This is discussed further, later in this chapter.

The general population in the UK has a tendency to have more Judging than Perceiving types. This tendency was found to be even stronger in the VR designer group but the VR design student group has slightly more Perceiving types. Judging types are more likely to make quick decisions than Perceiving types and this is probably a necessary skill when working to tight deadlines in job situations than in an academic environment, so this might explain the differences in the groups. However, Sharkey and Howe (1998) suggest that Perceptive or Perceiving types would be more suited to a VR environment as they give this learning style a high rating. It might be that Perceiving types are more likely to wander around the worlds taking in information than the Judging types who would like relevant information presented quickly. Judging designers may have a problem in only designing relevant information, i.e. only creating interaction for some of the objects, which might cause frustration for the Perceiving types who wish to explore more and interact with many other objects in the world.

Both the VR designers and the VR design students showed a tendency to be iNtuitive and Thinking or NT types. This seems to be a MBTI type pattern that is representative of VR designers and design students. It indicates a preference for preferring to attend to meanings rather than details and to make logical decisions rather than to use subjective values. However, the VR designers tended to be more IN or abstract reflective types whereas the VR design students tended to show an EN or abstract active pattern. This indicates, according to Schroeder (1993), that the VR design students were more active in their profiles, which possibly could be a more suitable profile for designing an active, participatory learning type of learning medium. It also indicates that the IN designers are the thoughtful innovators. "They are interested in knowledge for its own sake, as well as ideas, theory, and depth of understanding. They are the least practical of the types." (Myers and McCaulley, 1985, p 37). The VR design students, being EN, are the action-oriented innovators. "They see possibilities as challenges to make something happen" (Myers and McCaulley, 1985, p 37). The previous chapter also found that VR design students were more Activist in their learning styles than the VR designers, which was found to be linked to age.

The VR designers in this study had INTJ and ISTJ as their dominant MBTI types. These types would score a weighting of 6 and 5 according to the model produced by Sharkey and Howe (1998). These are quite good scores as the maximum is 7 for the INTP type. Although the INTP type has been chosen as the most suitable type for using VR worlds, it is interesting to note that in this study, there were very few INTPs in either of the two groups.

The INTJ type was found to be a dominant type when Tognazzini (1992) looked at Apple computer engineers and designers. He also found that Apple computing professionals were more Introverted than the general population which is supported by the results for VR designers in this study. This strongly suggests that many of the VR designers were probably computer programmers. The INTJ type is someone whose thinking is logical, precise and structured which is very useful for programming, however, it may not be the best type for creating interactive, exploratory types of VR worlds. This type would be good for the programming of such worlds, but the design aspects and the learning content of such an active, participatory world which is not logical and structured would not suit such designers.

The CAIUS grid for computer professionals (Durling, 1996) showed that they tended to be at the top part of the grid which relates to being thing-centred rather than people-centred and being more objective, logical and impersonal. The VR designers however, had some types in the bottom right quadrant, which suggested that some members had a more person-centred, subjective approach to learning. Such types are usually represented in the Fine Artists population and so it seems likely that these results reflect the fact that VR designers are a usually mix of computer programmers and graphics artists. Both skills would be necessary for the design of suitable VR worlds.

The VR design students tended to be mainly ENTP and ENFP. These types would score a weighting of 6 and 5 respectively, using the weightings from the Sharkey and Howe model (see Chapter 4). VR design students had MBTI profiles that also showed a tendency to have types in the top half of the CAIUS grid and the right side, mainly fourth column. This also indicates a mix of computer programmers and fine artists, which reflects the types of students that do take the VR modules. However, the VR design students did not show a tendency for being mainly INTJ and ISTJ as with the VR designers.

Durling (1996) found that his design students had a CAIUS grid profile very similar to Fine Artists with ENTP being the most common type. The VR design students in this study had a grid profile design grid which seemed to incorporate a mix of computer professionals and fine artists as they covered the top half of the grid and the right side of the grid.

More importantly, both VR designers and VR design students showed a lack of types in the bottom left of the CAIUS grid. These types are the SF types, which are quite strong in the general population. It is likely that these types may not be catered for by VR worlds because of the lack of designers with these types. The SF type is the Sensing-Feeling type who is subjective and personalistic and who wants to learn concrete examples, which will lead them to more abstract concepts (Durling, 1996). They are the sympathetic and friendly types and would be more interested in facts and details and come to conclusions based on subjective values and who want to be in situations where their "personal warmth can be applied to concrete situations" (Myers and McCaulley, 1985, p 35). It seems likely that these types would find VR too impersonal unless these worlds were designed with friendly virtual characters with whom they could communicate.

The general population, VR designers, Fine Artists and Computer Professionals all had Introversion as the dominant preference. This was contrasted with the VR design students and the Design students who had Extraversion as the dominant preference. This seems to suggest that age may have an influence on the results as the students tended to have a lower mean age. This supports the research and data in the previous chapter, which suggested that younger people tended to be more Activist in their learning styles. The correlation analysis carried out in this study showed a significant positive correlation with Introversion scores and a significant negative correlation with Extraversion scores. This seems to suggest that older participants were more Introverted. These results were supported by the VR design student data, which also showed a similar direction, but these results were not significant.

Previous discussions have highlighted the differences between VR designers and VR design students, with other design students and with the general population. Data for UK general college or university students was not available, however, Myers and McCaulley do give MBTI types for general US High School students. Their data suggested that college students tended to consist of Extraverted, Sensing, Thinking and Judgement (ESTJ) types. This is different from both VR design students (ENTP) and design students (ENTP) in this study. The student populations all shared a preference for Extraversion and for Thinking. They differed in that the design and VR design students were both mainly iNtuitive and Perceiving whereas the High School students were mainly Sensing and Judging. SJ types both score lower on the Sharkey and Howe model, which suggests that these types may find learning in VR more difficult than the NP types. Myers and Myers (1995) give data for high school and college preparatory students but divide the data for males and females. Their data for female college students showed mainly ESFJ and for males ENTJ. Here the common pattern was EJ, which relates to the Decisive Extraverts who are fast moving, decisive, confident and enjoy making things happen (Myers and McCaulley, 1995). This pattern, however, was not dominant in either the designer or the student groups in this study.

Teaching Styles Mismatch

Piirto (1998) suggests that teachers need to be aware of their own learning types and then they can start to address how to deal with students who have a different type. The S types rely on their senses for understanding and learning but need to be aware that N type students need to rely on their hunches or inner sense. Lawrence (1995) also found that school students tended to be S types but college students tended to be more balanced between S and N. A study by Betkouski and Hoffman (1981) showed that public school teachers in Canada and the US showed the S pattern but Piirto (1998) found that talented college students showed preferences for N types, a clear mismatch with teachers. Schroeder (1993) contended that university lecturers prefer the N or abstract types of students and few favour the S or concrete pattern. University lecturers were found to be mainly N types themselves. Other studies have supported the view that talented students are more N types than S types (Provost and Anchors, 1987). Evidence (Francis, 2000) also suggests that most of the students that drop out of higher education are S types. There is clearly a mismatch in teaching and learning styles, which is hindering the performance of these students. Unfortunately the VR designers group also showed a total lack of S types, which does not bode well for VR being a good medium for teaching these types

Felder (1993) proposed that Sensing types like well-established methods of learning that include a lot of repetition and facts with hands-on laboratory work. It is likely that Sensing types will not appreciate a constructivist approach to learning, as they need more structured methods. They also like courses that have a direct connection with the real world. It is likely that they would prefer VR worlds that closely resemble the world in look, behaviour and feedback where they could carry out 'hands-on' activities. This suggests that these types would need the use of haptic devices, which could enable them to carry out such activities in a realistic way.

Is there a correlation between any of the Honey and Mumford learning styles and the MBTI types?

The results showed many significant correlations between the MBTI and the Honey and Mumford leaning styles (see Chapter 6) for both the VR designers and the VR design students. Of particular interest, though, was the fact that all but one of correlations showed the same direction for both groups. Only one correlation was found to be in the opposite direction for each group.

The Activist learning style was significantly positively correlated with Extraversion, iNtuition (significant for students only), Feeling (designers only) and Perception. This means that Activists tended to also be EP types for both groups, EFP for the designers and ENP for the students. It was significantly negatively correlated with Introversion, Sensing (students only), Thinking (designers only) and Judging. This suggests that Activists tended not to be IJ types for both groups (ITJ for the designers or ISJ for the students).

The Reflector learning style is considered to be the opposite process to the Activist styles (Kolb, 1984; Schroeder, 1993). This style contained one pair of correlations that was the only difference between the two groups. The Reflector style was found to be positively correlated with iNtuition and negatively correlated with Sensing for the designers, but it was the opposite way around for the students. It was significantly positively correlated with Sensing (students only) and Judging. This suggests that Reflectors tended to be J types for both groups, and Sensing types for the students' group. This style was significantly negatively correlated with Extraversion (students only), and Perception. This means that Activists tended also to be Perceiving types for both groups and Extravert for the student group.

The results suggest support for the idea that Extraversion is strongly associated with an Activist learning style and there is an association between Introversion and a Reflector learning style, although not so strong. Schroeder (1993) had proposed that there was an association between Extraversion and Activist learning styles and Introversion and Reflective learning styles. This association was supported by the results in this study.

The Pragmatist learning style was not significantly correlated to any MBTI preference for the VR designer group and was only significantly positively correlated with Thinking in the VR design student group. This suggests that Pragmatists might also be Thinkers.

The Theorist learning style was found to have significant positive correlations with Sensing (designers only) and Judging. It was also found to have significant negative correlations with Extraversion (designers only) and Perception. This suggests that Theorists tend to be Judgers or J types rather than Perceivers or P types for both groups. They also tend to be Sensors and not Extraverts in the designer group.

Overall it was found that for both groups there were strong positive relationships between the Activist learning style and the Extraversion and Perception types. There were strong negative relationships between Activist and Introversion and Judging. These results suggest that if VR is an active type of environment that would suit active types, then it could possibly suit Extraversion and Perception learning styles since these seem to be correlated. These styles were common in the VR design student group but were not common in the VR designer group. It is also suggested that VR would not suit Introverted and Judging types. Unfortunately, these types were found in the VR designer group.

Feeling Types

Possibly one of the more worrying aspects of this study is that there were few feeling (F) types in the VR designer group. The F types are more subjective and value-driven and prefer people-orientated situations (Durling et al, 1996). People who use computers are usually more Thinking (T) or logical and analytical (Durling, 1996) but VR has the potential to include a more people-centred learning medium for these types, which other computer media cannot do. VR in a multi-user form, where other users can all participate in the world together, is able to produce communication between users. Such worlds may be more appropriate for Extroverted-Feeling (EF) types. For Introverted Feeling (IF) types, those who prefer independent study or communication with one or two people, single-user worlds, which contain virtual characters, may well be preferred.

F or Feeling types are considered to be more helpful and people-oriented than the Thinking types (Myers and Myers, 1995). This could be a problem when trying to design and develop VR worlds with appropriate guidance and help systems. Experience of worlds already created has shown a tendency for a lack of good help facilities. In particular Sensing types may need more step-by-step guidance. These types are found in the general population but did not represent a large proportion of the VR designers or students. Further research would be needed to investigate this issue. These types may need more structured help and instructions in order to successfully learn using VR worlds.

Overall a number of patterns have emerged from these results. Although Extraversion was shown to be positively correlated with the Activist learning style, a large number of VR designers do not show this type and may well tend to design VR worlds with little interaction. Further research is needed to clarify this. VR designers seem to have different styles from VR design students, but both have different patterns to the general population. In particular the N type or iNtuition is a common feature and the S pattern is more common in the general population, especially those who do not do well at school and college. These types may well need more structure help and instructions to do well in VR. The NT pattern seems to be the most common pattern for VR design.

This study has revealed a number of communication style patterns that may influence the design of learning worlds. Designers need to be aware of these patterns to ensure that they do not design worlds that reflect only these preferences. The results of this study need to be incorporated into the design model presented in Chapter 5 and details about how this can be done are given in Chapter 10 of this thesis.

CHAPTER 9: STUDY 4 – LEARNING MODALITIES AND HELP

9.1. Introduction

9.1.1 Learning Modalities, Natural Communication and Help Systems

As previously discussed in Chapter 4, help systems need to be designed for the medium as well as for the individual (Sellen and Nicol, 1990). With general computer software this means an on-line system, and with multimedia this means using all the capabilities of its interactive nature and multi-modal features. But there are no guidelines to design a natural VR help system. In the real world, humans obtain information through all their senses but when using a computer it is usually limited to the visual mode (Akamatsu et al, 1993). Learners also have different learning modalities (see Chapter 4) that might also affect their choice of help system. VR is mainly a visual type of medium that favours visual types of learners (see Chapter 4). Use of speech systems and haptic devices would enable VR to appeal to auditory and kinaesthetic learners. Help systems may also be better in the learners' modality preference; however, natural VR systems may be those that tend to mimic the real world, i.e. auditory systems and which are 'within-context' or part of the VR world and therefore enhance the user's sense of presence or immersion.

The questionnaire study in this thesis (see Chapter 6) suggested that VR designers tended to use on-screen text in the form of dialogue boxes as the main form of instructions; however, auditory instructions from a virtual character can increase the sense of presence and the naturalness of communication (see Chapter 2). Dual-coding theory (see Chapter 3) suggests that learning is enhanced if verbal and visual material is presented at the same time. Unfortunately there can be problems with verbal information due to its transient nature. Short-term memory limitations suggest that auditory methods are not good for long instructions as learners find it difficult to remember everything that has been said (Hapeshi and Jones, 1992; Harrison, 1996, Kozma, 1991; McDowd and Botwinick, 1984). There is no research to suggest that this applies to non-auditory learners only.

One of the most natural methods of communication in the real world is that of speech; people ask for help and discuss problems with each other by speaking. Recent advancements in speech recognition systems suggest that users are able to interact with computer devices in a more natural fashion (Johnson et al, 2000). Historically, systems had to undergo lengthy training in order to recognise an individual, each individual had to be trained separately, and users had to be slow and precise with their speech (McGlashan and Axling, 1996). Current systems are now supposed to be speaker-independent and offer continuous speech capabilities with much less training (McGlashan and Axling, 1996). Developments in noise-cancelling microphones have improved speech recognition capabilities (Fitzgerald, 2001). However, Noyes (2001) disagrees with this positive view and argues strongly that current speech technologies still have some serious problems to overcome. In particular, modern speech systems find it difficult to recognise different users without training, and also trained individuals in different environments. It is also necessary for users to say only the commands that are recognised by the system, as there are problems with error recognition handling. It seems that speech recognition systems have serious limitations that can only be overcome at present by constraining the user, which is not very natural (Noyes, 2001).

Even with these limitations there is still a great deal of interest in the development of speech recognition systems for controlling interface design. Such systems are being investigated by NASA and are proposed as suitable interfaces for VR worlds (Fitzgerald, 2001). This interest has led to a new field of design called conversational interfaces. It is envisaged that future technology will be more communication-based and will be small and light enough to be worn by the user. Interaction would be by spoken word (Zue and Glass, 2000). Speech interfaces are being investigated in cars to allow the driver to ask for directions (Graham et al, 1998). In some situations, where the system or task is complex, the user does not directly control the technology, but speaks to an intelligent agent or assistant who then completes the task for the user (Johnson et al, 2000). This new kind of interface is not only used to mediate information but also to establish a relationship with the user.

Use of virtual characters that can communicate with the user via speech recognition and sound systems would seem ideal forms of 3D virtual teachers and would ensure that those learners who had an auditory preference for learning would benefit from such help. Such characters could also provide immediate feedback, which has been shown to enhance learning (Irving and Hunt, 1994) and would not take the student away from the task in hand, another benefit for learning (Shneiderman, 1987). However, Jonassen and Hannum (1987) found that learning improved when learners were able to choose the kind of feedback and help that they received. This suggests that several methods for gaining help in a virtual world should be incorporated in the ideal VR learning environment.

In one study, (Moreno and Mayer, 2001), a VR educational game was used as the basis for teaching college students to learn how to design the roots, stems, and leaves of plants to survive in five different simulated environments. A virtual agent was created to give the students help instructions via on-screen text or via narration. The results showed that the narration condition proved more beneficial for retention and problem-solving tasks than on-screen text.

Addition of artificial intelligence could provide intelligent 3D characters, sometimes called intelligent agents or knowbots (Honavar et al, 2001; Dede, 1992). Complex computer-based systems already have facilities called performance support systems that use intelligence to act as a teacher, helper and advisor (Carr, 1992). The *DIVERSE* speech/VR system incorporates a virtual cartoon character agent that follows the user around the world, always appearing in the bottom right of the screen. The agent had a range of simple body gestures, which could portray its attention state, e.g. facing the user, facing the object that is being manipulated (Karlgren et al, 1995). Dede (1992) reported an application that incorporated simulated humans (knowbots) in a virtual corporation world. The knowbots helped the learner to utilise the range of multimedia material in order to learn how to carry out duties of a software engineer within the company. In this example, the knowbots are limited in their range of communication features; however, other researchers are investigating more complex animations and gestures for such agents in order to provide more realistic communication with the user (Johnson et al, 1999). Avatars will be able to show different emotions in their face to aid communication.

For VR environments to cater for different learning modalities speech as well as written material is necessary, but ideally haptic devices are also needed to cater for kinaesthetic and tactile learners. Overall the studies suggest that speech recognition systems, although still limited in use, are still being developed as more natural interface devices for the future. However, for VR worlds to employ more natural forms of communication and help systems, speech recognition needs to be implemented. At present only prototype solutions have been found but no research, as yet, has actually measured the effects of even limited recognition systems on the learning performance of VR environments. Such research needs to be carried out.

9.1.2 Aims of this Study

This study will firstly determine the learning modalities of both current VR designers and VR designer students using the Learning Styles Questionnaire (see Appendix 10) in order to correlate their choice of help system with their preferred learning modality. An experiment will be undertaken to investigate preferences for voiced or text help instructions within a virtual learning environment and correlate these with the learning modality results. The voiced instructions incorporate a female voice and differences between genders will be analysed in case this affected the results. Finally, an experiment was carried out to investigate the possibility of developing a simple speech recognition interface with a desktop VR world, in order to provide two-way natural communication between user and virtual characters.

Three main questions were formulated for the study:

(1) Question 1: Is there a preferred learning modality amongst VR designers and VR design students?

(2) Question 2: Is there a preference for a particular type of help system: voiced or text instructions and is this related to learning modalities?

(3) Question 3: Is it possible to provide a speech recognition interface to provide natural communication and control of a virtual reality world?

9.2 Method

The study was divided into three experiments. The first experiment carried out a survey to determine the learning modality preferences of VR designers and students using the Learning Styles Questionnaire. The second and main experiment investigated the choice of help system for VR design students carrying out a procedural task in a virtual world. Two choices, voiced instructions and text instructions were available to all participants. The number of times each type of instruction was used was recorded for analysis. In a third experiment, a feasibility study was carried out to investigate whether it was possible to provide a natural speech interface for a virtual reality environment.

9.2.1 Experiment 1: Learning Modalities

Participants

All participants had volunteered to take part in the study. They were informed of the aims of this study and were assured that results would be kept confidential. A large number of learning modality questionnaires were handed out to participants; only those that were completed and returned were used in this study.

VR Designers: The participants were 5 females and 19 males who were all VR designers, mainly of desktop VR systems. The age of the group ranged from 22 to 47 years old with a mean age of 35 years and a standard deviation of 8 years.

VR Design Students: The participants were 20 higher education students who were taking a VR module. The group had an age range of 20 to 45 years old, the mean age of 27 years with a standard deviation of 8 years.

Materials

The Learning Style Inventory was used to determine learning modalities (see Appendix 10).

Experimental Procedure

The learning style inventory was given to participants in paper format. Participants answered the questions and scored their choice in order to determine their learning modality preferences. Forms were handed back to the experimenter. All participants were volunteers and information was kept confidential and anonymous, although age, gender and personal code were recorded on the questionnaires for comparison purposes.

Data Analysis

Learning preference modalities were recorded and analysed in the form of counts and percentages (or nominal data). Chi-square tests were performed to determine significance of results.

9.2.2 Experiment 2: Text or Voiced Help

Participants

During the period of this thesis it was only possible to do this experiment with VR design students as the VR designers were not available. Participants were all higher education students taking a VR module option as part of a BSc degree in Multimedia. There were 13 females and 41 males in a total sample of 54. Their ages ranged from 20 to 50 years old, and there was a mean age was 28 years with a standard deviation of 9 years.

Materials

There are no interactive VR worlds that give a choice of VR help, so a world had to be designed and developed for the purposes of the experiment. A desktop virtual reality world called WormeryWorld was created by the author and used in an experiment. WormeryWorld was designed by the author to be used on an ordinary desktop computer system (ordinary PC monitor) and was available for students on windows-based PCs in the university multimedia laboratory. The PCs needed to have a sound card and speakers or headphones and to have Superscape VRT or 3D Webmaster software installed.

As certain aspects of the world were important for the experiment, details of the features in this world will be described here rather than in an Appendix. This world needed to teach users to build a real world object in a step-by-step manner. It could not be too hard or difficult to create, but was something that the users would not know how to build, and which they would need help to complete. It was decided that it should avoid too much navigation that might be a problem for novice users.

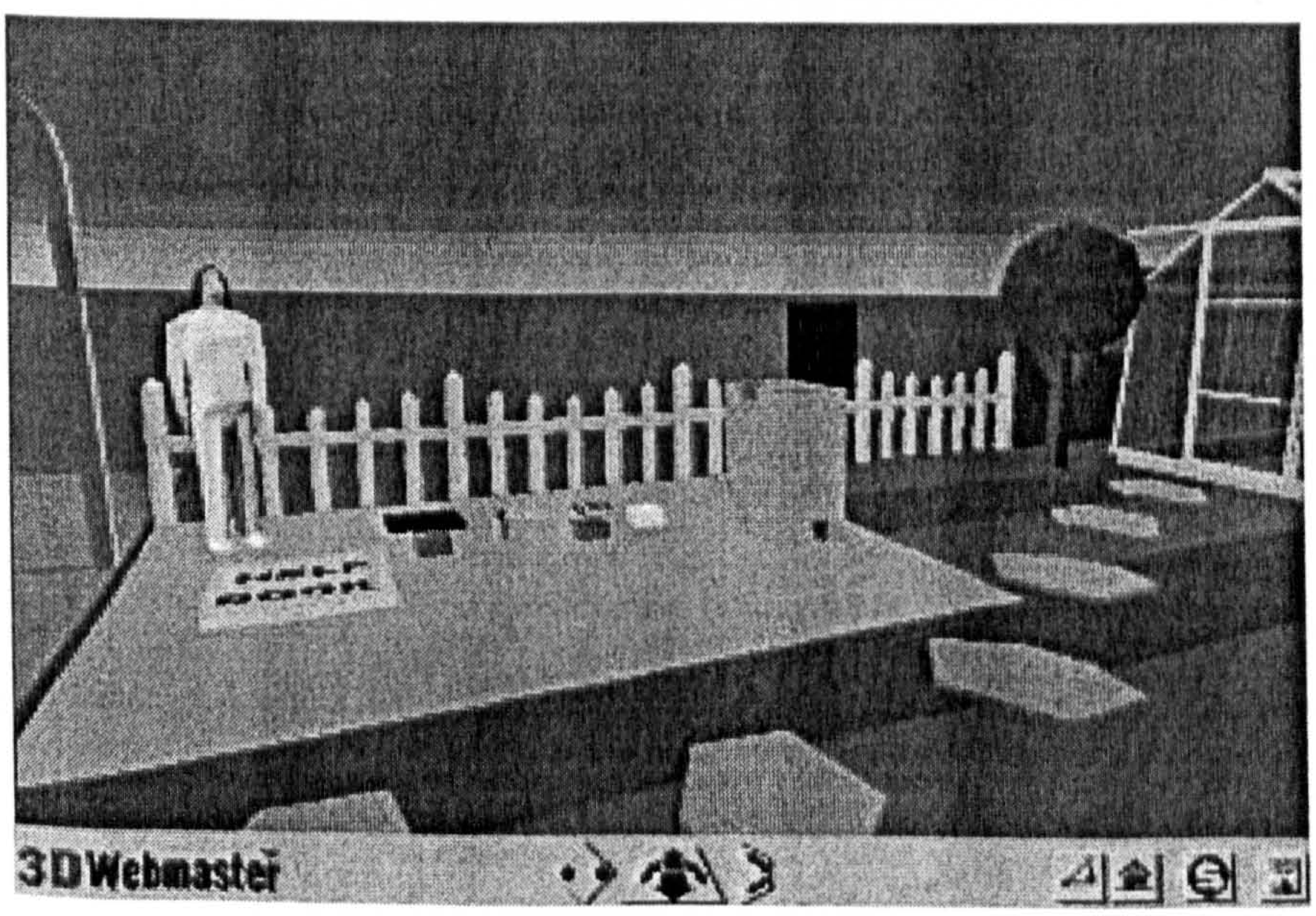

Figure 9.1 WormeryWorld showing Virtual Help Assistant, Help Book, Wormery Compost Bin and all the Contents

The finished world was called WormeryWorld and was set in a garden environment. The aim of the program was to teach users to build a wormery using a 3D modelled compost bin and materials (see Figure 9.1). The wormery bin was available for purchase in the real world through the Royal Society for the Protection of Birds (RSPB). The world was designed to include two different help systems, a voiced system and a text system. The voiced help system consisted of a female virtual avatar that could be activated to speak by clicking on her with the mouse and a text help system was obtained by clicking on a virtual instruction booklet that provided on-screen written text messages via 2D dialogue boxes (see Figure 9.2).

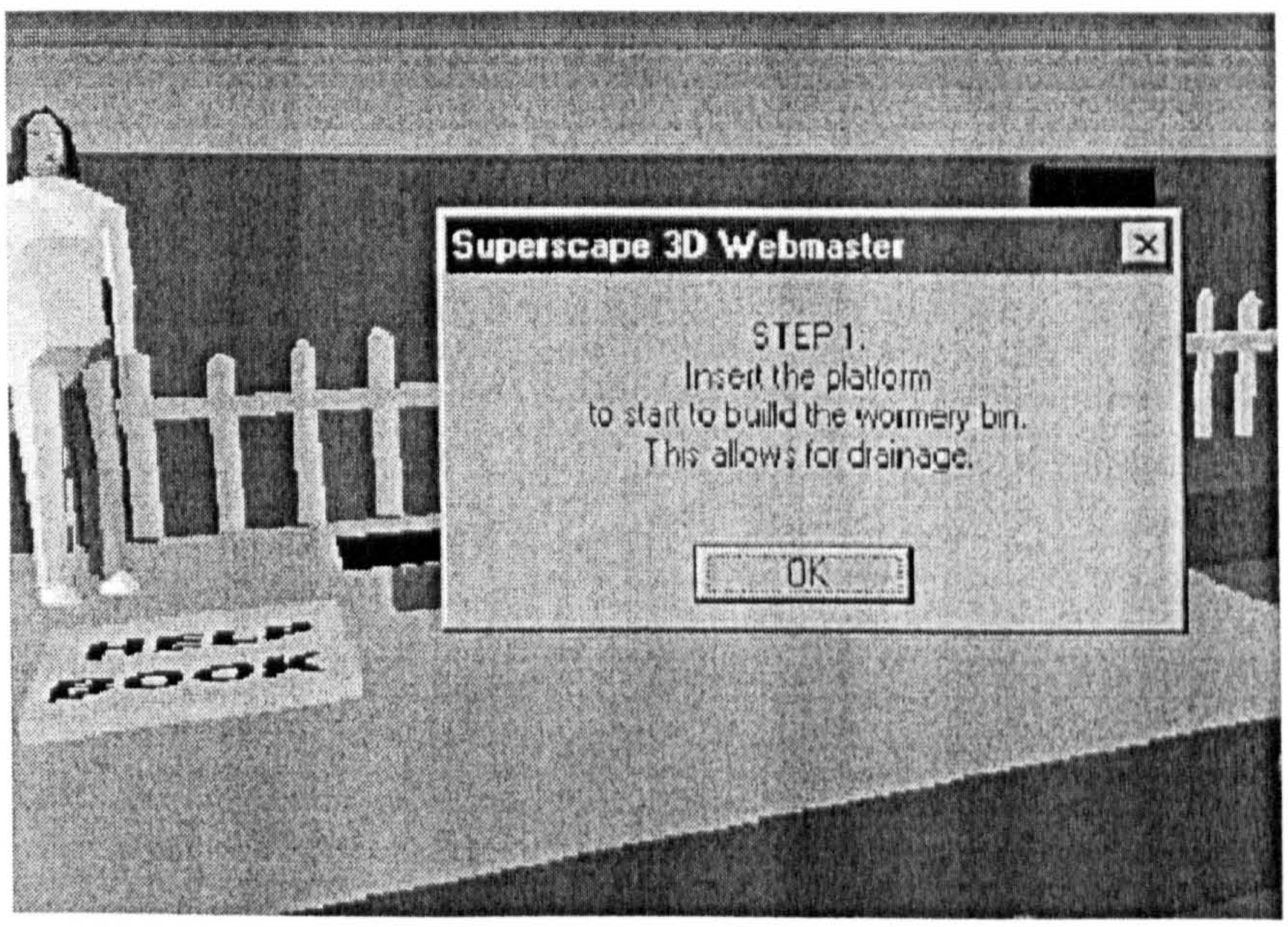

Figure 9.2 Clicking on Help Book gave Dialogue Box Instructions

Instructions varied for each stage of the task; however, the same instructions were given by the help book in written form or spoken by the avatar at that particular stage. Instructions were kept reasonably short in order to make sure that there was no disadvantage for hearing the instructions and seeing the instructions.

Tags were also added to the program (see Figure 9.3) to give extra information to the user. This is not representative of a real-world situation but compensates for the inability to create a picture instruction booklet or to use speech recognition to ask the assistant for help.

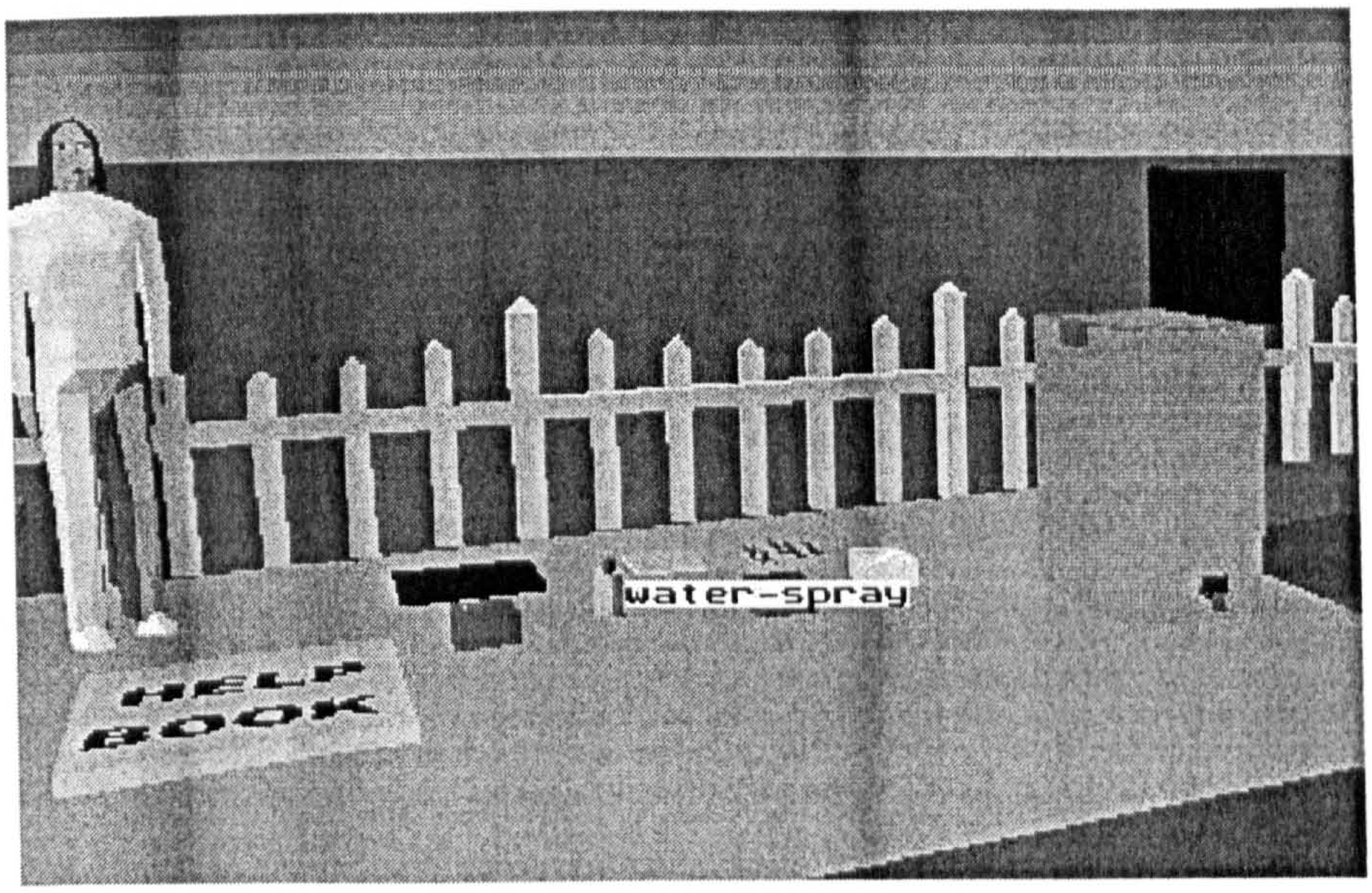

Figure 9.3 Tags gave Information to Help Users in the World

The world was designed to be used with all instructions built within the program itself. The world started with 2D text dialogue boxes that instructed the user to make sure that they had headphones that were set at the right level before the building the world. Then, voiced instructions, using a female voice, were given to tell the user about the objective of the world and how the user could obtain help by activating the virtual female assistant or the virtual help booklet inside the compost bin. The world enabled a user to move around the world from a first-person perspective viewpoint using a mouse and the navigation bar. Objects were manipulated by clicking on them using the mouse. Navigation around the world was kept to a minimum so that it did not interfere with the task in hand. After completing the task the users were instructed to press a key in order to change viewpoints in order to see a scoreboard with two scores (see Figure 9.4).

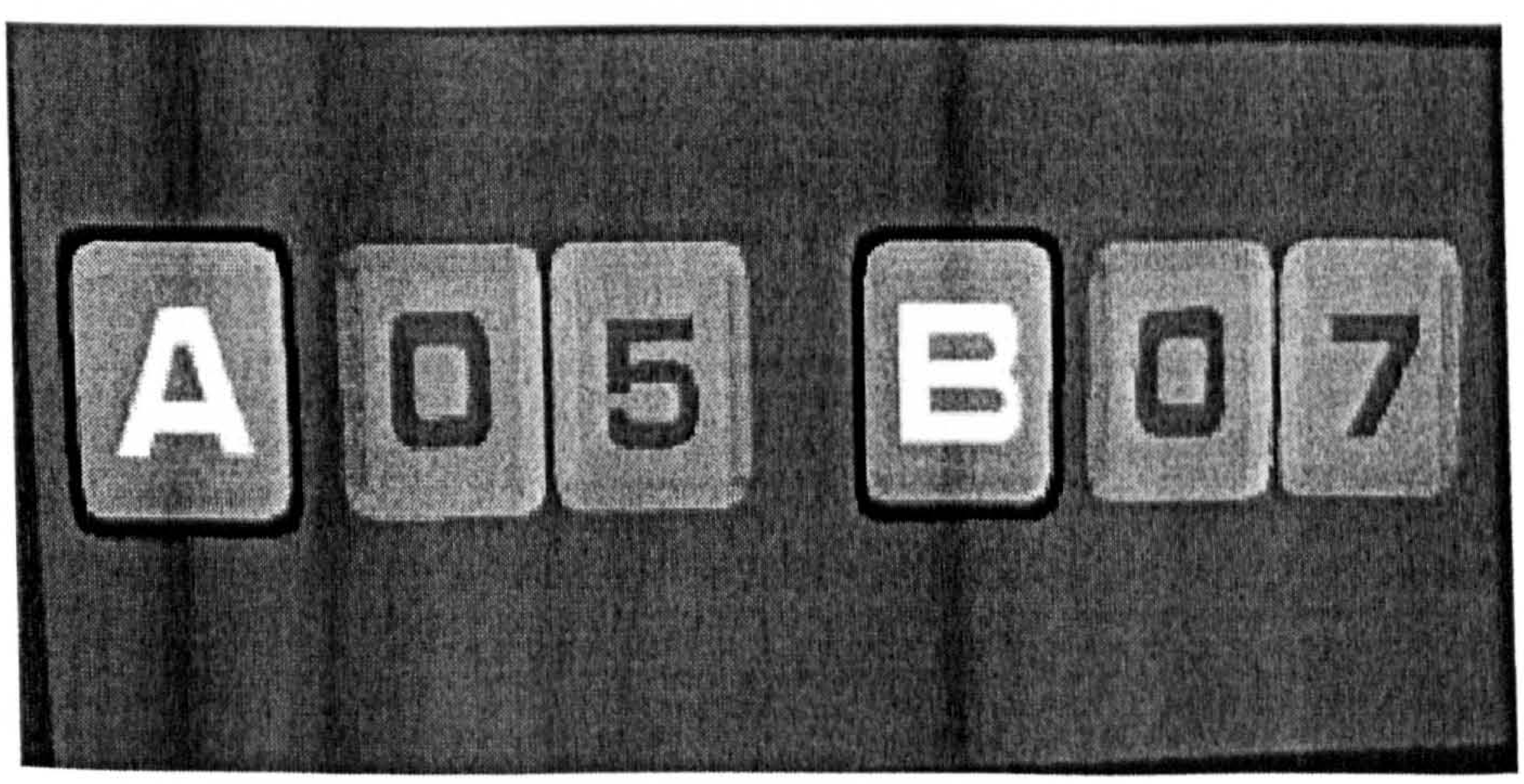

Figure 9.4 Scores were given to Students at end of WormeryWorld Task

These scores represented the number of times they had accessed the voiced help or the text help. User were not told what they indicated but were asked to write down the numbers in the appropriate boxes on a form given to them at the start of the experiment (see Appendix 11).

Procedure

A small pilot study was carried out on a group of eight multimedia first year students to ascertain what problems may occur in using WormeryWorld. The results showed few problems but initial instructions were slightly amended to give more clarification and instruction about what the participants needed to do. A form was created to record WormeryWorld scores.

Participants in the main experiment had been given prior experience of using virtual worlds in order to make sure that participants were used to moving around the world with a mouse and were able to manipulate objects easily.

Information about what was required from the students was given verbally by the experimenter to all participants before they started. Further directions and instructions were incorporated in the world itself. All participants were given the form for recording final scores. Participants continued with the world choosing what type of help they preferred and when until they had completed the task and were presented with the final scores. The session was not timed.

Data Analysis

Help scores were collected for all 54 participants and numbers of accesses to each type were recorded. Overall counts and percentages were calculated and analysed as nominal data. Chi-square tests were used to calculate the significance of any differences. Number of accesses to each type of help instruction were also analysed and a paired t-test was used to calculate significance. Both sets of data were further analysed for gender differences. Chi-square tests were used to investigate the significance of choice.

9.2.3 Experiment 3: Speech Recognition

A feasibility study was carried out to consider the potential of a speech recognition system as an interface for a VR world.

Materials

Superscape VRT software (version 5) and *Dragon Dictate* speech recognition software including the development toolkit (version windows 3.1) was used to explore the possibility of designing a speech recognition interface in order to control the world. The software enabled the user to build a library of commands that could be recognised by code in the virtual world.

Procedure

These tools were used by the author to produce a simple virtual world that could incorporate facilities for two-way speech communication. It was envisaged that the world would be assessed using a number of participants, but this proved to be too challenging.

9.3 Results

9.3.1 Experiment 1: Learning Modalities

The results for learning modality preferences were recorded and totals were calculated for each modality (see Table 9.1).

Table 9.1 Number and Percentage of Learning Modalities for Designers and Students

	Visual	*Auditory*	*Kinaesthetic*
VR designers	24 (92%)	1 (4%)	1 (4%)
VR design students	19 (95%)	1 (5%)	0 (0%)
Overall	43 (94%)	2 (4%)	1 (2%)

The results showed a majority of Visual learners in the VR designer group (92%) and in the VR design student group (95%). There is clear preference for the Visual modality (94%) rather than the Auditory (4%) or the Kinaesthetic (2%) overall. A chi-squared test showed that there were no significant differences between VR designers and VR design students.

Chi-square tests were carried on the data to compare each group with the figures suggested for children by Dunn and Dunn (1979) as given in Table 9.2.

Table 9.2 Number and Percentage of Learning Modalities for Children

	Visual	*Auditory*	*Kinaesthetic*
VR designers	24 (92%)	1 (4%)	1 (4%)
VR design students	19 (95%)	1 (5%)	0 (0%)
Children	40%	25%	35%

The difference between VR designers and children was found to be significant (chi = 60.333, p = 0.000) at the α = 0.1 level. The difference between VR design students and children was also found to be significant (chi = 70.741, p = 0.000) at the α = 0.1 level. No data was found for comparison with an adult population although Bell and Fogler (1997) suggest that it is between 50%-60%.

9.3.2 Experiment 2: Text or Voiced Help

Difference in Help Preferences

The raw data can be seen in Appendix 12 and summaries in Table 9.3 and 9.4.

Table 9.3 Preference for Text or Voiced Instructions

Preference	*No of Students*	*Percentage*
Text	30	56%
Voiced	21	39%
"="	3	6%

The results above showed that 30 participants (56%) preferred to access instructions via the on-line text help book and 21 participants (39%) by the voice of the virtual avatar. Three participants (6%) had no overall preference as they accessed both types of help equally.

Table 9.4 Access to Text or Voiced Help Instructions

Total	*No of Times*	*Percentage*	*Mean*	*StDev.*
Text	282	54%	5.208	3.511
Voiced	237	46%	4.389	4.058

The group accessed the text instructions a total of 282 times and voiced instructions a total of 237 times. The means in Table 9.4 showed that the participants on average accessed the Text facility 5.21 times and the Voiced facility 4.39 times.

Table 9.5 T-Test for Text and Voiced Help Instructions

	Paired T test for Help Types			
	N	Mean	StDev	SE Mean
Text	54	5.222	3.511	0.478
Voiced	54	4.389	4.058	0.552
Difference	54	0.833	7.118	0.969

95% CI for mean difference: (-1.110, 2.776)
T-Test of mean difference = 0 (vs not = 0)
T-Value = 0.86 P-Value = 0.394

The results for the paired t-test comparing the number of times Text and Voiced help instructions were accessed can be seen in Table 9.5. A p-value of 0.394 showed that there were no significant differences at the α level of 0.05 in the results.

Differences for Gender

Table 9.6 Data on Voiced/Text Instructions for Gender

	Male (n)	*Male (%)*	*Female(n)*	*Female (%)*
Text	23	56%	7	54%
Voiced	15	37%	6	46%
=	3	7%	0	0%
Total	41		13	

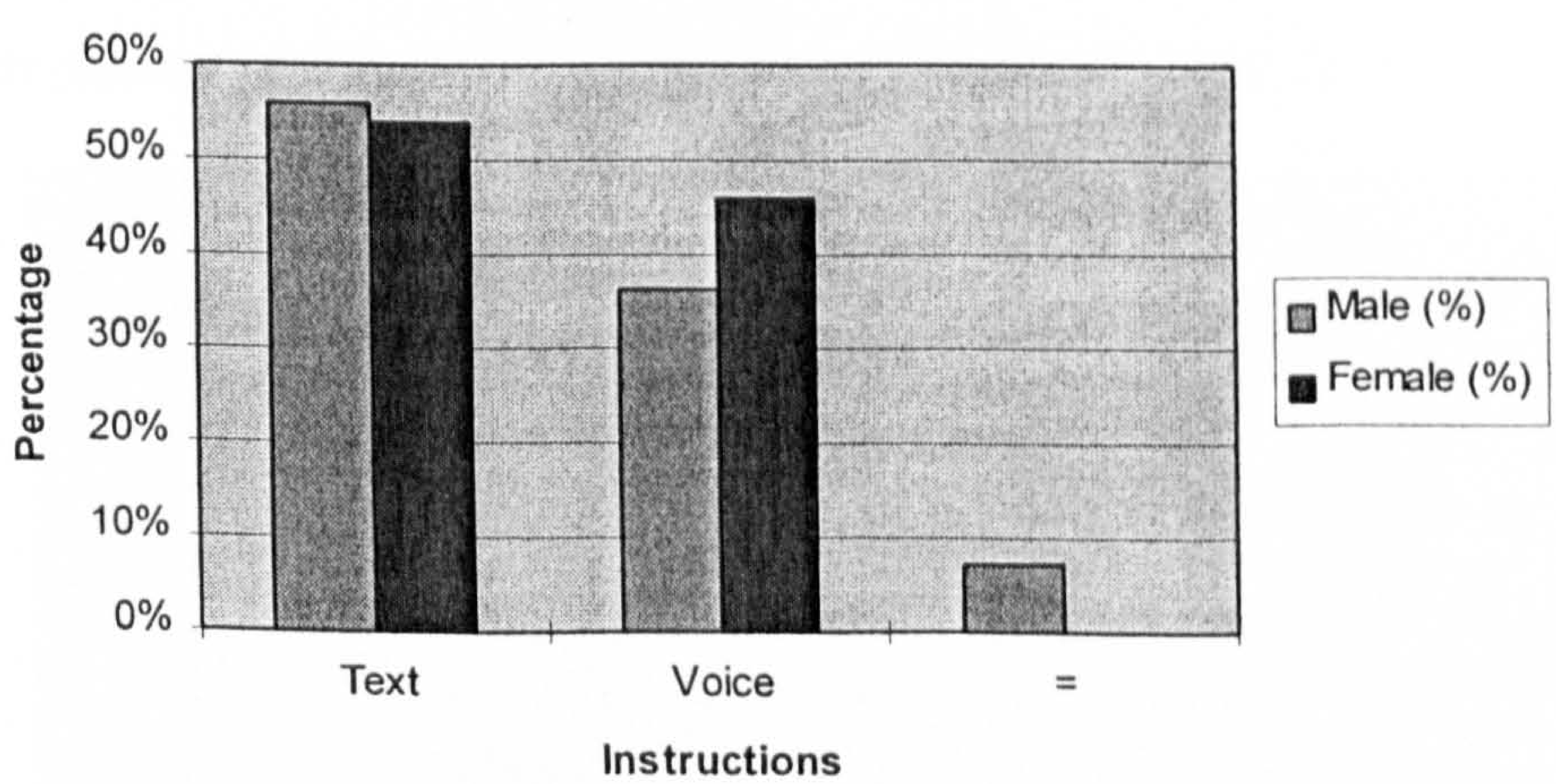

Figure 9.5 Gender Choices for Voiced/Text Instructions

As the help avatar had a female voice, the results were analysed in terms of gender and the preference results are shown in Figure 9.5 and Table 9.6 for the number of male and female participants who preferred either Text or Voiced instructions. Also shown are the three male participants who had an equal preference for both types of help. Overall the males preferred Voiced instructions (56%, n = 23) to Text instructions (37%, n = 15) whereas the females preferred Text instructions (54%, n = 7) to Voiced instructions (46%, n = 6). Three males (7%) had no preference for using either type of help system. A chi-square test was carried out on the results (chi = 0.178, p = 0.673) which showed that the results were not significant at the α = 0.05 level.

Table 9.7 Number of Times Text Or Voiced Instructions were accessed by each Gender

	Male (n)	*Male (%)*	*Female (n)*	*Female (%)*
Text	211	57%	71	48%
Voiced	159	43%	78	52%
Total	370		149	

The results for the actual number of times each gender accessed each type of instruction are shown in Table 9.7. These results showed that males accessed the Text instructions a total of 211 times (57%) compared to 159 for the Voiced instructions (43%). Females, accessed the Text instructions a total of 71 times (48%) compared to 78 times for the Voiced instructions (52%). A chi-square test was carried out on the results and this produced a value of chi = 3.764 and p = 0.052 which shows that the results were not quite significant at the α = 0.5 level.

9.3.3 Experiment 3: Speech Recognition Demonstration

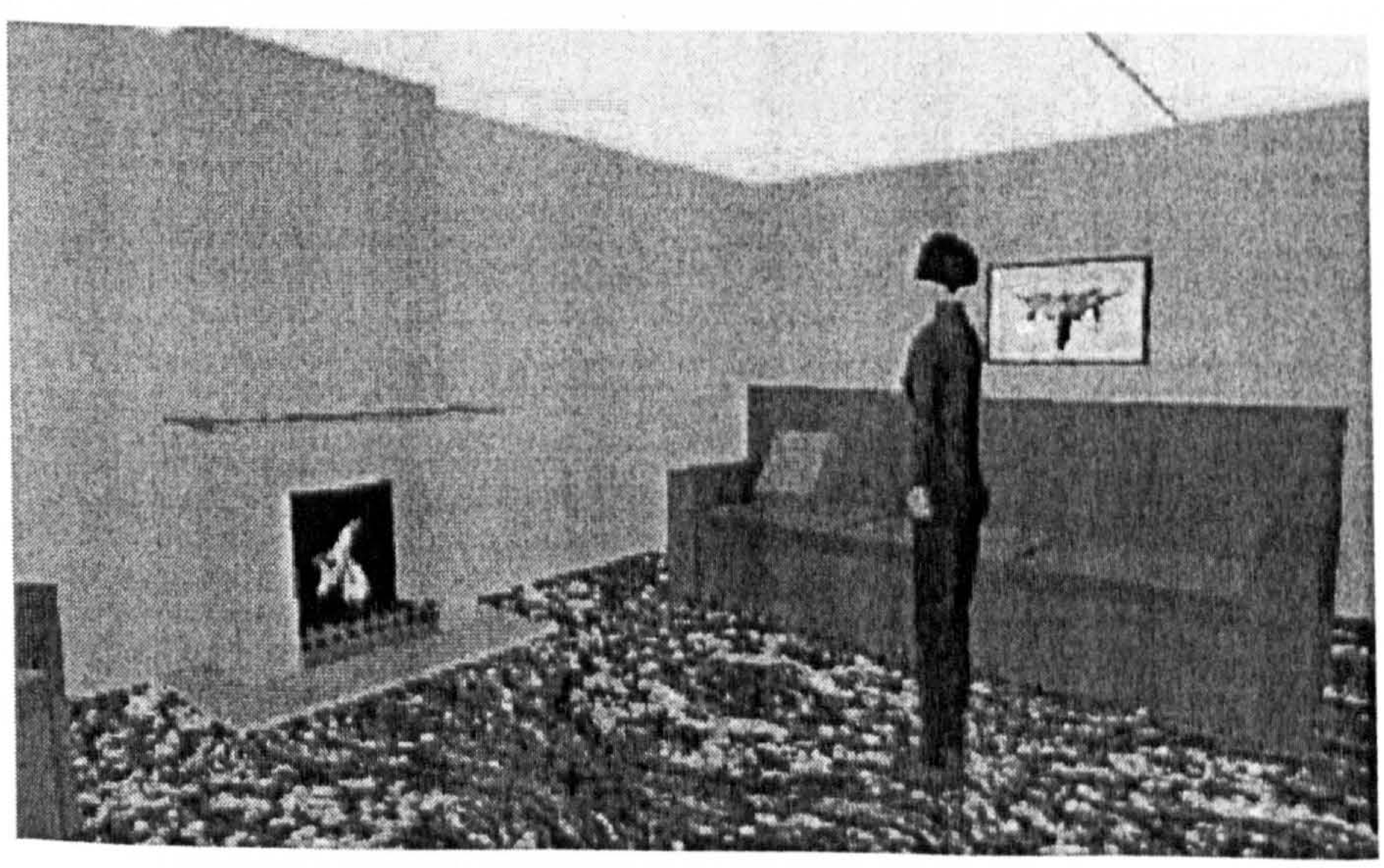

Figure 9.6 Virtual World Controlled by Dragon Speech Software

A simple world was created by the author that contained three virtual characters; one male and one female and one cat. It was based around a room with an animated fire and a sofa (see Figure 9.6). Commands were programmed using *Dragon Dictate* software and *Superscape* control language to speak to the characters in order to control the activities of the world by making the characters speak back or carry out particular activities.

A demonstration prototype speech recognition world was designed and created by the author and presented at a VR user meeting. The software was able to recognise a set of about 20 different commands that were transmitted to the virtual world. Various methods of trying to get the software to recognise commands from the *Dragon Dictate* software were considered and found to be ineffective. Finally, a method was found that seemed to work, which involved the communication and interpretation of key-presses from one software package to the other. The speech software was coded to convert commands into key-presses that it sent to the virtual world. *Superscape's Control Language* was used to interpret these key-presses into commands. A set of IF statements and SWITCH statements were created to interpret these commands and proceed with the appropriate functionality. This could be speech via one of the three characters (the cat meowed!) or activity by one of the three characters. Examples of activity included the cat being told to get off the sofa, Eve being asked if she could open the door and Adam being asked to jump up and down.

It was envisaged that the world would become part of the main experiment so that users could actually speak to the virtual assistant, but problems with the speech software were encountered that made this impossible. First, the prototype was created with *Dragon Development Software version 3.1* and this needed a great deal of training before commands could be recognised correctly. Second, each individual user had to undergo this training before their voice could be recognised. Third, there were also problems with recognising commands from trained voices in different rooms, different PCs and at different times when the voice may be slightly different. These problems meant that it was very time-consuming to try and train the number of subjects needed for an experiment. Training VR designers in particular would have been impossible as they would only have access to the world and the speech software for a very short period of time. Even training a large number of VR design students proved too difficult for an experiment.

9.4 Discussion

The discussion will focus upon the questions poised at the start of this chapter.

Is there a preferred learning modality amongst VR designers and VR design students?

This study suggested that the visual learning modality was significantly greater than that of the auditory and the kinaesthetic learning styles for both the VR designers and the VR design students, which supports the idea that VR is a mainly visual medium. It also supports the view that the visual learning modality is the most common one in the population, with 40% of children having a visual modality preference (Dunn and Dunn, 1997; Haggart, 1995) and around 50%-60% of adults (Bell and Fogler, 1997).

The VR designers and VR design students both showed greater proportions of visual learners than is found in children or adult studies. This suggests that visual learning types are indeed more attracted to the field of VR than other types. Such a dominance of visual learning types may explain why VR worlds do not have much sound or speech designed in them. The visual designers are probably not aware of how important auditory and haptic features are for non-visual learners.

Is there a preference for a particular type of help system: Voiced or Text instructions?

The participants in this study were able to access either on-line text instructions by clicking on a virtual 3D help book or to access voiced instructions by clicking on a virtual 3D female avatar. The data in this study showed that more students preferred to access the Text instructions in the WormeryWorld than the Voiced instructions but these results were not significant.

The number of times each VR design student had accessed each of the help systems showed that the virtual help book had been activated slightly more often than the virtual female assistant. These results were also found not to be significantly different. With the large number of visual learners amongst the VR design students it was expected that the favoured help system would be text. However, the results showed that the text instructions were accessed only a few more times than the verbal instructions. This does not seem to support the view that visual learners prefer written material (Barbe and Swassing, 1979). One reason for the higher than expected preference for auditory material could be that verbal information from a virtual avatar, was indeed, a more natural communication style for the virtual world and thus this seemed to override the learning modality principle. However, a further possibility for these results could have been that the students found the voiced instructions more unusual and the novelty effect might have persuaded them to choose this option more often. The virtual assistant used this experimental study was arbitrarily chosen as a female assistant with a female voice. The help data was also analysed to investigate any differences in choice between the female and male students in accessing this female avatar. The data showed that fewer males accessed the female avatar than did the female students. However, the differences in overall choice and number times accessed were not significant. There is little information in the literature to suggest that gender of virtual assistant would affect learners' choice. This seems to be an area needing further investigation.

Is it possible to provide a speech recognition interface to provide natural communication and control of a Superscape desktop virtual reality world?

The prototype developed in this study showed that it was possible to build a speech recognition interface for communication and control of a Superscape desktop VR world. However, this was very limited in the number of available commands and it was also found that this did not give very natural communication with the user. The amount of training and the problems of recognition in different situations were also found to be problematic. Some of these problems were due to the limited recognition capabilities of the speech recognition software at the time of development in the mid 1990s. Recently, a more modern version of this software has included the facility for natural speaking recognition; however, the literature suggests that modern systems are still limited and not ready to be implemented as a natural communication interface (Noyes, 2001).

A second main problem was that there were only a limited number of key-presses that could be sent and recognised. This reduced the number of commands that could be used in the VR world. Further research would be need to look at the possibility of using combinations of key presses and other alternative methods of using the code in the VR software, in order to recognise a greater number of commands. The software only had a limited method of addressing errors and that was to cancel and repeat commands. This might be a reasonable method for use with word-processing software, but was not appropriate for a VR world. An error could set off a sequence of events in the VR world before the user could identify the error, and try and stop it. Reversing the sequence of events would be extremely difficult to do and pretty well impossible in a multi-user world where actions from one user would trigger actions from other users, which could not be reversed. In summary, then, this study showed that whilst an interesting and amusing demonstration could be produced it would not be suitable for use as an interface unless all users were trained and were constrained in the way that they spoke and in the words that they used, and this would not be considered very natural.

Overall this chapter has found that VR designers and VR design students have a very clear preference for the visual learning modality. This might explain the dominance of text-based help systems. However, the WormeryWorld experiment showed that there was no significant difference between the choice of visual or verbal instructions. As most of the participants were visual learners, then about half of them had chosen to use the verbal instructions rather than the visual instructions. This seems to suggest that verbal instructions given by a virtual avatar are an attractive and effective choice, even for visual learners, when instructions are kept reasonably short. Although speech recognition would give a means for verbal two-way communication between users and between user and virtual avatars, the problems of speech training, limited commands and error problems suggest that it will be some time before these can be used in a natural manner.

The results of this experiment have given some insights into the nature of help systems and VR. Chapter 10 discusses how these insights can be incorporated into the design model that was presented in Chapter 5.

CHAPTER 10: FINAL DESIGN MODEL, LIMITATIONS & CONCLUSIONS

This chapter reviews the main findings of the four previous field studies and then presents new refinements to the model, outlined in Chapter 5, as additional guidelines derived from these findings. Limitations of the model are highlighted along with areas for further research. Final conclusions are given.

10.1 Fieldwork on Individual Differences

10.1.1 Attitudes/Beliefs about VR

Chapter 4 of this thesis presented information about the importance of positive attitudes in learning situations. To provide a general basis of information about the VR designers and VR design students in this study, the first study (Chapter 6) carried out a questionnaire survey to discover more about the attitudes and beliefs of VR designers and VR design students in order to assess how positive they were about creating VR software, how they added interaction in their worlds and how they created useful help systems. It was found that overall the participants in this study rated their enjoyment of using desktop VR software much more than other types of software and they contended that it enabled them to take pleasure in the opportunity and creativity of creating 3D shapes and using textures to produce realistic worlds. However, it is necessary to be aware that the participants had all chosen to use this software either for their job or for their course, and were therefore likely to have a high motivation to use it. The VR design students had found it enjoyable to use desktop VR software but had also found it difficult and time-consuming to create the objects and to incorporate interactivity via the VR programming language. Although this might support the view that interactivity is not found in VR worlds because of the difficulty of doing so, it is more likely that these students will decide to find work in the VR field. Those that enjoy and are more capable of producing interactivity, hopefully, will be more likely to go into the VR field and produce such worlds. Interestingly, whilst all the participants were positive about using computers in training they seemed less positive about the role of VR in learning and training. Not all the VR designers had had experience of using VR worlds in learning or training situations that might have been the reason for such a result; however, it is a limitation of the study that further questions were not asked about this matter in a follow-up study because the participants were unavailable many having changed jobs due to the decreasing market for VR in the UK.

Overall it is possible to conclude from the high VR ratings in the questionnaire study that there was indeed a general enthusiasm for VR software amongst the designers (see Tables 6.1 - 6.3) and the design students (see Tables 6.5 – 6.7) about creating 3D objects and using 2D textures to make them realistic. However, general answers about what designers liked about VR software suggested that there may be less enthusiasm towards incorporating much interactivity in the worlds, either from the difficulty of the programming or from the lack of awareness that this is needed.

10.1.2 Learning and Communication Styles

Chapter 4 gave evidence that suggested that individuals learn in different ways and these needs must be met in learning material. It also considered the possibility that differences in learning styles in the teacher or VR designer may be reflected in the design of their own learning material. The literature suggests that the teachers' preferences can be reflected in their teaching styles and materials and this may cause problems for students. In a similar manner, designers' learning styles may reflect, and therefore bias, their own applications. Teachers are able to change their learning styles if they find that some students are having problems; however, users of computer-based software are dependent upon the designers creating a variety of learning style methods for them to choose (Steuer, 1992). If these methods are not available then the learners can have problems.

As little research has investigated this issue, fieldwork was carried out to investigate the profiles of VR designers both for learning styles and communications styles to examine their learning style preferences, in particular to discover if their profiles were suitable for the creation of active, participatory learning environments.

Honey and Mumford's Learning Styles

VR, with its interactive nature, held a particular interest for a number of researchers who felt that the experiential nature of the medium would offer a new type of learning environment for the classroom, both for learning and training situations (Bricken, 1992; Byrne and Furness, 1994; Helsel, 1992). Central to this argument was the idea that the user could participate in the learning process in an active manner by interacting with the objects in the world rather than sitting passively and listening to words and images as in a traditional classroom or multimedia setting (Felder and Silverman, 1988). Researchers have speculated that, using Honey and Mumford's (1992) model of learning preferences (Activist; Reflector; Theorist; Pragmatist), Activists would be the group most comfortable with computer-aided-learning software (Riding and Cheema, 1991; Cousin and Davidson, 1999). The literature presented in Chapters 4 and 7 suggested that Activist users would also find VR to be a motivating and interesting experience if given a wide range of learning activities in the world although there are no known studies to confirm this.

This thesis (see Chapter 7) carried out an investigation into the learning styles of VR designers and VR design students to assess if they had an Activist learning style. The results of this study showed that whilst there were some Activists amongst the group of VR designers, the overall scores revealed that the Activist learning style was the weakest style amongst the group. It is possible to conclude from these results that most of the designers did not seem to have learning profiles that were suited to the creation of active participatory learning environments. However, this has not been 'proved' by these results and further research is needed to assess if Activist VR designers do indeed produce more interactive worlds than non-Activist designers. For example, it may be useful to compare worlds from Activist and non-Activist designers using suitable criteria to evaluate the active, participatory nature of these worlds.

The results also showed that most of the VR designers were Reflectors. This tends to be a passive learning style where users prefer to watch and observe others and need evidence that an approach is correct before they carry it out (Honey and Mumford, 1992). This further supports the view that VR designers tend not to have learning style profiles that are suitable for the development of active, participatory learning environments. Chapters 4 and 6 emphasised how traditional classroom and lecture-room teaching are not suitable for Activist types of learners. These types could, however, benefit from the active potential of VR, but not if most of the designers have a Reflector learning style that incorporates a non-active learning mode. Again further research comparing the active, participatory nature of the designs from Reflectors versus Activists is needed to show if Reflectors are less likely to produce interactive worlds.

The results of the VR design student group in this thesis showed that whilst there seemed to be more Activists in the VR design student group than the VR designer group, the group norms were still lower than for general student populations. Given the premise taken in this thesis that Activists may be more likely to produce active, participatory worlds (see Chapter 6), these results also highlight a possible problem for the creation of active learning media if these participants typify the VR designers of the future.

Myers-Briggs Communication Styles

Chapter 4 presented evidence to suggest that communication styles are considered an important factor in learning. The Myers-Briggs Communications Styles have been used effectively in a variety of learning situations (Lawrence, 1995). These styles are based on Jung's theory of psychological type, which was developed into a model of temperament by Briggs (Myers and Myers, 1995) and were determined using the MBTI (Myers-Briggs Type Indicator) questionnaire produced by Briggs and Myers (McCaulley and Myers, 1985). Schroeder (1993) has associated the Extraversion-Introversion dimension of the MBTI with the Activist-Reflector learning styles of Honey and Mumford. Howe and Sharkey (1998) have also suggested that it can be used to determine the suitability of an individual for using VR, with INTP being the most appropriate style for VR (see Chapter 4). No previous research had investigated the style or types for VR designers although Durling (1996) had found that general designers generally tended to have a preference for N or iNtuition.

Chapter 8 presented the results of fieldwork in this thesis that explored the communication styles of the VR designers and VR design students in this study. It was found that they both showed the pattern of NT, which relates to logical and ingenious qualities (McCaulley and Myers, 1985). This seemed to support the idea that iNtuition (N) was important for design (Durling, 1996) although Durling found that his design students had more Feeling (F) styles. The most popular types for the VR designer group were INTJ and ISTJ; both these types are typical of computer programmers (Myers and McCaulley, 1985; Tognazzini, 1992), which is likely to be a significant skill amongst the VR designer. The INTJ style is similar to the INTP style which Howe and Sharkey (1998) proposed as the most suited to VR. However, the association of Introversion (I) with the Reflector learning style of Kolb and Honey and Mumford (Schroeder, 1993) does not seem to suggest a style that suits an active, participatory nature of learning. Howe and Sharkey (1998) used their own personal judgments in deciding introversion would be more suitable than extraversion, based on the fact that there would not be other people with which to communicate. It is proposed in this thesis that whilst Introversion might be suited towards current limited single-user VR systems, it might not be appropriate for exploiting the true nature of VR in terms of active participation with multi-user environments.

The most popular types in the VR student group were ENTP and ENFP, which are more likely to appear in a population of fine artists than computer programmers (Durling, 1996). The ENTP is more like the style proposed by Howe and Sharkey (1998) with the extra advantage of having the Extraversion (E) style that is associated with an Activist learning style (Schroeder, 1993) and which was found to be significantly correlated with Activist in this study. However they also had a fair amount of INTJ and ISTJ types, suggesting some programming skills present in the group. Both programming and graphics skills would be necessary to design effective VR worlds.

From a learning perspective, the literature suggests that all students tended to be more Extravert (E) than the general population (Myers and McCaulley, 1985) and this supports the earlier premise that students tend to be more Activist. Age seems a likely factor in this and indeed correlations were found in the results of this study (Chapter 8) that indicated that older individuals in both the VR designer and VR design student groups tended to be more Introverted than younger participants who were more Extraverted. Extraverts tend to prefer more communication and group discussions in order to clarify ideas and to study with friends. These types would only be suited to multi-user VR where there were ways of communicating between users. Introverts are more likely to prefer single-user environments where they can work independently; however, it is not clear whether they would like to speak to virtual characters in the world, although research suggests that Introverts do prefer to email other people compared to Extraverts and to take part in online discussions more than group discussions (Dewar and Whittingham, 2000). More research is needed to clarify this.

Overall the results in this thesis showed that intuition and thinking were the most dominant types for both groups. This could cause problems for the teaching of Sensing-Feeling (SF) types. In particular there was a lack of Feeling (F) types found in both groups. The Feeling preference is related to subjective and person-oriented types of learning environments and these people would probably prefer worlds that have lots of characters that can communicate with the user (Lawrence, 1995; Myers and McCaulley, 1995). This would involve the use of speech communication between users or speech recognition systems and intelligent agents

(Kinshuk, 1996). Chapter 9 presented evidence to suggest that a speech interface could be created with 'off-the-shelf' VR and sound recognition systems, but the results were limited in use. Problems were found in recognising different users and in handling errors made by users in conversations. Speech systems need to be more intelligent in their interpretation of users' words and recognition of mistakes. If user commands are not recognised then a useful feature would be for the system to make the virtual character ask for further clarification from the user.

Communication styles can also help a designer to provide more effective help systems. Feeling types are person-centred and tend to be friendly, helpful individuals (Myers and Myers, 1995). Designers need to incorporate the use of 'friendly' helpful avatars for these types. Sensing (S) types tend to like structured activities, lots of details and the ability to repeat and practice skills (Myers and Myers, 1995). Designers would need to incorporate more details about activities in the world and enable the ability to repeat certain sequences of actions again. This may be difficult to do in a multi-user world, where other non-sensing type users may get irritated if the events were continually repeated. These types may also benefit from the use of haptic devices that would facilitate the execution of concrete, practical 'hands-on' activities. It is also likely that these types may prefer a great deal of structured help and step-by-step guidance (Lawrence, 1995) and would therefore benefit from appropriate instructions. More research into investigating the choices and effects of different types of help for different communication types is needed to clarify these ideas.

10.1.3 Help Systems

The fourth area of the model covers the design of appropriate help systems for active, participatory VR learning environments. Feedback and help are two important parts of any learning process (Harrison, 1996). Chapter 4 of this thesis presented literature relating to the provision of help systems for computer-based software but could not find any evidence of investigation into the design of VR help systems. Research into design and evaluation of feedback and help systems for modern multimedia and e-learning systems is still in its infancy (Harrison, 1996). It is also fair to say that this is true of VR. It has been argued that whilst a lot of effort has been given to the design of interactive multimedia content, the same cannot be said for the accompanying help systems (Harrison, 1996). Text-based online systems seem to be the most popular form of help, even in multimedia and graphics packages that could exploit the visual aspects of their media. This thesis carried out fieldwork that questioned VR designers about the types of help systems that they provided with their VR solutions and also explored the preferences for text or voiced instruction in a virtual world experiment.

Questionnaire Study

When asked about the types of help systems that were provided with their VR software most of the participants in this thesis mentioned the use of online text features via menus or mouse-clicks, telephone support or written manuals. Only one person mentioned the use of an avatar and speech recognition or the use of verbal instructions even though the literature suggests that these facilities would be more natural and appropriate for VR environments (Karlgren et al 1995; Mason, 1996). There seemed to be a general lack of awareness about the design of more natural and realistic forms of VR help systems. Even when asked about with what forms of help they would like to provide users, there were no suggestions that really reflected the unique nature of the medium of VR. Only one person suggested a 'friendly' virtual character that could interact with the users within the world. It is not possible to conclude from these results as to why the designers did not suggest 'within-context' help systems that would complement the novel and interactive nature of VR, but this might be a good question to ask in any future research. Possible reasons to be explored could include the technical and practical problems in producing these facilities or the lack of awareness of the effectiveness of more natural help systems that increase the sense of presence or immersion in the VR world. More research, however, is needed to investigate the use of natural help systems such as help avatars and auditory communication for users in order to provide data that can highlight the effectiveness of such additions to the designers.

Learning Modalities

Chapter 4 argued that teaching styles must match learning styles for the individual to gain the most from the learning environment (Pimentel and Teixeira, 1992; Reiff, 1992). Fleming and Mills (1992) argued that matching learning modalities was one of the most important to things to do in a learning environment. The main learning modalities are visual, auditory and kinaesthetic and about 40% of children are visual (Dunn and Dunn, 1997) and between 50% and 60% of adults (Bell and Fogler, 1997). VR is mainly a visual medium and would therefore suit visual learners and designers (Pimentel and Teixeira, 1992). However, the addition of auditory and haptic devices that could produce sound, speech, verbal information, tactile and force-feedback faculties, could ensure that VR learning environments would be beneficial to an auditory and kinaesthetic users.

Chapter 9 of this thesis investigated the learning modality preferences of VR designers and VR design students. It was found that over 90% of the participants were visual learners, which is significantly more than normal children or adult populations. This supports the view that VR is likely to suit visual learners and therefore attract visually dominant designers. It also suggests that VR designers might be more likely to favour using the instructions of a visual nature to the detriment of auditory or kinaesthetic facilities. However, the results of the field study of VR design students' preferences for text (visual) or voiced (auditory) instructions suggested that the visually dominant students were almost equally likely to use the voiced instructions than the text boxes. Once possible conclusion that can be obtained from these results is that the VR design students preferred the auditory instructions because they were more realistic or natural in the virtual world; however, further investigation is needed before such a conclusion can be assumed. Other reasons are also possible. For example, the students may have used the voiced instructions because they were novel. It is a limitation of this study that no follow-up interviewing could be carried out with the students before they left the university.

These results also show the difficulty of presenting only one choice of instruction for users. It would be better to produce both visual and auditory instructions in a virtual world to satisfy more users. Byrne (1992) suggested that VR should provide experiential instruction. There are two ways that VR can do this. First, by the self-directed 'discovery learning' process proposed by Bruner (1960) or secondly, by the 'cognitive apprenticeship' method, where learners pick up skills from experts in an authentic situation (Brown et al 1989). The latter would need the use of animated avatars that could act out the particular skills and move around the world with the user, giving advice and guidance where necessary, thus providing the modelling, scaffolding, and coaching attributes of successful mentors in apprenticeship learning (Collins et al, 1989). This would be an appropriate means of giving practical help in a VR world but more research is needed to show its effectiveness against other forms of help and of its technological possibility.

10.2 Refinements to the Model

10.2.1 Designer Differences

VR Designer Differences
Experiences (p. 1) *Need to make sure experiences are suitable for design of VR learning*
Age (p. 166) ***Older designers need to incorporate more active learning techniques into their designs*** ***(Older designers and design students tend to be less Activist).***
Gender (p. 69) *This was not investigated and more research is needed*
Skills (p. 190) ***Designers need a mix of programming and artistic skill and knowledge of how users learn*** ***(The designers in the experiments in this thesis had some design and computer skills but not many had any experience of learning material)***
Motivation (pp. 141 and 166) ***Designers need to be more motivated to create interactive worlds with active learning content***
Attitude (pp. 118 and 140) ***Designers should have a positive attitude towards using VR*** ***(The designers in this study had a positive towards the use of VR generally)***
Beliefs (p. 117) ***Designers generally need favourable beliefs towards using computer technology in learning and training situations*** ***(The designers in this study did have positive beliefs towards the use of VR technology, but these could be improved)***
Learning Styles (pp. 149 and 152) ***Designers need to be aware of their own learning style and have an understanding of how they can make VR worlds more active and participatory and less passive.*** ***(The designers in this study were found to be mainly Reflectors and to have low Activist scores)***
Communication Styles (pp. 172, 176 and 194) ***Designers need to incorporate more techniques for communication for Extraverted type users.*** ***(The designers in the fieldwork were found to be mainly I or Introverted types which are suited to programming but are inversely correlated with the Activist learning style))***
Learning Modalities (p. 209) ***VR tends to be a visual medium and may suit visual types of users. Non-visual users may be at a disadvantage and the designers need to give more emphasis to non-visual communication*** ***(The designers and design students were mainly visual learners and thus are likely to favour visual media and not consider use of auditory or kinaesthetic facilities in a VR world)***

Figure 10.1 Modified Elements of Designer Differences (bold indicates new guidelines)

This section will incorporate guidelines about the individual differences of VR designers that might be relevant to consider in the design of active, participatory VR learning environments. These guidelines have been derived from the questionnaire and test data produced in the fieldwork and are shown in bold in Figure 10.1 which was previously presented and discussed in Chapter 5.

10.2.2 User Differences

User Differences
Different gender *This was not investigated and more information is needed*
Different ages *This was not investigated and more information is needed*
Different attitudes and beliefs *This was not investigated and more information is needed*
Different learning styles (p. 159) ***Designers need to ensure that there are plenty of activities in the world and provide opportunities for Reflectors to observe others carrying out these activities*** ***(Student populations tend to be more Activist and Reflector and less Theorist and Pragmatist than the general population)***
Different communication styles (pp. 173, 197 and 199) ***Designers need to be aware of the differences in iNtuition (N) and Sensing (S) communication and learning styles and design the worlds to suit both types*** ***Designers need to create more opportunities for students to carry out more structured activities in VR worlds and provide step-by-step guidance for Sensing types.*** ***(N is dominant in VR designers and VR design students but S is more dominant in high school and adult populations)***
Different modalities (p. 209) ***Designers need to include auditory and kinaesthetic features in VR learning worlds to benefit these students*** ***(Around 40%-60% of the adult and younger populations are not visual learners)***

Figure 10.2 Modified Elements of User Differences (bold indicates new guidelines)

Providing data for user differences was beyond the scope of this thesis; however, Chapters 7 and 8 presented information about differences in learning styles and communication styles of possible students' populations. A small number of studies have also found other differences in the way that users approach VR. These differences can be incorporated into the model as information about possible factors for designers to consider, but more research is needed in order to provide design guidelines.

The issues and guidelines relevant to the identification and assistance of typical users are given in Figure 10.2. The new guidelines from fieldwork and related literature are highlighted in bold.

10.2.3 Help Systems

Help Systems
Direct Feedback (p. 95) *Objects etc. should give direct feedback to the users* Immediate and Delayed Feedback (pp. 94 and 96) *Designers need to use collision detection to increase realism and sense of presence and assist the user in navigating around the world* *If teachers or trainers are going to given overall (delayed) feedback to users after they have completed their VR session then video-tapings or other methods of recording behaviours might be necessary to link feedback to actions* Exploit VR Media (p. 99) *Help systems are necessary in VR worlds and should exploit all the capabilities of the system* Different Modalities (pp. 210 and 214) ***Natural auditory help systems would be of benefit to auditory learners and some visual learners*** ***Designers need to ensure that text and voiced systems are available and are designed to be a natural part of the VR world*** ***(Visual learners had no significant preference for text over voiced help systems)*** Natural and Realistic Techniques (p. 99) *Avatars can be used to speak to the users either by intelligence or by other expert users (e.g. the teacher or trainer)* *Help should not be accessed by key presses, it should seem to be natural to the world, so activating objects like help books, posters; PDAs (personal digital assistants) could be used as mediators between the world and the text instructions* *Textures could be used to indicate pages of a book or text messages on a mobile telephone for example*

Figure 10.3 Modified Elements of Help Systems (bold indicates new guidelines)

Some of the fieldwork concerning learning modalities has relevance to the need to provide different help systems. Although it is generally assumed that visual learners may prefer visual text and auditory learners verbal text, the fieldwork in this thesis suggested that many visual learners have a preference for auditory instructions when they are presented in a natural and 'within-context' way. Guidelines from the field studies carried out in Chapter 9 are shown in bold in Figure 10.3.

10.2.4 The Final Model

There are still many issues to be resolved in the provision of adequate and effective help facilities. This thesis intended to use speech recognition to enable the communication between user and virtual world to be more natural but this was not possible given the technical resources at the time. It would be useful to explore help choices using more modern speech systems and immersive VR worlds with haptic devices with a wide variety of users with different learning modalities, to investigate their choices further. It would also be interesting to explore the issue of Myers-Briggs types to discover if there is a difference in help choices for the different types. In particular, the Sensing types may prefer to have short written step-by-step instructions and the Feeling types may prefer to have more communication with virtual characters. Sensing types may certainly have problems with getting sufficient help and guidance within the framework of an active, exploratory VR world.

This chapter has presented all the refinements to the general design model gathered from the fieldwork and related literature. The areas that have been addressed are shown in bold in Figure 10.4, which shows the overview of elements considered in the final model. This model shows groups of elements that need to be considered by designers and feed into the design of the central element, the VR learning environment. The help system is seen in this model as an integral part of the learning world. Most of the elements in the model feed into the learning environment that also contains the help system, but the elements of the Help Systems box are shown to directly have an impact on the help system itself.

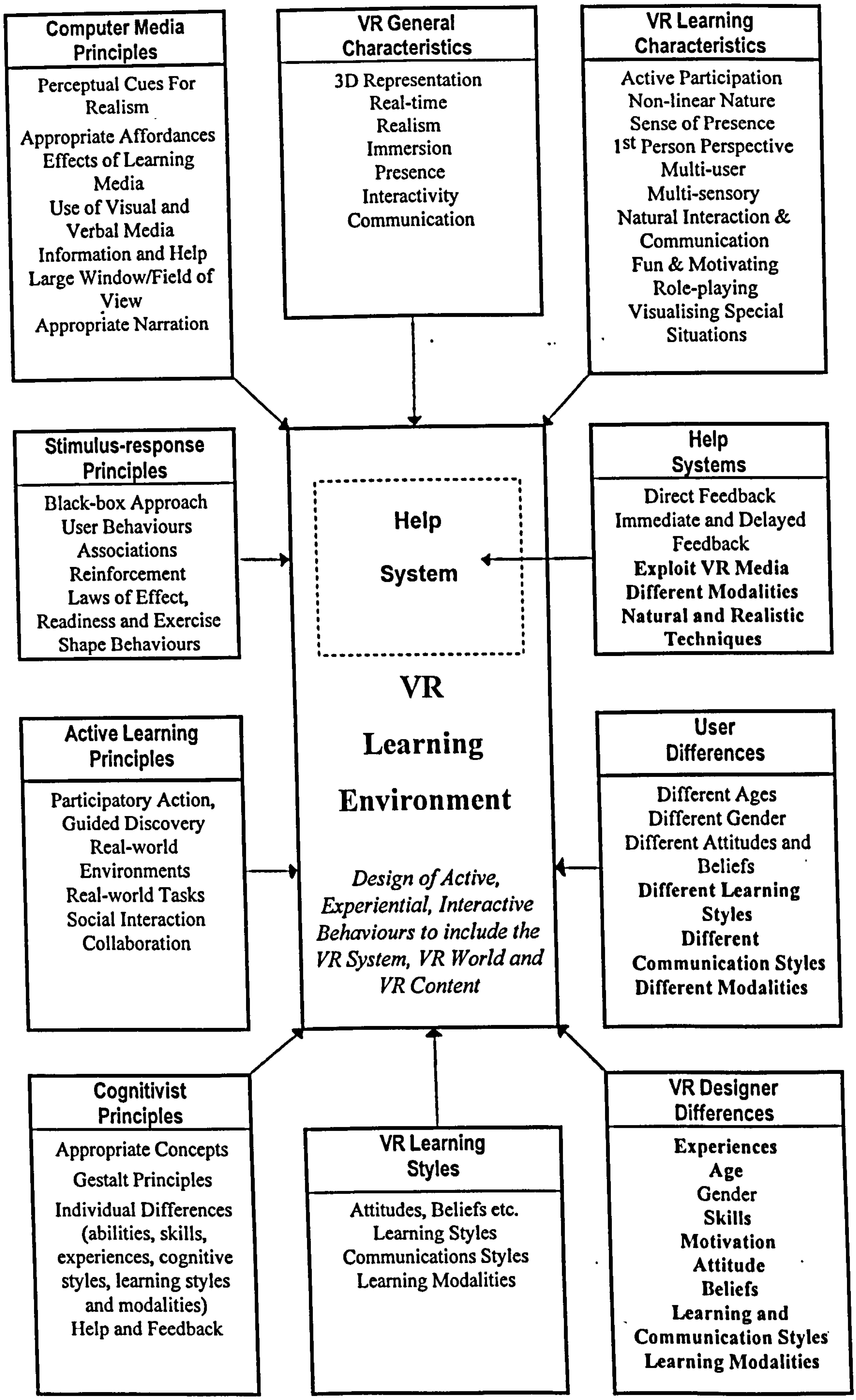

Figure 10.4 Overview of the Design Model for Active, Participatory VR Learning Environments (bold indicates new guidelines from the fieldwork)

10.3 Limitations of the Model and Further Research

The model presented here has been developed using principles derived from the literature and from field studies in this thesis. As such it is only the first step towards a complete design model. Indeed it is possible that completeness will never be obtained because there are so many other issues that could be included as the number of boxes and list of elements is not meant to be exhaustive and other areas could be included in the model. In particular, the model could be extended to include issues of usability (Kaur, 1998), design of abstract worlds (Salzman et al, 1999), design for effective learning outcomes and user instructions and design of facilities to improve navigation and orientation in the world.

The guidelines that have been derived from fieldwork are the result of only one set of experiments using a small number of VR designers. As such they may be limited in their reliability and validity. Indeed, more than half the participants in this thesis consisted of VR design students. Although it has been argued that these students may represent VR designers of the future, no evidence has been provided that this assumption is true. Although the VR design module is an option, the students may have chosen it for other reasons. Proof could be obtained by monitoring the types of jobs that these students get; however, the university does not do such monitoring. Also given the decline in the VR market it may be that whilst the students would like to work as VR designers they are unable to find this type of employment. Further field studies are needed to investigate the learning differences of a larger number of VR designers, especially those who have chosen to build VR learning environments rather than other types of applications.

In its current state, the model consists of a proposed set of broad guidelines at a top-level stage. Further work is needed before these guidelines could be produced in a form that can be easily interpreted and followed by VR designers. However, although limited, it is fair to conclude that these guidelines highlight a number of elements that should be considered in order to create active, participatory learning environments for users.

Before the guidelines can be taken any further, they need to be tested for validity. These guidelines need to be assessed to see if they do indeed create more active, participatory worlds. In order to do this, firstly, criteria would be needed to evaluate the active nature of resulting VR medium and secondly, designers would need to create worlds that can be assessed for the active nature of VR medium. Such criteria are not yet available in the current literature and separate field studies are needed to derive and test such criteria. Also as discussed previously, it would be very difficult to assess the work of VR designers, as this tends to be the property of their clients. It would, therefore, be necessary to persuade VR designers to produce worlds in an experimental situation, which, given the time needed to produce such worlds, may be difficult to undertake without some monetary compensation.

It is not really necessary for VR designers to have specialist knowledge about the design of learning material if they work alongside education or training specialists. However, they do need to be more aware of the effectiveness for VR as an active, learning medium. There does not seem to be any research that provides evidence of its effectiveness, only its enjoyment with children (Byrne, 1993; Byrne and Furness, 1994). Before the claims of researchers (e.g. Helsel, 1992; Mason, 1996; Pantelidis, 1993) can be taken forward it is necessary for fieldwork to show that users, even if only the active learning types, do benefit from active, participatory VR worlds. It would have been helpful to compare the effectiveness of an active learning world versus a non-active learning world on a group of users, perhaps correlating their attitudes and performance with their own learning style preferences. Such an experiment could be extended to consider the kind of help that needs to be given to those students who find it difficult to learn in an active exploratory manner.

Although the literature suggests that active learning media benefit active learners (see Chapter 4), it is also necessary to provide help and guidance for non-active learners who may find it difficult to reach satisfactory learning outcomes without proper help and assistance. Researchers have argued that VR worlds should be designed to enhance the user's sense of presence in the virtual world (Vince, 1998; Winn, 1997) and it has been argued (in Chapters 4 and 9) that help systems should be natural and 'within-context' in order to do this, e.g. use of auditory communication as provided in the real world. Whilst it may be difficult to provide speech recognition in current VR systems, it is reasonably easy to provide appropriate sounds and auditory instructions and the fieldwork in this thesis suggests that this should be encouraged given that almost half the visual dominant participants preferred receiving instructions in this manner.

The lack of design of auditory help systems was considered in relation to the learning modality profiles of the designers. Those designers with auditory profiles may prefer auditory instructions, those with visual profiles, visual instructions. However, correlations could not be made as most VR designers and design students were visually dominant. The results were further limited since most of the VR designers were not available to carry out the experiment. The resulting data for VR design students indicated that almost half preferred to use auditory instructions even though they were visually dominant. One possible conclusion from these results is that auditory instructions should be included in worlds because even many visual learners would prefer them. The fieldwork, however, did not reveal why the participants preferred to use one type of instruction to another. In retrospect it would have been good to go back to the VR students to discuss this matter further.

Further research is needed to test the principles and to validate the effectiveness of the guidelines, with different types of users. This would be necessary in order to convince designers to consider the guidelines in a serious manner, especially given the constraints of costs and clients' preferences.

In summary, the limitations of the model are:

(1) The principles and guidelines, which have been derived from the literature, have not been tested empirically.

(2) The modified guidelines have been based on empirical evidence from only one set of field studies in this thesis.

(3) The field work in this study focussed upon the use of single-user desktop VR systems and designers.

(4) The model has not been tested with a range of different users.

(5) The list of areas covered and elements included are not exhaustive.

(6) The model applies mainly to the design of real world learning environments and not abstract worlds.

(7) The model does not refer to issues such as usability of hardware, usability of software, problems of navigation and orientation, novice versus expert users and use of speech recognition systems and haptic devices.

(8) There are many guidelines and it may be necessary to emphasise the most important ones in a form that can be used by designers as part of the design process.

(9) The assumption that VR worlds should be active and participatory has not been proven.

(10) The assumption that VR designers with active learning profiles would create more active, participatory worlds has not been tested.

The research carried out in Chapter 9 was directed upon the choice of voiced and text instructions. The experiment provided short instructions in order to make sure that the students could remember them easily. There did not seem to be any gender effect caused by the use of a female voiced avatar. The experiment was originally intended to incorporate the use of speech recognition facilities, but these proved to be too ambitious given the current state of technology and resources. There are still many issues to be resolved in the provision of adequate and effective help facilities. Further research is needed to investigate the use of help systems with general users to investigate the choices of auditory and kinaesthetic learners. It would also be useful to explore help choices using more modern VR systems that incorporate speech and haptic devices to see if these make a difference. It would also be useful to explore the issue of Sensing and Feeling types of learners to find out what kind of help and guidance would be suited to their particular communication styles. Feeling types are person-oriented and might find two-way communication with a helpful avatar to be the most appropriate form of help. Sensing types may need to have structured help and guidelines on how to do this, since they tend not to like the exploratory nature of an active learning medium.

To summarise, the following areas are identified for further research from this thesis:

(1) To test and validate the model using a larger number of VR designers, including more designers of non-desktop VR systems.

(2) To test and validate the model using a number of different types of users.

(3) More research is needed to consider the aspects of designing for age differences and gender differences in students.

(4) Principles and guidelines are needed to cover the design of abstract worlds.

(5) Research must address the problems of navigation and orientation for users and relate these to suitable design guidelines.

(6) More investigation and research of help systems is needed, especially the use of intelligent agents, teachers communicating in multi-user worlds and the use of speech recognition systems.

(7) Lack of haptic devices is a problem for kinaesthetic types of learners and modern VR design systems need to include these features for effective learning. Use of haptic help and feedback needs to be considered in more detail.

(8) The assumption about learning styles and the resulting types of learning worlds needed to be tested.

Overall, this thesis has presented a large number of broad guidelines for the design of VR learning environments and presented them in the form of a top-level model. This model is still only at a first-step stage and more research is needed to validate the elements and principles and to explore each in more depth before such guidelines can be published for designers to follow in detail. Although the elements have been judiciously selected but without validation, many of these principles have been derived from the literature on VR and on general learning. As such the model, whilst ambitious in its offerings, is able to provide some guidance, even in its current state, for VR designers wishing to produce more interactive VR worlds, both generally and for VR learning environments in particular.

10.4 Final Conclusions

This thesis has argued that VR has been acclaimed as having the potential for providing an active, participatory learning environment. In order to do this the world needs to be designed in a truly interactive manner; however, it has been argued that many VR worlds are not truly active and participatory in their interactions. Two possible reasons for this include: a lack of guidelines for the designers on how to do this successfully and inappropriate learning styles that might influence the nature of the designs. Although other reasons may exist, it is these two reasons that have been investigated within the content of this thesis.

The literature review carried out within this thesis found that there were no clear-cut guidelines for designers but there was evidence that could be used to provide the general guidelines in order to fulfil the requirements of Aim (1) (see Chapter 1). A model consisting of a number of guidelines was produced and this is presented as a first step towards providing effective guidelines for VR designers. It is reasonable to conclude that whilst there are a number of limitations of this model the guidelines might be useful as a first step toward the design of active, participatory learning environments. It is also reasonable to conclude that further research is needed to provide further validation for the selection and effectiveness of these guidelines.

Fieldwork in this thesis also investigated the attitudes, learning and communication styles of VR designers in order to answer the second reason and fulfil Aim (2) in Chapter 1. It is possible to conclude from the results that VR designers have reasonably positive attitudes towards designing VR worlds but are less positive about their use in learning/training. More research into the effectiveness of VR in learning situations may be needed to further convince designers of its benefits.

In addition, it can be concluded from the fieldwork in this thesis that VR designers may not have learning style profiles favourable for the design of active, participatory learning environments, although they do have profiles that match other computer programming personnel. However, further verification that Activist and Extroverted designers do create more active, participatory learning environments than non-Activist, non-Extraverted designers is needed to support such a conclusion. The results are very tentative in that the sample of designers was small and the results for VR design students showed slightly more active style profiles. Indeed it is also fair to say there is no proof that designers with active learning profiles would be more likely to produce more active, participatory worlds than the others. In an ideal situation, it would have been appropriate to go back to the VR designers in order to assess their designs. Unfortunately this was not possible given that many of these designers were not available for follow-up study due to career changes as a result of unfavourable VR market conditions in the UK.

Finally, whilst the literature suggests that visually dominant learners may prefer text instructions and auditory learners voiced instructions, it cannot be concluded from this research that this is true for VR. Instead, since almost half of visually dominant VR design students preferred to use voiced instructions, it may be concluded that auditory help systems should be included in VR learning environments given that they seem to be more natural, representative of the real world, enhance the user's sense of presence and be more appropriate for active, participatory learning environments. Further research is needed to verify this.

Overall this thesis has shown that whilst the learning style profiles of VR designers may not be suitable for the design of active, participatory VR learning environments, a number of elements can be derived from the literature that could form the basis for suitable guidelines that could compensate for this.

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Appendices

Appendix 1: Bloom's Taxonomies

Bloom identified three domains of educational activities: cognitive (mental skills), affective (feelings and emotions) and psychomotor (manual or physical skills).
The three domains are divided into subdivisions and arranged in a hierarchy, from the simplest to the more complex behaviours. Each category of behaviour must be mastered before the next one can be tackled.

Cognitive Domain

Competence	Skills Demonstrated
Knowledge	• observation and recall of information • knowledge of dates, events, places • knowledge of major ideas • mastery of subject matter
Comprehension	• understanding information • grasp meaning • translate knowledge into new context • interpret facts, compare, contrast • order, group, infer causes • predict consequences
Application	• use information • use methods, concepts, theories in new situations • solve problems using required skills or knowledge
Analysis	• seeing patterns • organization of parts • recognition of hidden meanings • identification of components
Synthesis	• use old ideas to create new ones • generalize from given facts • relate knowledge from several areas • predict, draw conclusions
Evaluation	• compare and discriminate between ideas • assess value of theories, presentations • make choices based on reasoned argument • verify value of evidence • recognize subjectivity

Appendix 1a: Bloom's Taxonomy or Hierarchy of Learning (Bloom, 1956)

Affective Domain

This domain includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes. The five major categories listed in order are:

Receiving phenomena: Awareness, willingness to hear, selected attention.	Examples: Listen to others with respect. Listen for and remember the name of newly introduced people. Keywords: asks, chooses, describes, follows, gives, holds, identifies, locates, names, points to, selects, sits, erects, replies, uses.
Responding to phenomena: Active participation on the part of the learners. Attends and reacts to a particular phenomenon. Learning outcomes may emphasize compliance in responding, willingness to respond, or satisfaction in responding (motivation).	Examples: Participates in class discussions. Gives a presentation. Questions new ideals, concepts, models, etc. in order to fully understand them. Know the safety rules and practices them. Keywords: answers, assists, aids, complies, conforms, discusses, greets, helps, labels, performs, practices, presents, reads, recites, reports, selects, tells, writes.
Valuing the phenomena: The worth or value a person attaches to a particular object, phenomenon, or behaviour. This ranges from simple acceptance to the more complex state of commitment. Valuing is based on the internalisation of a set of specified values, while clues to these values are expressed in the learner's overt behaviour and are often identifiable.	Examples: Demonstrates belief in the democratic process. Is sensitive towards individual and cultural differences (value diversity). Shows the ability to solve problems. Proposes a plan to social improvement and follows through with commitment. Informs management on matters that one feels strongly about. Keywords: completes, demonstrates, differentiates, explains, follows, forms, initiates, invites, joins, justifies, proposes, reads, reports, selects, shares, studies, works.

Psychomotor Domain

The psychomotor domain includes physical movement, coordination, and use of the motor-skill areas. Development of these skills requires practice and is measured in terms of speed, precision, distance, procedures, or techniques in execution. The seven major categories listed in order are:

Perception: The ability to use sensory cues to guide motor activity. This ranges from sensory stimulation, through cue selection, to translation.	Examples: Detects non-verbal communication cues. Estimate where a ball will land after it is thrown and then moving to the correct location to catch the ball. Adjusts heat of stove to correct temperature by smell and taste of food. Adjusts the height of the forks on a forklift by comparing where the forks are in relation to the pallet. Keywords: chooses, describes, detects, differentiates, distinguishes, identifies, isolates, relates, selects.
Set: Readiness to act. It includes mental, physical, and emotional sets. These three sets are dispositions that predetermine a person's response to different situations (sometimes called mindsets).	Examples: Knows and acts upon a sequence of steps in a manufacturing process. Recognize one's abilities and limitations. Shows desire to learn a new process (motivation). NOTE: This subdivision of Psychomotor is closely related with the "Responding to phenomena" subdivision of the Affective domain. Keywords: begins, displays, explains, moves, proceeds, reacts, shows, states, volunteers.
Guided response: The early stages in learning a complex skill that includes imitation and trial and error. Adequacy of performance is achieved by practicing.	Examples: Performs a mathematical equation as demonstrated. Follows instructions to build a model. Responds hand-signals of instructor while learning to operate a forklift. Keywords: copies, traces, follows, react, reproduce, responds
Mechanism: This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency.	Examples: Use a personal computer. Repair a leaking faucet. Drive a car. Keywords: assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches.

(Clark, D, 1999)

Appendix 2: Affective Questionnaires

Designer Questionnaire

IN CONFIDENCE

D. Information about Virtual Reality Developers.

Name: ______________________

Gender: ____________ Age: ____________

The following questions are concerned with you and your work in virtual reality.

1. Please describe the type of virtual reality work that you do and the application/areas that you have developed VR.

2. What do you like best about developing VR software (e.g. using SCL, creating detailed shapes etc.)?

3. Please indicate any experience you have had of developing any training software.

4. Please indicate any experience you have had of developing VR training software.

2

IN CONFIDENCE

IN CONFIDENCE

<u>The following questions are concerned with the provision of help for users.</u>

5. How do you usually provide 'help' facilities for the users of your software?

6. How do you ensure that they are indeed 'helpful'?

7. What other 'help' facilities would you like to provide your users?

3

IN CONFIDENCE

IN CONFIDENCE

The following questions are concerned with your beliefs about training media.
For the following three questions, please rank your beliefs about each by putting a circle around the number which most represents your feelings/thoughts

8. How important is the use of computers in training?

1	2	3	4
Very Important	Important	Not very Important	Unimportant

9. How important is the use of virtual reality as a training tool?

1	2	3	4
Very Important	Important	Not very Important	Unimportant

10. How effective is the use of virtual reality as a training tool?

1	2	3	4
Very Effective	Effective	Not very Effective	Ineffective

In the following 3 questions, please indicate your beliefs about computers and virtual reality by ticking the statement with which you mostly agree.

11.

Beliefs about using computers in training courses	*Tick one*
Should not be used or used only on computer programming courses.	
Should be used only as an alternative with people having the choice of different forms of computer media.	
Should be used alongside other forms of media on suitable training courses.	
Should be used as the main form of training medium for many training courses.	
Should be used instead of other forms of training media for all types of training.	

12.

Beliefs about using virtual reality in training courses	*Tick one*
Should not be used or used only on virtual reality programming courses.	
Should be used only as an alternative with people having the choice of different forms of computer media.	
Should be used alongside other forms of media on suitable training courses.	
Should be used as the main form of training medium for many training courses.	
Should be used instead of other forms of training media for all types of training.	

13.

Beliefs about computers and the future of mankind.	*Tick one*
They should not be encouraged and have caused unemployment and anti-social behaviour.	
Computers have some use but it should be limited because they can cause huge errors.	
Computers can be useful for many things but will not be able to take over every job.	
Computers are very useful and should be used more and more effectively in the future.	
Computers are wonderful and should be used by everyone and everything in the future.	

IN CONFIDENCE

The following questions are concerned with the enjoyment that you have experienced in developing and using different types of software.

Please give overall rankings on a scale of 1 to 4 for each type of software in general.

Rankings:-

1	2	3	4
Very Enjoyable	Enjoyable	Not very Enjoyable	Not Enjoyable at all

14. Please indicate in the table below tick ALL the software that you have *developed* and rank each one on its enjoyment factor by writing in the most appropriate number from the above ranks.

Type of Software	*Tick ALL developed*	*Enjoyment Ranking for each type*
Games for entertainment		
Educational games		
Word-processing software		
Databases		
Computer-based training software		
Multimedia software		
Superscape virtual reality software		
Other virtual reality software		

14. Please indicate in the table below tick ALL the software that you have *used* and rank each one on its enjoyment factor by writing in the most appropriate ranking number.

Type of Software	*Tick ALL used*	*Enjoyment Ranking for each type*
Games for entertainment		
Educational games		
Word-processing software		
Databases		
Computer-based training software		
Multimedia software		
Superscape virtual reality software		
Other virtual reality software		

THANKYOU VERY MUCH FOR FILLING IN THE QUESTIONNAIRE AND HELPING ME WITH MY RESEARCH.

5

IN CONFIDENCE

Design Student Questionnaire

Questionnaire about your computer experience and attitudes:

In the following questions, please rate your answer on a scale of 1 to 5. For example in the first question, 1 would indicate Little Experience, 5 would indicate Much Experience. Put a circle around the number which best fits your answer. Circle ONLY ONE number for each question.

1. How much experience of using computers have your had?

Little Experience	1	2	3	4	5	Much Experience

2. Do you think/feel that computers should be used for training purposes?

Not at all	1	2	3	4	5	All the time

3. Do you think/feel that computers are 'good for the future of mankind'?

Definitely Not	1	2	3	4	5	Yes Indeed

4. Do you think/feel that computer-based software is an effective training medium at present?

No	1	2	3	4	5	Yes

5. Do you think/feel that computer-based software could be an effective training medium in the future?

No	1	2	3	4	5	Yes

6. Do you think/feel that virtual reality is an effective training medium at present?

No	1	2	3	4	5	Yes

7. Do you think/feel that virtual reality could become an effective training medium in the future?

No	1	2	3	4	5	Yes

Enjoyment of different types of computer software.

The following represents a numerical scale of enjoyment (or pleasure).

1	2	3	4	5
little or no enjoyment	some enjoyment	reasonable enjoyment	much enjoyment	great enjoyment

In the following questions could you please indicate which ones you have used or not used by placing a tick in the box below each type of software. Then indicate your enjoyment rating by recording the appropriate number in the box below the tick.

8. Types of software that you HAVE used

Tick all the types of software that you HAVE USED and please give an indication of your enjoyment for each type ticked?

TYPE OF SOFTWARE	games for education	games for fun	word processing	spread-sheets	databases	computer-based-training packages	multimedia packages	virtual reality software	computer programming software
TICK									
RATING									

9. Types of software that you HAVE NOT used

Tick all types that you HAVE NOT USED and give an indication of your expectation of the possible enjoyment value for each type ticked?

TYPE OF SOFTWARE.	games for education	games for fun	word processing	spread-sheets	databases	computer-based-training packages	multimedia packages	virtual reality software	computer programming software
TICK									
RATING									

Please add any comments about the methods of help that you have experienced from using these packages.

____

____

____

10. If you have ever used a form of multimedia training software, please describe good points and bad points and how effective it was for your training? If you have used more than one, then please describe up to three of them

(i) ____________________

____

____

____

____

(ii) ____________________

____

____

____

____

(iii) ____________________

____

____

____

____

11. If you have ever used a form of virtual reality, please describe good points and bad points.

____
____
____
____
____

12. If you have used virtual reality as a form of training, describe how effective you thought it was.

____
____
____
____
____

13. If you have never experienced virtual reality, describe some of your thoughts or feelings about what you think its good points and bad points may be.

____
____
____
____
____

14. **What forms of help would you like with virtual reality software?**

In the following questions, please consider how effective the following types of help method would be for you if you were using virtual reality for training for real-life situations (e.g. for fighting fires or DIY). Rate your answer on a scale of 1 to 5 by placing a circle around the number which best fits your answer. Circle ONLY ONE number for each question.

A. A well written manual?

Not effective	1	2	3	4	5	Very effective

B. Good telephone support line?

Not effective	1	2	3	4	5	Very effective

C. Online text help system?

Not effective	1	2	3	4	5	Very effective

D. Online multimedia help system (with sounds, pictures and videos)?

No	1	2	3	4	5	Yes

E. Real Instructor whom you can ask for help?

No	1	2	3	4	5	Yes

F. Virtual reality instructor whom you can ask or interact with for help?

No	1	2	3	4	5	Yes

F. Would you like any other methods of help?

____

____

____

____

____

15. Could you please give some of your beliefs about virtual reality. Please tick one box for each question to show your response.

Questions	YES	NO	UNSURE
Do you believe that VR is the ultimate form of training medium?			
Do you believe that VR is only useful for enjoyment purposes?			
Do you believe that social interaction with people will decrease if VR is constantly used?			
Do you believe that VR has to have all the senses included such as taste, smells, touch etc.			
Do you have to wear a head-set device to believe that you are part of the VR world?			
Do you believe that realistic 'touch' sensations have to be part of VR?			
Would you prefer a 'virtual world' to the 'real world'?			

16. Are there any disadvantages or dangers that could result from using VR?

____

____

____

____

____

____

Appendix 3: Affective Questionnaire Raw Data

Questions for VR Designers concerned with Beliefs about Training Media

Individual ratings for the first six questions.

Q1	Q2	Q3	Q4	Q5	Q6
2	2	2	3	3	3
2	3	3	3	2	3
2	2	1	3	3	4
1	2	3	3	3	4
2	2	2	3	3	4
2	2	2	3	3	4
2	2	1	3	3	3
2	2	2	4	3	4
1	2	2	3	3	4
2	2	2	3	3	3
2	2	2	3	3	4
1	2	2	4	4	4
2	1	1	3	3	4
2	2	2	3	3	3
2	2	2	3	3	3
2	2	1	3	3	4
2	2	1	3	3	4
2	2	2	3	2	4
2	3	3	3	3	4
2	2	2	3	3	3
1	1	1	3	4	4
2	3	3	3	3	3
2	2	2	3	3	4
2	2	2	3	3	4
3	3	3	3	3	3
2	2	2	3	3	3

Questions for VR Designers about Enjoyment of Using Software

Individual ratings for Question 14.

Q14a	Q14b	Q14c	Q14d	Q14e	Q14f	Q14g	Q14h
0	0	0	0	0	0	1	0
0	0	0	0	0	0	2	0
0	0	0	0	0	0	1	0
0	0	0	3	0	2	1	1
0	0	0	3	0	2	2	3
0	0	0	2	0	0	1	0
0	0	0	3	0	0	1	0
0	0	0	0	0	0	1	0
0	0	0	3	0	0	1	0
0	0	0	0	0	0	2	0
1	0	2	2	2	2	1	0
0	2	0	0	2	2	1	2
2	0	0	0	2	2	1	0
1	0	0	0	0	2	2	0
0	0	0	0	0	0	2	0
1	0	0	0	2	2	2	0
0	0	0	2	0	0	1	4
0	0	0	0	0	2	1	1
1	0	0	2	0	0	1	0
0	0	0	0	1	0	1	0
0	0	0	3	3	2	1	4
0	0	0	0	0	0	1	0
1	0	2	2	4	2	2	0
0	0	0	0	0	0	1	0
0	0	0	0	0	0	2	0
0	0	0	0	0	0	1	0

Questions for VR Designers about Beliefs of Enjoyment of Software not used

Individual ratings for Question 5.

Q15a	Q15b	Q15c	Q15d	Q15e	Q15f	Q15g	Q15h
2	0	3	0	0	2	1	0
2	0	2	2	0	2	2	0
1	2	3	4	3	2	1	3
1	2	3	3	2	2	1	1
1	0	3	3	3	2	2	2
1	0	4	3	4	4	2	4
2	0	3	0	2	2	1	2
1	2	2	0	0	0	1	0
1	0	3	3	2	1	1	0
2	2	3	4	2	2	1	0
1	2	3	3	3	2	1	1
1	1	2	2	1	1	1	1
1	2	3	4	3	2	1	3
1	3	3	4	3	3	2	2
2	3	3	3	2	2	1	2
1	3	3	3	3	2	2	2
0	0	2	2	0	0	1	4
1	0	4	4	3	2	2	2
1	2	2	2	3	3	1	3
0	3	2	2	3	2	1	0
2	2	3	4	2	2	1	2
2	2	3	3	2	2	2	2
1	0	2	2	4	2	2	0
1	2	4	4	2	3	1	0
2	2	4	4	3	2	1	2
1	2	3	4	3	2	1	4

Questions for VR Design Students about Computer Experience and Attitudes

Ratings for first 7 questions.

Q1	Q2	Q3	Q4	Q5	Q6	Q7
5	3	4	2	3	3	4
5	3	4	2	3	2	5
5	5	5	5	5	4	5
4	4	4	4	4	2	4
5	5	5	3	5	3	5
4	2	3	1	2	2	3
2	2	1	1	2	1	2
5	3	4	2	4	3	4
4	3	3	3	4	3	4
4	4	3	3	4	2	4
4	3	4	2	5	2	5
5	3	3	3	3	2	3
3	3	3	4	4	2	5
4	4	3	4	5	4	4
5	3	3	4	4	4	4
5	5	5	4	4	5	4
5	3	4	3	3	1	5
3	3	4	3	5	2	5
5	3	5	3	3	3	4
4	4	4	1	4	1	3
4	3	2	3	4	3	4
5	5	4	5	5	4	4
4	4	3	4	4	2	4
5	3	3	4	5	4	4
3	3	4	4	4	3	4
4	3	5	3	5	4	5
5	4	4	4	4	2	4
3	3	4	4	4	5	5
5	5	5	3	5	3	5
4	4	5	3	4	2	4
5	5	4	4	4	3	4
4	4	3	3	4	2	4
5	4	2	3	4	2	3
4	3	3	4	4	3	4
4	5	5	3	5	2	4
4	4	3	3	4	3	5
5	3	3	3	4	2	4
4	4	4	4	5	3	4
4	4	4	4	4	3	4
5	4	3	4	3	1	3
3	3	3	4	4	1	1
4	4	4	3	4	2	4
5	5	3	4	5	2	4
5	4	5	3	4	1	3
4	3	3	2	5	3	5
3	4	4	4	4	3	5
5	5	5	5	5	2	4
3	4	4	1	5	1	5

5	4	4	4	4	3	5
4	4	5	3	5	2	5
4	4	4	4	5	3	3
3	4	4	4	4	5	5
4	5	3	3	5	3	4
5	4	4	3	4	2	3
5	3	3	5	5	3	5
4	5	3	1	5	1	4
2	3	1	3	5	1	5
5	5	4	3	5	3	5
5	3	3	3	4	3	4

Questions for VR Design Students about Enjoyment of Software (used)

Enjoyment ratings for Question 8; types of software used.

Q8a	Q8b	Q8c	Q8d	Q8e	Q8f	Q8g	Q8h	Q8i
2	4	3	3	1	0	4	4	3
2	5	3	2	0	1	4	4	3
3	4	3	3	3	3	4	2	4
2	4	1	1	1	2	3	4	1
0	4	5	5	4	5	5	4	3
3	2	2	2	2	1	2	4	0
0	2	3	0	0	0	4	4	0
1	5	1	1	2	1	4	3	2
0	0	3	2	3	3	4	3	2
0	1	3	0	2	3	3	4	0
0	5	2	2	2	0	5	5	3
3	3	3	3	0	3	3	2	1
3	5	3	3	3	0	5	4	0
3	4	3	2	1	2	4	4	0
3	5	1	2	2	3	3	4	1
1	4	1	1	1	1	2	2	2
4	4	1	3	4	4	4	5	4
0	3	1	0	1	3	4	5	2
0	2	3	3	3	0	4	3	4
0	2	3	2	2	2	4	4	0
4	4	2	1	0	4	4	5	0
3	5	3	2	2	4	5	4	0
3	5	2	2	2	3	4	3	4
3	3	2	2	4	3	3	2	4
2	5	2	2	2	3	4	3	1
4	5	3	1	1	0	5	3	2
3	5	1	1	1	3	5	4	2
0	4	5	0	3	0	5	3	2
3	5	3	2	3	3	5	4	4
3	5	4	3	4	0	4	3	5
3	3	3	3	4	3	4	4	2
3	4	3	4	4	0	3	4	2
3	5	2	2	1	3	5	3	1
3	4	2	1	1	1	3	1	1
2	3	4	3	3	3	4	4	4
4	4	3	3	1	0	3	3	4
0	5	2	2	1	0	3	3	3
4	5	3	2	0	0	4	2	1
4	4	3	3	3	4	5	5	4
2	5	2	2	2	1	4	3	4
2	4	1	1	1	0	3	3	0
0	2	3	3	2	1	3	3	0
2	1	2	2	3	2	3	2	5
0	5	1	0	0	2	4	2	0
0	3	2	1	1	2	4	5	1
4	4	3	3	3	4	4	4	1
5	5	3	1	1	2	5	1	2

0	3	5	4	0	2	3	4	0
0	4	2	3	2	1	4	5	3
3	4	3	2	2	3	3	4	2
2	3	4	0	0	4	4	3	0
4	4	4	2	2	0	5	4	0
3	5	2	2	1	1	4	3	1
3	5	2	1	1	2	4	1	1
1	5	1	1	1	2	4	3	2
0	4	2	1	1	0	4	3	2
0	5	1	1	0	0	5	5	0
2	5	1	1	2	1	3	1	3
5	5	3	2	2	3	4	4	4

Questions for VR Design Students about Enjoyment of Software (not used)

Enjoyment ratings for Question 9; types of software not used.

Q8a	Q8b	Q8c	Q8d	Q8e	Q8f	Q8g	Q8h	Q8i
0	0	0	0	0	2	0	0	0
0	0	0	0	2	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1
2	0	0	2	2	2	2	0	1
0	0	0	0	0	0	0	0	0
3	3	0	0	0	0	0	0	0
3	0	0	2	0	0	0	0	1
4	0	0	0	0	4	0	0	0
0	0	0	0	1	0	0	0	0
0	0	0	0	0	3	4	0	3
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
4	0	0	2	0	0	0	0	0
3	0	0	0	0	3	0	0	0
1	0	0	0	0	0	0	0	1
0	0	0	0	1	0	0	0	2
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	3	0	0	0
0	0	0	0	0	0	0	0	0
2	0	0	2	0	3	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	3	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	3	0	0	0
4	0	0	0	0	3	0	0	0
0	0	0	0	1	3	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	2
2	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0
3	0	0	1	1	0	0	0	2
3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

3	0	0	0	2	0	0	0	2
4	0	0	0	0	0	3	0	0
0	0	0	0	0	0	0	0	0
0	0	0	2	1	0	0	0	1
0	0	0	0	0	1	0	0	3
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
2	0	0	0	0	2	0	0	0
1	0	0	0	1	1	1	0	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

Questions on Help Methods preferred by the VR Design Students

Ratings for Question 14 referring to different help techniques.

Q14a	Q14b	Q14c	Q14d	Q14e	Q14f
4	3	4	4	5	5
3	3	3	5	5	5
4	3	4	4	5	4
2	4	2	2	5	3
2	3	5	5	4	4
1	1	2	2	4	3
4	4	3	3	5	2
4	4	3	4	5	3
4	4	3	4	5	4
2	3	4	5	4	4
4	1	4	5	4	4
1	2	3	4	3	2
5	4	5	3	5	5
4	3	3	5	5	5
3	4	4	4	5	4
1	2	2	2	4	4
2	3	2	4	5	5
1	1	2	4	5	4
5	2	4	4	5	4
1	2	2	2	5	4
3	5	4	4	4	4
4	4	3	5	5	4
2	2	3	3	4	4
4	4	2	5	5	4
5	4	4	5	4	3
5	3	4	4	5	4
4	5	5	4	5	4
4	1	4	5	4	4
3	4	4	4	4	5
4	2	4	5	5	4
4	4	3	4	5	4
4	5	3	4	5	4
5	2	4	4	5	2
4	3	4	4	5	3
2	3	4	5	5	5
5	4	4	5	5	5
5	3	4	4	5	4
4	3	4	4	5	2
3	3	3	4	4	5
2	2	2	5	4	5
4	1	2	5	5	4
2	2	3	4	4	5
2	1	3	4	5	5
5	5	3	3	3	2
3	1	5	5	3	3
5	3	5	5	5	3
4	2	4	4	5	3
1	2	3	4	4	4

1	2	3	5	4	5
2	2	1	3	5	4
3	2	4	5	3	3
4	4	4	4	4	2
5	5	4	3	4	3
3	4	4	4	5	5
5	5	4	5	5	5
5	3	3	4	3	3
3	1	1	4	5	5
3	3	3	5	3	3
4	3	5	5	5	4

Questions about Beliefs about Virtual Reality for VR Design Students

Individual ratings for Queston 15.

Q15a	Q15b	Q15c	Q15d	Q15e	Q15f	Q15g
2	1	3	2	3	3	1
1	1	3	3	1	3	2
1	1	1	1	1	1	1
3	1	2	2	1	1	2
1	1	2	1	2	2	1
1	1	3	3	1	3	1
1	1	3	2	2	2	1
2	2	2	2	2	2	1
2	2	2	2	2	2	2
1	1	3	1	2	2	1
3	1	1	3	3	1	1
1	1	1	1	1	3	1
2	2	1	3	1	1	2
2	1	1	3	3	2	1
2	1	2	2	2	3	1
3	3	2	3	3	3	2
3	3	1	2	2	2	1
1	1	2	1	1	1	1
1	1	3	1	2	1	1
1	1	2	1	1	1	1
2	1	3	2	1	3	1
1	1	3	3	3	3	1
1	1	2	1	1	3	1
1	1	3	1	1	1	1
2	2	1	2	2	3	1
1	1	1	3	1	3	1
1	1	1	3	3	3	3
1	1	3	1	1	2	1
1	3	3	2	3	3	1
2	1	3	1	3	1	1
2	1	1	3	3	3	1
1	1	3	1	3	1	1
1	2	1	3	2	3	1
2	1	1	1	1	3	3
2	2	1	1	1	3	1
1	1	1	2	2	2	2
1	1	1	3	1	3	1
1	1	1	1	2	1	1
2	3	3	2	1	2	2
1	2	1	3	2	3	1
1	1	3	1	2	3	1
1	1	1	3	1	2	1
1	1	1	1	1	1	1
1	1	3	1	2	1	1
1	1	1	2	2	2	1
1	1	1	1	2	2	1
2	3	2	1	1	3	2

1	1	3	3	1	1	1
1	1	3	1	2	1	1
1	1	3	2	2	3	1
1	1	2	3	2	3	1
1	3	2	3	1	3	2
2	1	2	2	2	2	1
1	1	1	3	3	3	1
1	1	1	1	1	1	1
1	1	2	1	2	3	1
2	3	3	3	1	1	1
2	1	3	1	1	1	1
1	1	1	2	1	2	1

Appendix 4: Kolb LSI

This is an example of the Kolb Learning Style Inventory (LSI)

Learning Style Inventory (adapted from Kolb and McCarthy)

This survey is designed to explore the way you prefer to learn.

> Look at the four statements in each row, and decide how they refer to you. Give four marks for the statement nearest to you, three to the second, two for the third and one for the statement least appropriate to you. There are no right or wrong answers.

	a	b	c	d
1	I like to get involved.	I like to take my time before acting.	I am particular about what I like.	I like things to be useful.
2	I like to try things out.	I like to analyse things and break them into parts.	I am open to new experiences.	I like to look at all sides of issues.
3	I like to watch.	I like to follow my feelings.	I like to be doing things.	I like to think about things.
4	I accept people and situations the way they are.	I like to be aware of what is around me.	I like to evaluate.	I like to take risks.
5	I have gut feelings and hunches.	I have a lot of questions.	I am logical.	I am hard working and get things done.
6	I like concrete things, things I can see, feel touch or smell.	I like to be active.	I like to observe.	I like ideas and theories.
7	I prefer learning in the here and now.	I like to consider and reflect about them.	I like to think about the future.	I like to see the results of my work.
8	I have to try things out for myself.	I rely on my own ideas.	I rely on my own observations.	I rely on my feelings.
9	I am quiet and reserved.	I am energetic and enthusiastic.	I tend to reason things out.	I am responsible about things.

(1)

Preferred Learning Style

Use the grid below to summarise your score on the Learning Styles Inventory and fill in your total score (Calculation 1) for each column in the spaces provided below.

n.b. Only put down the 'marks' you are asked for. You will notice, for instance, that the marks for 1c and 1d are not asked for. This is deliberate and not a mistake.

	CE		RO		AC		AE
1a		1b		2b		2a	
2c		2d		3d		3c	
3b		3a		4c		6b	
4a		6c		6d		7d	
8d		8c		8b		8a	
9b		9a		9c		9d	

Calculation 1

Totals CE= [ ] RO= [ ] AC= [ ] AE= [ ]

You will need these scores in the second part of the activity involving the learning kite.

To discover your preferred Learning Quadrant, complete Calculation 2 and plot the results on the Learning Style Type Grid p5

Calculation 2

AC - CE= [ ]

AE - RO= [ ]

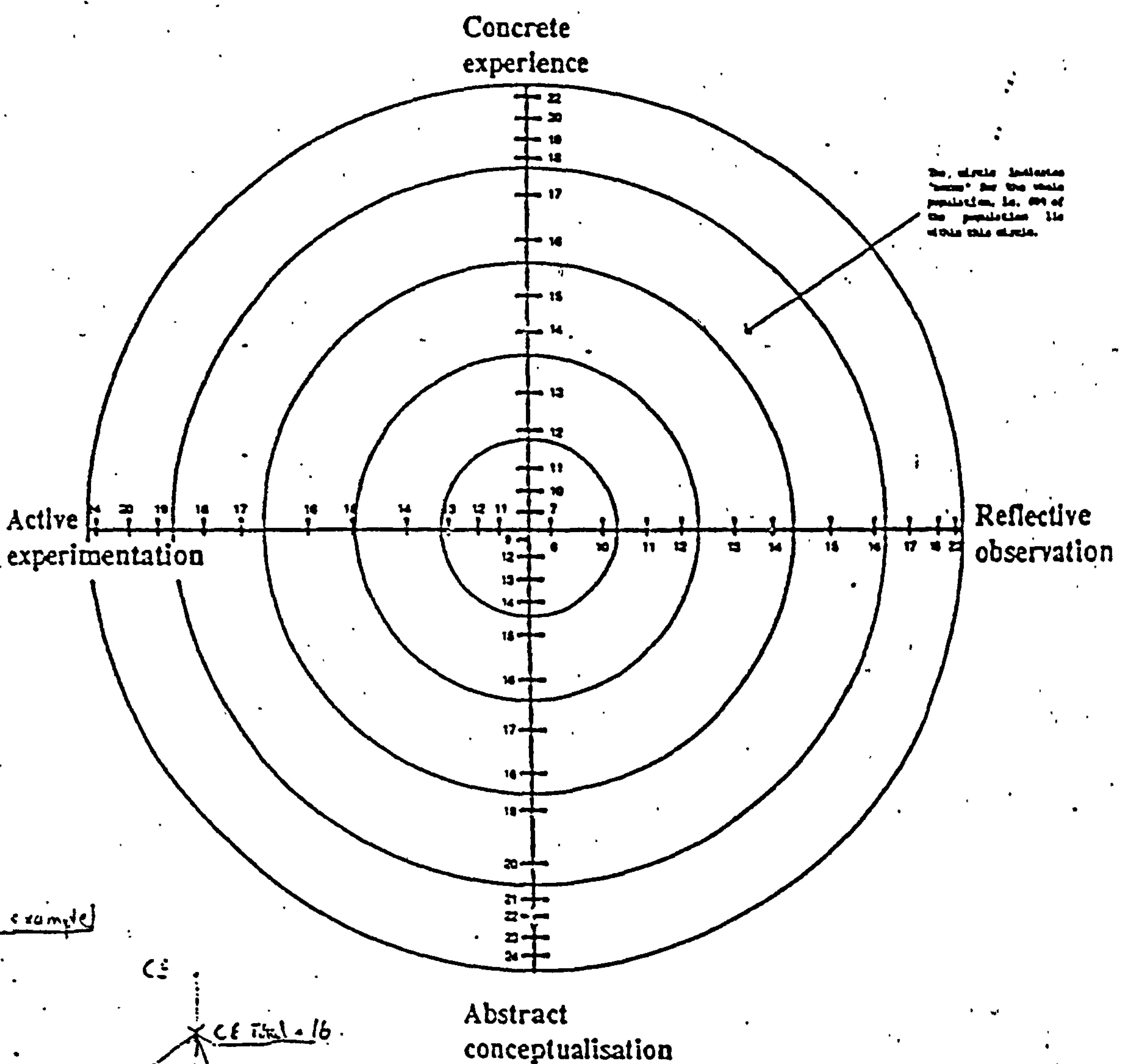
You may get a minus answer to either or both calculations It is not a mistake!

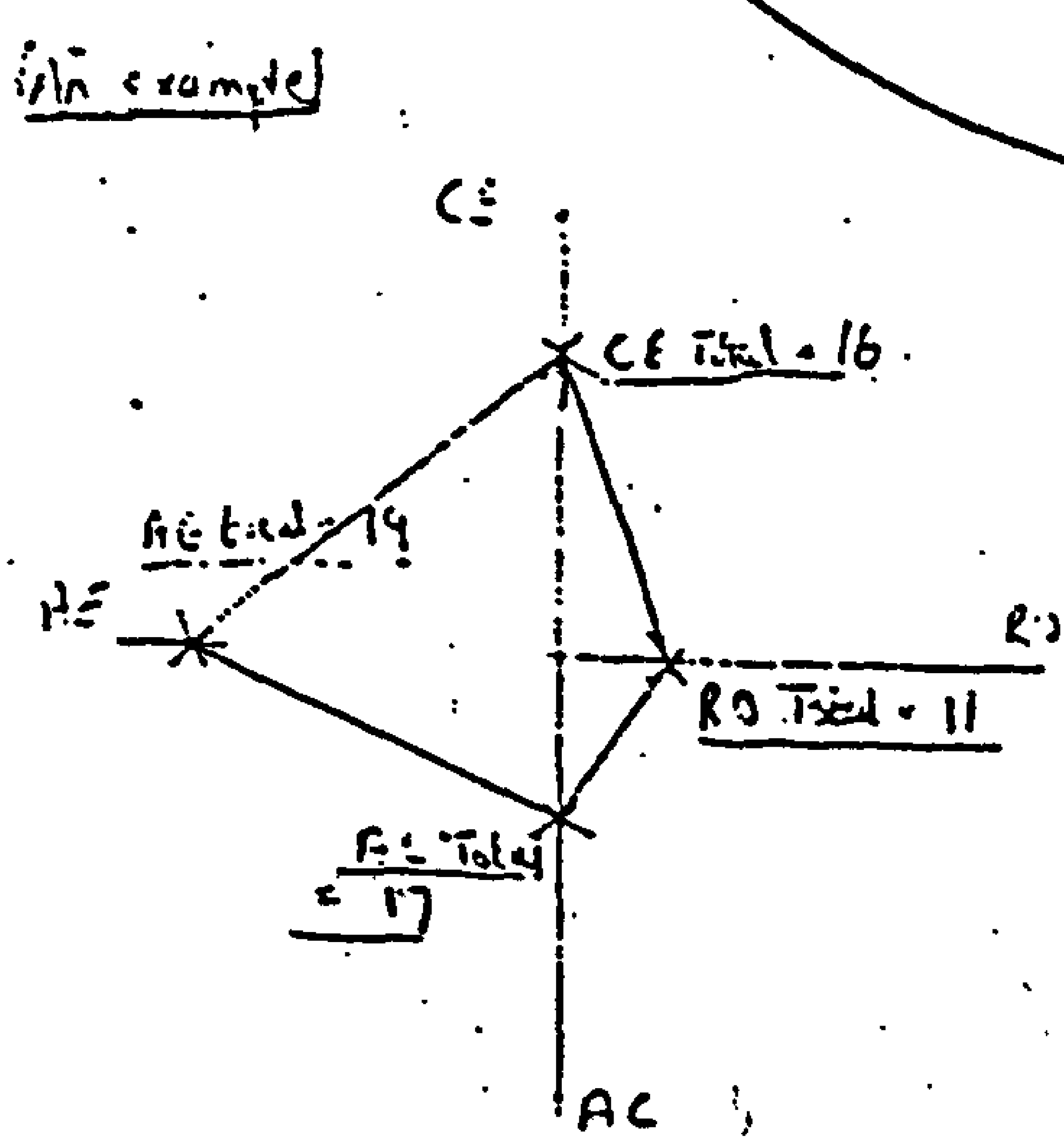
partnership

The Learning Kite

The scores you previously arrived at can now be plotted onto the diagram below to produce your Learning Kite.

CE = ____ RO = ____ AC = ____ AE = ____

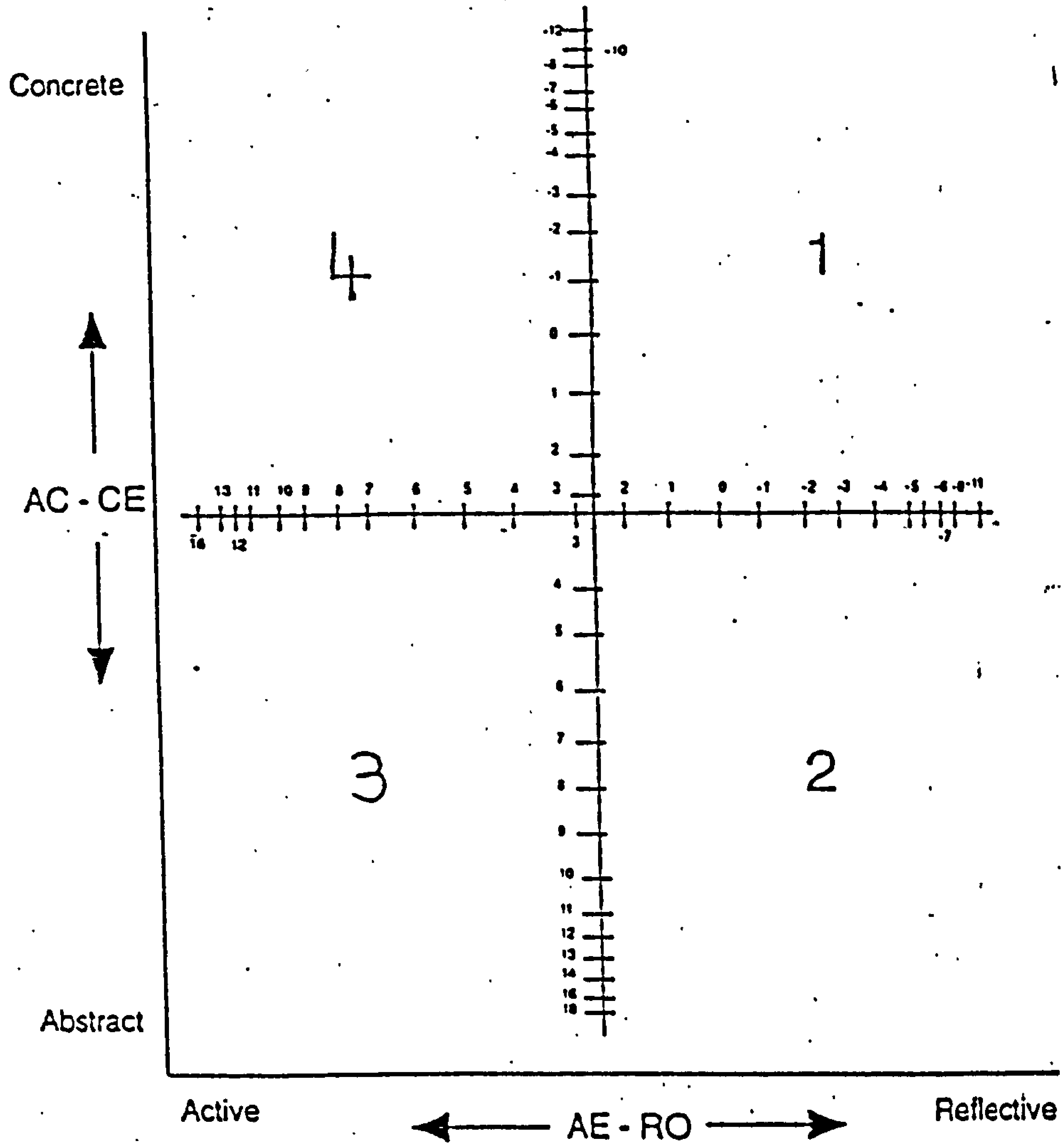




③

Learning Style Type Grid

Kolb and McCarthy



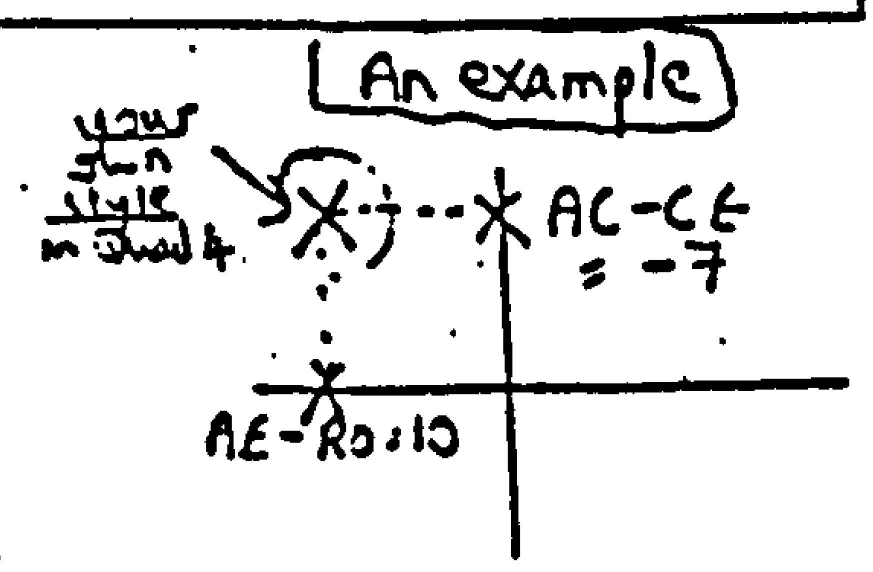
The information on the following pages gives an analysis of the strengths and weaknesses of learners in each of the quadrants above. (if your plot falls in quadrant 1 you are a type 1 learner and so on.)

partnership

To Complete

- Look back to calculation 2 on page. 2
- Plot your answer to AC-CE on the vertical axis
- Plot your answer to AE-RO on the horizontal axis

An example



Appendix 5: Honey and Mumford's Learning Styles Questionnaire (LSQ)

This is an example of Honey and Mumford' Learning Styles Questionnaire.

LEARNING STYLES QUESTIONNAIRE revised 1986

Name

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed learning 'habits' that help you benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pinpoint your learning preferences so that you are in a better position to select learning experiences that suit your style.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depends on how honest you can be. There are no right or wrong answers. If you agree more than you disagree with a statement put a tick by it (✓). If you disagree more than you agree put a cross by it (x). Be sure to mark each item with either a tick or cross.

☐ 1. I have strong beliefs about what is right and wrong, good and bad.

☐ 2. I often act without considering the possible consequences.

☐ 3. I tend to solve problems using a step-by-step approach.

☐ 4. I believe that formal procedures and policies restrict people.

☐ 5. I have a reputation for saying what I think, simply and directly.

☐ 6. I often find that actions based on feelings are as sound as those based on careful thought and analysis.

☐ 7. I like the sort of work where I have time for thorough preparation and implementation.

☐ 8. I regularly question people about their basic assumptions.

☐ 9. What matters most is whether something works in practice.

☐ 10. I actively seek out new experiences.

☐ 11. When I hear about a new idea or approach I immediately start working out how to apply it in practice.

☐ 12. I am keen on self discipline such as watching my diet, taking regular exercise, sticking to a fixed routine, etc.

☐ 13. I take pride in doing a thorough job.

☐ 14. I get on best with logical, analytical people and less well with spontaneous, 'irrational' people.

☐ 15. I take care over the interpretation of data available to me and avoid jumping to conclusions.

☐ 16. I like to reach a decision carefully after weighing up many alternatives.

☐ 17. I'm attracted more to novel, unusual ideas than to practical ones.

☐ 18. I don't like disorganised things and prefer to fit things into a coherent pattern.

☐ 19. I accept and stick to laid down procedures and policies so long as I regard them as an efficient way of getting the job done.

☐ 20. I like to relate my actions to a general principle.

☐ 21. In discussions I like to get straight to the point.

☐ 22. I tend to have distant, rather formal relationships with people at work.

☐ 23. I thrive on the challenge of tackling something new and different.

☐ 24. I enjoy fun-loving, spontaneous people.

☐ 25. I pay meticulous attention to detail before coming to a conclusion.

☐ 26. I find it difficult to produce ideas on impulse.

☐ 27. I believe in coming to the point immediately.

☐ 28. I am careful not to jump to conclusions too quickly.

☐ 29. I prefer to have as many sources of information as possible - the more data to think over the better.

☐ 30. Flippant people who don't take things seriously enough usually irritate me.

☐ 31. I listen to other people's points of view before putting my own forward.

☐ 32. I tend to be open about how I'm feeling.

☐ 33. In discussions I enjoy watching the manoeuvrings of the other participants.

☐ 34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance.

☐ 35. I tend to be attracted to techniques such as network analysis, flow charts, branching programmes, contingency planning, etc.

☐ 36. It worries me if I have to rush out a piece of work to meet a tight deadline.

☐ 37. I tend to judge people's ideas on their practical merits.

☐ 38. Quiet, thoughtful people tend to make me feel uneasy.

☐ 39. I often get irritated by people who want to rush things.

☐ 40. It is more important to enjoy the present moment than to think about the past or future..

☐ 41. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition.

☐ 42. I tend to be a perfectionist.

☐ 43. In discussions I usually produce lots of spontaneous ideas.

☐ 44. In meetings I put forward practical, realistic ideas.

☐ 45. More often than not, rules are there to be broken.

☐ 46. I prefer to stand back from a situation and consider all the perspectives.

☐ 47. I can often see inconsistencies and weaknesses in other people's arguments.

☐ 48. On balance I talk more than I listen.

☐ 49. I can often see better, more practical ways to get things done.

☐ 50. I think written reports should be short and to the point.

☐ 51. I believe that rational, logical thinking should win the day.

☐ 52. I tend to discuss specific things with people rather than engaging in social discussion.

☐ 53. I like people who approach things realistically rather than theoretically.

☐ 54. In discussions I get impatient with irrelevancies and digressions.

☐ 55. If I have a report to write I tend to produce lots of drafts before settling on the final version.

☐ 56. I am keen to try things out to see if they work in practice.

☐ 57. I am keen to reach answers via a logical approach.

☐ 58. I enjoy being the one that talks a lot.

☐ 59. In discussions I often find I am the realist, keeping people to the point and avoiding wild speculations.

☐ 60. I like to ponder many alternatives before making up my mind.

☐ 61. In discussions with people I often find I am the most dispassionate and objective.

☐ 62. In discussions I'm more likely to adopt a 'low profile' than to take the lead and do most of the talking.

☐ 63. I like to be able to relate current actions to a longer term bigger picture.

☐ 64. When things go wrong I am happy to shrug it off and 'put it down to experience'.

☐ 65. I tend to reject wild, spontaneous ideas as being impractical.

☐ 66. It's best to think carefully before taking action.

☐ 67. On balance I do the listening rather than the talking.

☐ 68. I tend to be tough on people who find it difficult to adopt a logical approach.

☐ 69. Most times I believe the end justifies the means.

☐ 70. I don't mind hurting people's feelings so long as the job gets done.

☐ 71. I find the formality of having specific objectives and plans stifling.

☐ 72. I'm usually one of the people who puts life into a party.

☐ 73. I do whatever is expedient to get the job done.

☐ 74. I quickly get bored with methodical, detailed work.

☐ 75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events.

☐ 76. I'm always interested to find out what people think.

☐ 77. I like meetings to be run on methodical lines, sticking to laid down agenda, etc.

☐ 78. I steer clear of subjective or ambiguous topics.

☐ 79. I enjoy the drama and excitement of a crisis situation.

☐ 80. People often find me insensitive to their feelings.

LEARNING STYLES QUESTIONNAIRE – SCORING

You score one point for each item you ticked (✓). There are no points for items you crossed (✗).

Simply indicate on the lists below which items were ticked.

Activist	Reflector	Theorist	Pragmatist
2	7	1	5
4	13	3	9
6	15	8	11
10	16	12	19
17	25	14	21
23	28	18	27
24	29	20	35
32	31	22	37
34	33	26	44
38	36	30	49
40	39	42	50
43	41	47	53
45	46	51	54
48	52	57	56
58	55	61	59
64	60	63	65
71	62	68	69
72	66	75	70
74	67	77	73
79	76	78	80

Totals

Activist	*Reflector*	*Theorist*	*Pragmatist*

Ring your scores on this chart and join up.

Activist	Reflector	Theorist	Pragmatist	
20 19 18 17 16 15 14 13	20 19 18	20 19 18 17 16	20 19 18 17	Very strong preference
12 11	17 16 15	15 14	16 15	Strong preference
10 9 8 7	14 13 12	13 12 11	14 13 12	Moderate preference
6 5 4	11 10 9	10 9 8	11 10 9	Low preference
3 2 1 0	8 7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	8 7 6 5 4 3 2 1 0	Very low preference

Honey and Mumford 1992

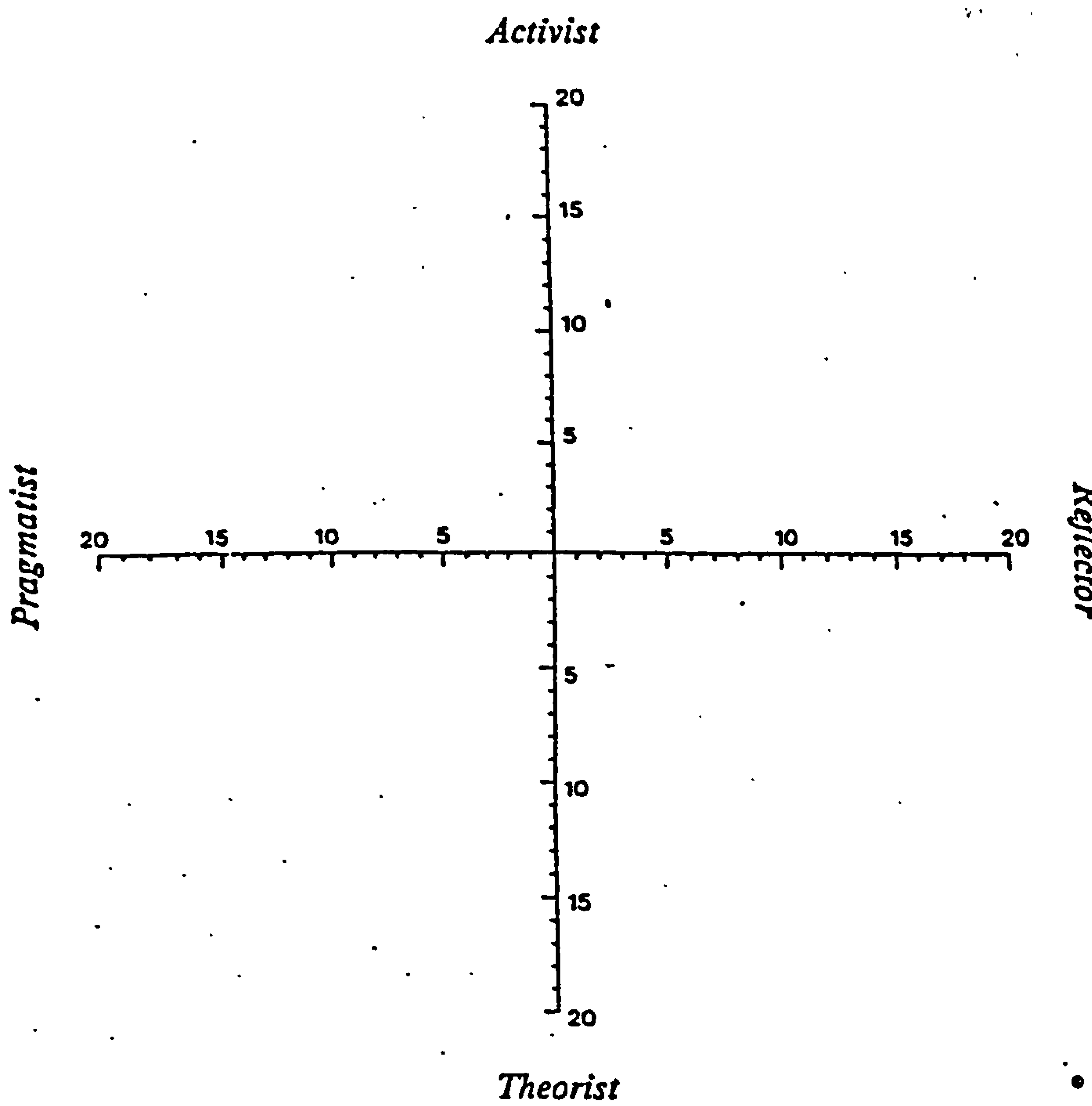
LEARNING STYLES QUESTIONNAIRE – SCORING

You score one point for each item you ticked (✓). There are no points for items you crossed (X).

Simply indicate on the lists below which items were ticked.

	Activist	Reflector	Theorist	Pragmatist
	2	7	1	5
	4	13	3	9
	6	15	8	11
	10	16	12	19
	17	25	14	21
	23	28	18	27
	24	29	20	35
	32	31	22	37
	34	33	26	44
	38	36	30	49
	40	39	42	50
	43	41	47	53
	45	46	51	54
	48	52	57	56
	58	55	61	59
	64	60	63	65
	71	62	68	69
	72	66	75	70
	74	67	77	73
	79	76	78	80
Totals				

Plot the scores on the arms of the cross below and apply the appropriate norms from Section I (pages 3-10) in the booklet "Using Your Learning Styles".



Appendix 6: Raw Data for LSQ

This section contains raw data for both the VR designers and VR students who carried out the Honey and Mumford survey described in Chapter 6 of this thesis.

The first two sets of raw data contain the order of learning styles for the designers and the students.

The second two sets of data contain the overall adjusted scores for each learning style for each participant.

Honey and Mumford Learning Style Preferences for 26 Designers

Data in table shows the order of learning style preferences for each participant. Overall numbers of Activists are also given for each preference. Data here shows that there were 9 participants who had Activist as the first choice, 2 for 2nd choice, 2 for 3rd choice and 14 participants had Activist as their weakest learning style.

1st Preference	2nd Preference	3rd Preference	4th Preference	Gender	Age
Reflector	Pragmatist	Theorist	Activist	Male	23
Theorist	Reflector	Pragmatist	Activist	Male	40
Theorist	Reflector	Pragmatist	Activist	Male	46
Theorist	Reflector	Pragmatist	Activist	Male	47
Reflector	Theorist	Activist	Pragmatist	Male	38
Activist	Reflector	Theorist	Pragmatist	Male	46
Reflector	Theorist	Pragmatist	Activist	Male	45
Reflector	Theorist	Pragmatist	Activist	Male	44
Reflector	Theorist	Pragmatist	Activist	Male	39
Reflector	Pragmatist	Theorist	Activist	Male	38
Reflector	Pragmatist	Theorist	Activist	Male	37
Activist	Pragmatist	Reflector	Theorist	Male	26
Activist	Pragmatist	Reflector	Theorist	Male	24
Activist	Pragmatist	Reflector	Theorist	Male	25
Activist	Reflector	Theorist	Pragmatist	Male	38
Activist	Theorist	Reflector	Pragmatist	Male	24
Reflector	Theorist	Pragmatist	Activist	Female	24
Pragmatist	Activist	Reflector	Theorist	Male	23
Theorist	Activist	Pragmatist	Reflector	Male	40
Theorist	Pragmatist	Reflector	Activist	Female	46
Activist	Reflector	Pragmatist	Theorist	Female	36
Activist	Reflector	Pragmatist	Theorist	Female	34
Activist	Reflector	Pragmatist	Theorist	Male	22
Theorist	Pragmatist	Reflector	Activist	Male	45
Reflector	Theorist	Activist	Pragmatist	Female	25
Reflector	Pragmatist	Theorist	Activist	Male	22
9 Activists	2 Activists	2 Activists	14 Activists		

Honey and Mumford Learning Style Preferences for VR Design Students

Data in table shows the order of learning style preferences for each participant. Overall numbers of Activists are also given for each preference. Data here shows that there were 9 participants who had Activist as the first choice, 2 for 2nd choice, 2 for 3rd choice and 14 participants had Activist as their weakest learning style.

1st Preference	2nd Preference	3rd Preference	4th Preference	Gender	Age
Activist	Reflector	Theorist	Pragmatist	Male	20
Reflector	Activist	Pragmatist	Theorist	Male	20
Activist	Reflector	Theorist	Pragmatist	Male	21
Activist	Theorist	Reflector	Pragmatist	Male	30
Activist	Reflector	Pragmatist	Theorist	Male	21
Activist	Reflector	Pragmatist	Theorist	Male	20
Pragmatist	Theorist	Activist	Reflector	Male	36
Reflector	Theorist	Pragmatist	Activist	Male	22
Pragmatist	Activist	Reflector	Theorist	Male	21
Reflector	Activist	Pragmatist	Theorist	Female	31
Activist	Pragmatist	Reflector	Theorist	Male	21
Activist	Pragmatist	Reflector	Theorist	Male	20
Activist	Pragmatist	Reflector	Theorist	Female	21
Activist	Theorist	Pragmatist	Reflector	Male	27
Pragmatist	Theorist	Activist	Reflector	Male	46
Reflector	Theorist	Pragmatist	Activist	Female	21
Activist	Pragmatist	Reflector	Theorist	Male	39
Reflector	Theorist	Activist	Pragmatist	Female	55
Activist	Reflector	Pragmatist	Theorist	Male	22
Activist	Theorist	Reflector	Pragmatist	Male	20
Reflector	Theorist	Pragmatist	Activist	Male	20
Theorist	Reflector	Pragmatist	Activist	Male	20
Activist	Pragmatist	Reflector	Theorist	Male	43
Reflector	Theorist	Pragmatist	Activist	Female	37
Activist	Reflector	Theorist	Pragmatist	Female	24
Activist	Reflector	Pragmatist	Theorist	Female	30
Activist	Reflector	Theorist	Pragmatist	Male	21
Activist	Pragmatist	Reflector	Theorist	Male	20
Activist	Pragmatist	Theorist	Reflector	Female	20
Reflector	Activist	Pragmatist	Theorist	Female	24
Activist	Pragmatist	Theorist	Reflector	Male	20
Reflector	Pragmatist	Theorist	Activist	Male	20
Reflector	Pragmatist	Activist	Theorist	Male	20
Activist	Theorist	Reflector	Pragmatist	Male	20
Activist	Reflector	Theorist	Pragmatist	Male	21
Reflector	Pragmatist	Theorist	Activist	Male	36
Theorist	Reflector	Pragmatist	Activist	Male	45
Pragmatist	Theorist	Activist	Reflector	Male	31
Reflector	Activist	Theorist	Pragmatist	Female	22
Activist	Theorist	Pragmatist	Reflector	Male	21
Reflector	Activist	Theorist	Pragmatist	Female	21
Reflector	Pragmatist	Theorist	Activist	Male	22

Reflector	Activist	Pragmatist	Theorist	Male	20
Reflector	Activist	Theorist	Pragmatist	Male	21
Activist	Reflector	Pragmatist	Theorist	Female	24
Activist	Reflector	Pragmatist	Theorist	Male	26
Activist	Pragmatist	Reflector	Theorist	Male	22
Reflector	Theorist	Activist	Pragmatist	Male	22
Activist	Reflector	Pragmatist	Theorist	Male	21
Reflector	Activist	Pragmatist	Theorist	Male	21
Activist	Reflector	Theorist	Pragmatist	Male	21
Activist	Pragmatist	Theorist	Reflector	Male	21
Activist	Reflector	Theorist	Pragmatist	Female	23
Reflector	Pragmatist	Theorist	Activist	Female	40
Pragmatist	Activist	Reflector	Theorist	Male	35
Theorist	Activist	Reflector	Pragmatist	Male	30
Activist	Pragmatist	Reflector	Theorist	Female	24
Activist	Reflector	Theorist	Pragmatist	Male	34
Activist	Reflector	Theorist	Pragmatist	Male	24
Reflector	Activist	Pragmatist	Theorist	Male	21
Reflector	Theorist	Activist	Pragmatist	Male	23
Activist	Reflector	Pragmatist	Theorist	Male	22
Activist	Reflector	Theorist	Pragmatist	Male	21
Reflector	Theorist	Activist	Pragmatist	Male	20
Reflector	Theorist	Activist	Pragmatist	Male	20
Activist	Reflector	Theorist	Pragmatist	Male	46
Theorist	Pragmatist	Activist	Reflector	Male	25
Activist	Pragmatist	Theorist	Reflector	Male	50
Reflector	Theorist	Activist	Pragmatist	Male	22
Activist	Reflector	Pragmatist	Theorist	Female	20
Pragmatist	Activist	Reflector	Theorist	Male	21
Activist	Reflector	Theorist	Pragmatist	Male	21
Reflector	Theorist	Activist	Pragmatist	Female	22
Reflector	Theorist	Activist	Pragmatist	Male	30
38 Activists	13 Activists	13 Activists	10 Activists		

Learning Style Adjusted Scores for VR Designers

Each row represents the scores for each learning style for one participant.

Activist	Pragmatist	Reflector	Theorist
13	18	23	16
12	15	28	23
11	16	17	24
7	20	17	23
14	12	20	19
21	15	16	16
7	10	20	18
2	11	23	18
12	12	17	16
13	15	17	13
12	15	16	12
10	13	12	8
10	15	12	7
20	16	15	12
19	8	13	9
18	8	9	10
13	13	17	15
15	18	15	12
18	18	15	21
10	18	17	24
23	16	12	11
21	16	18	13
20	16	20	15
12	13	23	23
10	10	23	18
12	15	23	13

Learning Style Adjusted Scores for VR Design Students

Individual scores for each of the four learning styles.

Activist	Pragmatist	Reflector	Theorist
19	6	12	9
15	15	20	8
19	5	12	5
14	8	11	13
21	9	15	8
19	15	20	12
18	22	16	18
10	16	23	21
14	18	10	9
15	12	16	8
20	13	8	7
16	15	13	12
19	11	9	7
24	13	7	13
14	18	12	18
9	9	20	12
22	16	7	7
13	9	26	19
16	12	12	10
22	7	9	12
5	6	16	13
7	24	23	24
21	16	12	12
10	16	23	21
19	6	18	13
15	7	8	3
12	5	11	10
22	15	13	10
18	5	3	4
16	11	16	7
19	16	15	16
9	13	15	9
12	12	20	11
18	12	12	13
18	8	12	9
7	11	18	11
9	13	18	21
14	18	11	15
13	8	15	10
24	8	8	9
16	8	23	12
10	13	17	13
15	8	15	4
16	10	17	15
15	12	15	11

16	13	13	10
23	12	10	9
12	8	16	12
18	13	15	12
12	8	15	7
16	8	15	9
21	13	11	12
18	7	12	9
2	12	18	11
14	15	12	10
16	10	15	18
23	15	7	7
18	4	11	4
14	9	13	13
18	12	18	10
11	8	15	11
19	13	18	8
15	10	12	4
9	8	17	15
13	11	18	13
18	10	13	11
15	15	13	19
14	13	9	10
11	9	20	18
21	7	11	5
14	15	11	9
20	9	18	10
13	11	17	16
15	13	18	16

Appendix 7: LSQ Grid

Learning Styles Questionnaire Preference Grid

This grid was used for determining the preferences of the original scores from columns one to four. The fifth column was added to enable each score to be adjusted to an overall scale, which could be used to compare scores using statistical analyses.

Activist	Pragmatist	Reflector	Theorist	Adjusted	Preference
20	20	20	20	26	Very
19				25	Strong
18	19		19	24	Preference
17		19	18	23	
16	18			22	
15			17	21	
14	17	18		20	
13			16	19	
12	16	17	15	18	Strong
		16		17	Preference
11	15	15	14	16	
10	14	14	13	15	Moderate
9				14	Preference
8	13	13	12	13	
7	12	12	11	12	
6	11	11	10	11	Low
5	10	10	9	10	Preference
4	9	9	8	9	
	8	8	7	8	Very
3	7	7	6	7	Low
	6	6		6	Preference
2	5	5	5	5	
	4	4	4	4	
	3	3	3	3	
1	2	2	2	2	
	1	1	1	1	
0	0	0	0	0	

Appendix 8: The MBTI Personality Types

Psychological type descriptions of the nature of the 16 MBTI types.

Table 4.3 The 8 MBTI Introvert Personality Types (Myers and McCaulley, 1985)

ISTJ	ISFJ
Serious, quiet, earn success by concentration and thoroughness. Practical, orderly, matter-of-fact, logical, realistic, and dependable. See to it that everything is well organised. Take responsibility. Make up their own minds as to what should be accomplished and work toward it steadily, regardless of protests or distractions	Quiet, friendly, responsible, and conscientious. Work devotedly to meet their obligations. Lend stability to any project or group. Thorough, painstaking, accurate. Their interests are usually technical. Can be patient with necessary details. Loyal, considerate, perceptive, concerned with how other people feel.
ISTP	**ISFP**
Cool onlookers - quiet, reserved, observing and analysing life with detached curiosity and unexpected flashes of original humour. Usually interested in cause and effect, how and why mechanical things work, and in organising facts using logical principles. Excel at getting to the core of a practical problem and finding the solution.	Retiring, quietly friendly, sensitive, kind, modest about their abilities. Shun disagreements, do not force their opinions or values on others. Usually do not care to lead but are often loyal followers. Often relaxed about getting things done because they enjoy the present moment and do not want to spoil it by undue haste or exertion.
INFJ	**INTJ**
Succeed by perseverance, originality, and desire to do whatever is needed or wanted. Put their best efforts into their work. Quietly forceful, conscientious, concerned for others. Respected for their firm principles. Likely to be honoured and followed for their clear visions as to how bet to serve the common good.	Have original minds and great drive for their own ideas and purposes. Have long-range vision and quickly find meaningful patterns in external events. In fields that appeal to them, they have a fine power to organise a job and carry it through. Sceptical, critical, independent, determined, have high standards of competence and performance.
INFP	**INTP**
Quiet observers, idealistic, loyal. Important that outer life be congruent with inner values. Curious, quick to see possibilities, often serve as catalysts to implement ideas. Adapatable, flexible, and accepting unless a value is threatened. Want to understand people and ways of fulfilling human potential. Little concern with possessions or surroundings.	Quiet and reserved. Especially enjoy theoretical or scientific pursuits. Like solving problems with logic and analysis. Interested mainly in ideas, with little liking for parties or small talk. Tend to have sharply defined interests. Need careers where some strong interest can be used and useful.

Table 4.4 The 8 MBTI Extravert Personality Types (Myers and McCaulley, 1985)

ESTP	ESFP
Good at on-the-spot problem solving. Like action, enjoy whatever comes along. Tend to like mechanical things and sports, with friends on the side. Adaptable, tolerant, pragmatic; focused on getting results. Dislike long explanations. Are best with real things that can be worked, handled, taken apart, or put together.	Outgoing, accepting, friendly, enjoy everything and make things more fun for others by their enjoyment. Like action and making things happen. Know what's going on and join in eagerly. Find remembering facts easier than mastering theories. Are best in situations that need sound common sense and practical ability with people.
ESTJ	**ESFJ**
Practical, realistic, matter-of-fact, with a natural head for business or mechanics. Not interested in abstract theories; want learning to have direct and immediate application. Like to organise and run activities. Often make good administrators; are decisive, quickly move to implement decisions; take care of routine details.	Warm-hearted, talkative, popular, conscientious, born co-operators, active committee members. Need harmony and may be good at creating it. Always doing something nice for someone. Work best with encouragement and praise. Main interest is in things that directly and visibly affect people's lives.
ENFP	**ENTP**
Warmly enthusiastic, high-spirited, ingenious, imaginative. Able to do almost anything that interests them. Quick with a solution for any difficulty and ready to help anyone with a problem. Often rely on their ability to improvise instead of preparing in advance. Can usually find compelling reasons for whatever they want.	Quick, ingenious, good at many things. Stimulating company, alert and outspoken. May argue for fun on either side of a question. Resourceful in solving new and challenging problems, but may neglect routine assignments. Apt to turn to one new interest after another. Skilful in finding logical reasons for what they want.
ENFJ	**ENTJ**
Responsive and responsible. Feel real concern for what others think or want, and try to handle things with due regard for the other's feelings. Can present a proposal or lead a group discussion with ease and tact. Sociable, popular, sympathetic. Responsive to praise and criticism. Like to facilitate others and enable people to achieve their potential.	Frank, decisive, leaders in activities. Develop and implement comprehensive systems to solve organisational problems. Good in anything that requires reasoning and intelligent talk, such as public speaking. Are usually well informed and enjoy adding to their fund of knowledge.

Appendix 9: Raw Data for MBTI

This section contains raw data for both the VR designers and VR students who carried out the MBTI survey described in Chapter 7 of this thesis.

The first two sets of raw data contain the order of learning styles for the designers and the students. The second two sets of data contain the overall adjusted scores for each learning style for each participant.

MBTI Preferences for VR Designers

E-I	S-N	T-F	J-P	Gender	Age
Introversion	Sensing	Thinking	Judgement	Male	23
Introversion	Sensing	Thinking	Judgement	Male	40
Introversion	iNtuition	Thinking	Judgement	Male	46
Introversion	iNtuition	Thinking	Judgement	Male	47
Extraversion	Sensing	Thinking	Judgement	Male	38
Introversion	iNtuition	Thinking	Judgement	Male	46
Introversion	Sensing	Thinking	Judgement	Male	45
Introversion	Sensing	Thinking	Judgement	Male	44
Introversion	iNtuition	Thinking	Judgement	Male	39
Introversion	iNtuition	Thinking	Judgement	Male	38
Introversion	Sensing	Thinking	Judgement	Male	37
Introversion	Sensing	Thinking	Judgement	Male	26
Extraversion	iNtuition	Thinking	Perception	Male	24
Extraversion	iNtuition	Feeling	Perception	Male	25
Introversion	iNtuition	Thinking	Perception	Male	38
Extraversion	iNtuition	Feeling	Perception	Male	24
Extraversion	Sensing	Thinking	Judgement	Female	24
Introversion	iNtuition	Feeling	Perception	Male	23
Extraversion	Sensing	Thinking	Judgement	Male	40
Introversion	iNtuition	Feeling	Judgement	Female	46
Introversion	iNtuition	Feeling	Perception	Female	36
Introversion	iNtuition	Feeling	Judgement	Female	34
Extraversion	iNtuition	Feeling	Judgement	Male	22
Introversion	iNtuition	Thinking	Judgement	Male	45
Introversion	iNtuition	Thinking	Judgement	Female	25
Introversion	Sensing	Thinking	Judgement	Male	22

MBTI Preferences for VR Students

E-I	S-N	T-F	J-P	Gender	Age
Introversion	Sensing	Thinking	Perception	Male	20
Extraversion	iNtuition	Thinking	Perception	Male	20
Extraversion	iNtuition	Feeling	Perception	Male	22
Introversion	iNtuition	Feeling	Judgment	Male	20
Introversion	iNtuition	Feeling	Perception	Male	21
Introversion	Sensing	Thinking	Perception	Male	30
Introversion	Sensing	Thinking	Judgment	Male	36
Introversion	Sensing	Thinking	Judgment	Male	22
Extraversion	Sensing	Thinking	Perception	Female	31
Extraversion	iNtuition	Feeling	Perception	Female	21
Extraversion	iNtuition	Thinking	Perception	Male	27
Extraversion	Sensing	Thinking	Judgment	Male	46
Extraversion	iNtuition	Thinking	Judgment	Male	39
Introversion	iNtuition	Thinking	Judgment	Female	55
Extraversion	Sensing	Thinking	Perception	Male	22
Extraversion	iNtuition	Feeling	Perception	Male	20
Extraversion	iNtuition	Thinking	Judgment	Male	43
Introversion	Sensing	Thinking	Judgment	Female	37
Introversion	iNtuition	Feeling	Perception	Female	24
Extraversion	iNtuition	Thinking	Perception	Female	30
Extraversion	Sensing	Thinking	Judgment	Male	40
Introversion	iNtuition	Thinking	Perception	Male	22
Introversion	Sensing	Feeling	Judgment	Male	22
Extraversion	iNtuition	Thinking	Judgment	Male	30
Introversion	iNtuition	Thinking	Judgment	Male	21
Extraversion	iNtuition	Feeling	Perception	Male	20
Extraversion	iNtuition	Feeling	Perception	Female	23
Introversion	iNtuition	Thinking	Judgment	Female	40
Extraversion	iNtuition	Thinking	Perception	Male	35
Extraversion	iNtuition	Thinking	Perception	Male	34
Extraversion	Sensing	Feeling	Perception	Male	46
Introversion	iNtuition	Thinking	Judgment	Male	25
Introversion	Sensing	Thinking	Perception	Male	50
Extraversion	iNtuition	Feeling	Judgment	Female	22
Extraversion	Sensing	Thinking	Perception	Male	20

MBTI Adjusted Scores for VR Designers

Introversion	Extraversion	Sensing	INtuition	Thinking	Feeling	Judgement	Perception
11.00	15.79	4.59	14.56	9.45	8.21	21.36	3.25
10.00	16.71	13.76	3.12	13.39	4.11	23.21	1.63
4.00	23.21	8.41	17.68	18.12	5.47	17.64	6.50
3.00	24.14	9.18	16.64	18.91	2.74	26.00	7.31
20.00	7.43	9.18	9.36	22.06	0.00	26.00	0.00
24.00	0.93	6.12	11.44	16.55	5.47	16.71	8.13
7.00	19.50	13.76	2.08	14.18	10.95	25.07	3.25
8.00	18.57	13.76	3.12	13.39	12.32	24.14	3.25
8.00	18.57	7.65	17.68	12.61	5.47	17.64	6.50
7.00	20.43	10.71	7.28	16.55	2.74	16.71	12.19
7.00	19.50	9.94	8.32	15.76	2.74	14.86	11.38
17.00	10.21	3.06	23.92	12.61	6.84	6.50	15.44
17.00	9.29	2.29	21.84	11.82	5.47	7.43	16.25
22.00	6.50	1.53	20.80	5.52	13.68	6.50	16.25
10.00	16.71	2.29	22.88	7.88	10.95	9.29	15.44
20.00	8.36	3.82	16.64	6.30	15.05	7.43	14.63
15.00	12.07	9.94	10.40	11.82	11.14	16.71	6.50
19.00	8.36	6.88	15.60	6.30	10.95	9.29	15.44
13.00	10.21	8.41	10.40	21.27	4.11	24.14	2.44
9.00	16.71	9.94	13.52	6.30	9.90	21.36	4.88
4.00	22.29	9.94	20.80	3.94	26.00	7.43	17.06
16.00	8.36	8.41	13.52	4.73	19.81	16.71	8.94
14.00	7.43	8.41	12.48	7.88	21.89	17.64	9.75
8.00	17.64	4.59	19.76	12.61	2.74	21.36	3.25
6.00	21.36	14.53	6.24	11.03	13.62	22.29	4.88
11.00	13.00	18.35	5.20	13.39	9.58	18.57	6.50

MBTI Adjusted Scores for VR Students

Introversion	Extraversion	Sensing	INtuition	Thinking	Feeling	Judgement	Perception
7.00	20.43	19.12	3.12	17.33	6.84	4.64	16.25
13.00	7.43	6.88	17.68	7.09	10.95	1.86	18.69
18.00	7.43	3.06	18.72	4.73	17.79	12.07	14.63
11.00	12.07	9.94	14.56	5.52	19.16	14.86	8.94
4.00	22.29	9.94	17.68	4.73	20.53	7.43	17.06
7.00	20.43	19.88	2.08	16.55	5.47	5.57	15.44
6.00	18.57	5.35	13.52	21.27	2.74	15.79	8.94
11.00	13.00	18.35	5.20	13.39	9.58	18.57	6.50
16.00	13.93	9.18	11.44	8.67	8.67	8.36	15.44
22.00	4.64	3.06	18.72	3.15	23.52	3.71	21.13
22.00	5.57	3.82	19.76	11.82	6.84	11.14	13.00
6.00	21.36	14.53	6.24	11.03	5.47	22.29	4.88
18.00	9.29	1.53	22.88	13.39	8.21	15.79	8.94
3.00	22.29	8.41	17.68	11.82	9.90	14.86	11.38
7.00	14.86	14.53	11.44	9.45	13.68	11.14	11.38
18.00	7.43	3.06	18.72	4.73	17.79	12.07	14.63
15.00	11.14	7.65	11.44	17.33	8.21	13.93	8.13
6.00	19.50	12.24	7.28	11.03	6.19	16.71	8.13
12.00	11.14	3.82	22.88	5.52	13.62	9.29	13.00
14.00	9.29	9.18	12.48	9.45	11.14	6.50	17.06
5.00	21.36	14.53	6.24	11.82	6.84	22.29	4.88
5.00	18.57	2.29	21.84	7.88	12.32	2.79	20.31
2.00	23.21	15.29	5.20	5.52	19.16	13.93	9.75
17.00	10.21	1.53	22.88	12.61	9.58	15.79	8.94
9.00	17.64	9.94	15.60	11.03	5.47	17.64	5.69
18.00	7.43	3.82	23.92	6.30	12.32	9.29	13.81
19.00	10.21	6.88	14.56	3.15	21.05	1.86	20.31
4.00	21.36	8.41	15.60	11.82	9.90	13.93	11.38
22.00	5.57	4.59	18.72	11.82	5.47	11.14	12.19
13.00	7.43	2.29	23.92	7.88	10.95	5.57	15.44
17.00	6.50	13.00	12.48	7.09	17.79	10.21	13.00
8.00	17.64	4.59	19.76	12.61	2.74	21.36	3.25
7.00	21.36	19.88	2.08	17.33	6.84	5.57	15.44
14.00	7.43	8.41	12.48	6.30	22.29	17.64	9.75
17.00	6.50	13.00	12.48	8.67	12.32	11.14	12.19

Appendix 10: Learning Modalities

A number of different versions of the Learning Modality Questionnaire are available on the Internet. The first one was used in the study and an example of the completed questionnaire can be seen in this appendix.

Learning Modality Questionnaires available on the Internet.

(1) Learning Style Inventory: (adapted from Barsch Leaning Style Inventory by Jeffrey Barsch) and (Sensory Modality Checklist by Nancy A Haynie). Found at http://www.hcc.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/m-files/m-lernst.htm

(2) Barsch Learning Style Inventory: by Jeffrey Barsch, Ed.D. Found at http://lac.smtc.net/barsch.htm

(3) Modality Preference Inventory: designed by Middlesex Community College. Found at http://www.mxctc.commnet.edu/clc/survey.htm

(4) Modality Questionnaire: Simple checklist. Found at http://www.muskingum.edu/~cal/database/ModQuest.html

(5) VARK Questionnaire: Mixture of learning styles including modalities. Found at http://www.hcc.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/vark.htm

Copy of the Barsch Learning Style Inventory

An example of the on-line Barsch Learning Style Inventory which identifies an individual's dominant learning modality.

LEARNING STYLE INVENTORY

Directions:

To gain a better understanding of yourself as a learner, you need to evaluate the way you prefer to learn or process information. By doing so, you will be able to develop strategies which will enhance your learning potential. The following evaluation is a short, quick way of assessing your learning style.

This 24 item survey is not timed. Answer each question as honestly as you can.

Place a check on the appropriate line after each statement

	OFTEN	SOMETIMES	SELDOM
1. Can remember more about a subject through the lecture method with information, explanations and discussion.	____	____	____
2. Prefer information to be written on the chalkboard, with the use of visual aids and assigned readings.	____	____	____
3. Like to write things down or to take notes for visual review.	____	____	____
4. Prefer to use posters, models, or actual practice and some activities in class.	____	____	____
5. Require explanations of diagrams, graphs, or visual directions.	____	____	____
6. Enjoy working with my hands or making things.	____	____	____
7. Am skillful with and enjoy developing and making graphs and charts.	____	____	____
8. Can tell if sounds match when presented with pairs of sounds.	____	____	____
9. Remember best by writing things down several times.	____	____	____
10. Can understand and follow directions on maps.	____	____	____
11. Do better at academic subjects by listening to lectures and tapes.	____	____	____
12. Play with coins or keys in pockets.	____	____	____
13. Learn to spell better by repeating the words out loud than by writing the word on papers	____	____	____
14. Can better understand a news article by reading about it in the paper than by listening to the radio.	____	____	____
15. Chew gum, smoke, or snack during studies.	____	____	____
16. Feel the best way to remember is to picture it in your head.	____	____	____

17. Learn spelling by "finger spelling" words.	____	____	____
18. Would rather listen to a good lecture or speech than read about the same material in a textbook.	____	____	____
19. Am good at working and solving jigsaw puzzles and mazes.	____	____	____
20. Grip objects in hands during learning period.	____	____	____
21. Prefer listening to the news on the radio rather than reading about it in the newspaper.	____	____	____
22. Obtain information on an interesting subject by reading relevant materials.	____	____	____
23. Feel very comfortable touching others, hugging, handshaking, etc.	____	____	____
24. Follow oral directions better than written ones.	____	____	____

SCORING PROCEDURES

DIRECTIONS:

Place the point value on the line next to the corresponding item. Add the points in each column to obtain the preference scores under each heading.
OFTEN = 5 points
SOMETIMES = 3 points
SELDOM = 1 point

VISUAL NO	PTS.	AUDITORY NO.	PTS.	TACTILE NO.	PTS.
2	____	1	____	4	____
3	____	5	____	6	____
7	____	8	____	9	____
10	____	11	____	12	____
14	____	13	____	15	____
16	____	18	____	17	____
19	____	21	____	20	____
22	____	24	____	23	____
VPS =		APS =		TPS =	

VPS = Visual Preference Score
APS = Auditory Preference Score
TPS = Tactile Preference Score

If your are a VISUAL learner, then by all means be sure that you look at all study materials. Use charts, maps, filmstrips, notes and flashcards. Practice visualizing or picturing words/concepts in your head. Write our everything for frequent and quick visual review.

If you are a AUDITORY learner, you may with to use tapes. Tape lectures to help you fill in the gaps in your notes. But do listen and take notes, reviewing notes frequently. Sit in the lecture hall or classroom where you can hear well. After you have read something, summarize it and recite it aloud.

If you are a TACTILE learner, trace words as you are saying them. Facts that must be learned should be written several times. Keep a supply of scratch paper for this purpose. Taking and keeping lecture notes will be very important. Make study sheets.

Appendix 11: WormeryWorld Score Form

An example of a completed form showing scores obtained after completing the WormeryWorld for the study carried out in Chapter 8.

Wormery VR World

Please record your scores, which you will receive at the end of the WormeryWorld task.

Initials or Pseudonym

Scores

A		B	

Appendix 12: Raw Data for Text versus Voice Help Instructions

Data shows the number of times that text or voiced instructions were accessed.

Preference	Text	Voice	Gender
Text	7	2	Male
Voiced	2	6	Male
Text	10	1	Male
Text	7	0	Male
Voiced	0	8	Male
Text	9	2	Female
Both	5	5	Male
Both	5	5	Male
Text	9	0	Male
Voiced	2	11	Male
Text	7	4	Female
Text	9	2	Female
Text	11	0	Female
Voiced	1	5	Male
Text	10	0	Male
Text	5	4	Male
Text	9	0	Male
Text	8	0	Male
Voiced	1	12	Female
Text	7	1	Male
Voiced	4	12	Female
Text	7	1	Female
Voiced	3	12	Female
Text	11	3	Female
Text	3	2	Male
Voiced	0	12	Male
Voiced	8	9	Male
Voiced	0	4	Male
Voiced	2	8	Male
Text	8	2	Male
Text	8	0	Male
Voiced	1	5	Male
Text	7	1	Male
Text	8	0	Male
Voiced	1	7	Female
Voiced	2	10	Female
Voiced	2	8	Male
Voiced	0	10	Female
Text	8	3	Male
Text	7	2	Male
Text	8	0	Male
Text	8	0	Male
Voiced	0	8	Male
Voiced	0	8	Male

Voiced	2	13	Male
Text	7	4	Male
Text	7	0	Male
Voiced	0	8	Male
Text	8	0	Male
Text	6	3	Female
Voiced	0	7	Male
Text	8	0	Male
Text	9	2	Male
Both	5	5	Male