Investigating the potential of on-line 3D virtual environments to improve access to museums as both an informational and educational resource

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Abstract

New digital technological possibilities allow physical museum artefacts to be transferred into a virtual environment using 3D computer models with rich information content for educational purposes. However, although several museum websites have applied relevant educational theories to learning activities in these 3D environments, these alone are not enough to develop 3D museum environments without consideration of virtual visiting styles in the learning context. This research addresses the relationship between visiting styles and the design of 3D museum environments based on pedagogic approaches for learning efficacy.

Relevant literature on the nature of web-based museum systems was reviewed. Three stages of primary research (a critical review, observations and interviews) were also conducted in this study. The critical review examined the use of 3D technologies in current museum websites in terms of informational aspects and the learning context. The observation studies identified the relationship between visitor behaviours and associated learning activities within 3D museum environments. The interviews further elicited experts' views and were used to test the research hypotheses.

A theoretical design reference model was developed. Initially based on the Reeves multimedia design model, the model consists of three phases: analysis, design and assessment. A prototype 3D exhibition was created based on the theoretical model and two pedagogic approaches. Evaluation of this showed that the design of the exhibits with rich multimedia formats had the potential for more effective visitor learning. The two pedagogic approaches encouraged the related visiting style(s), leading to a deeper engagement with the content and ultimately improving learning efficiency.

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Chapter One: Introduction

1.1 Introduction

Institutions like museums play an important role in education by providing their collections of cultural materials and knowledge through the Internet to a global audience. In recent years, the advent of 3D web technologies has impacted on museum websites, particularly as the connection systems for broadband Internet access have become faster and more widely available. This has allowed the development of 3D on-line virtual museum displays and exhibition applications for educational purposes.

According to White et al (2004), recent surveys indicate that about 35 percent of museums have already started to develop virtual forms of 3D presentation of their artefacts in online virtual exhibition environments as a novel mode of communication. In addition, the notion of creating 3D virtual museum environments is not only to increase accessibility, but also to use the potential of the innovative 3D web technologies to present their cultural content as both informational and educational resources from which virtual visitors can learn the historical and cultural significance of museum artefacts and associated information in 3D virtual worlds.

1.2 Background to the study

The conceptual framework of a virtual museum using the Internet and presenting itself online is being exploited to enhance the experience of the virtual visitor – an example is El Pais Virtual Museum of Arts (http://muva.elpais.com.uy/) (Figure 1.1) (Haber 2000). A virtual museum such as this can be created by digitising a collection of artefacts and text resources, and by providing associated interpretations and explanations to a wide audience. Recently, one of the main roles of a virtual museum which has developed is to provide museum resources for educational needs. Moreover, many science museums on the web, such as those of the San Francisco Exploratorium (www.exploratorium.edu/index.html) and the London Science Museum (www.sciencemuseum.org.uk), often have a strong educational purpose and offer educational activities through their virtual museum learning environments.

Figure 1.1 El País Virtual Museum of Arts

3D technologies such as VRML[1] with interactive multimedia can be used to create a 3D virtual environment for informational and educational purposes. Virtual Reality (VR), an interactive 3D virtual environment in which the user feels presence, is an emerging computer-based 3D technology that offers promise as a learning tool for a virtual museum environment. Moreover, a new form of electronic learning is emerging which uses 3D technologies as learning tools in an educational environment (Nentwig 1999); in particular, a three dimensional virtual museum environment. It has become apparent that a virtual museum using 3D technologies has great potential in this area of educational provision.

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[1] VRML (Virtual Reality Markup Language) is a scene description language and file format for describing interactive virtual environments, animations and movement.

1.3 Problem statement

Museum collections are now able to display 3D virtual forms including 3D digital models of the museum objects (Figure 1.2) with layers of associated information in virtual environments. Immersive 3D virtual worlds using Virtual Reality technologies offer the unique possibility of allowing virtual visitors to view 3D images of museum objects with multiple media formats on display in a 3D web-based exhibition environment (Taylor et al 2003). Moreover, a virtual learning environment for a web-based museum can offer improved access to museum objects through interpretative content, structured activities, virtual exhibitions and interactive museum resources using 3D technology.

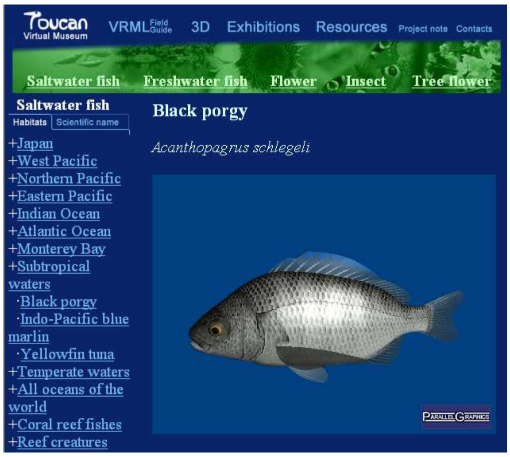


Figure 1.2 A 3D model fish in the Toucan Virtual Museum

In Chittaro and Ieronutti's (2004) visitor study, virtual visitors' behaviours in the 3D virtual environments were identified as similar to the behaviours of real visitors in a real museum environment. The information regarding visitor behaviours is an important indicator of the ability of exhibits, virtual or otherwise, to engage visitors' attention and maintain their interest.

Educational theories can be used to underpin both real and virtual museums in the learning context (Hawkey 2001, 2004). To be effective online museum learning, activities or programmes should be based on an educational theory and a coherent pedagogic strategy to meet learning requirements and enhance learning experience. However, these educational theories and coherent pedagogic approaches are not enough on their own to develop 3D virtual museum learning environments. In addition, it is also important to have an understanding of visitor behaviours in terms of visitor pathways, movements, stops at exhibits and time spent in viewing exhibits in 3D museum environments as this will also impact on learning efficacy.

Currently, there are no studies that address these aspects concerning the design of 3D virtual environments based which match the intended pedagogic approaches to visitor behaviour patterns. This research is therefore concerned with the effective design of 3D museum environments based on pedagogic approaches to encourage the related visiting styles, leading to a deeper engagement with the subject matters for learning efficiency.

1.4 Aims and objectives of the research

The proposed research is an attempt to establish a theoretical design reference model for the development of on-line 3D virtual environments in order to improve access to museums as both an informational and educational resource. The aims and objectives of the research are presented in detail as follows:

Aims:

1. To investigate the potential of interactive 3D technologies to improve access for people to museum as an informational and leaning resource.
2. To examine innovative ways of using 3D technology to improve web-based

museum virtual environments in terms of their effectiveness and usability as information and learning resources.

3. To devise and test a theoretical model for the effective design of web-based 3D virtual museum information and learning environments.

Objectives:

1. To review the relevant literature on web-based museum online environments focusing on information and learning, museum theory, visitor behaviours within physical and virtual museums, education theories, virtuality and simulation theory, existing 3D web technologies, suitability and effectiveness of online information design strategies in 3D environments.
2. To examine the existing websites using 3D technology for online learning in a 3D virtual environment with a focus on museums by use of a critical review.
3. To determine a potential relationship between the visiting styles and learning activities within 3D virtual museum environments based on the pedagogic approaches by use of observations combining performance tasks with questionnaire.
4. To identify the existing problems and limitations of current 3D virtual learning and information environments and potential needs by use of expert interviews.
5. To propose a theoretical design reference model for developing effective 3D virtual museum exhibition information and learning environments.
6. To validate the theoretical model through the evaluation of a prototype 3D exhibition through user testing and expert evaluation.

1.5 Structure of the thesis

The structure of the thesis is divided into eight chapters: introduction, literature review, methodology, critical review, observation studies, interviews, the development and evaluation of the theoretical model, conclusions and recommendations. The content of each chapter is outlined as follows:

Chapter 1: describes the research motivation, the statement of the research problems, aims and objectives of the research, and the overall structure of the thesis.

Chapter 2: is the literature review which consists of seven sections, including: 1) virtual museums on the Internet, 2) representational practices from a semiotic perspective for cultural interpretations, 3) the role of museums as both informational and learning resources, 4) visitor behaviours in traditional and virtual museums, 5) educational theories for web-based learning application, 6) realism levels and simulation dimensions, and 7) presence, immersion and usability issues.

Chapter 3: covers the overall research framework and methodology and explains the determination of the chosen research methods in terms of their validity and reliability.

Chapter 4: provides a description of the critical review undertaken of ten current virtual museum websites which were selected to represent the main categories of museums. These ten museum websites were critically examined in terms of their effectiveness and usability as informational and learning resources.

Chapter 5: consists of observations combining performance tasks with questionnaire for the three typical groups of visitors (i.e. general public, researchers and schools) in the four most successful and effective museum websites from the critical review. These four museum websites were selected in order to investigate the relationship between visiting styles and learning approaches and activities in the 3D museum environments.

Chapter 6: presents the six research hypotheses generated from the previous observations regarding the design of 3D environments and tests them through in-depth semi-structured interviews with eight experts.

Chapter 7: discusses the development of the theoretical design reference model based on the results of the secondary and primary research findings for developing a 3D virtual museum environment. It then explains how the prototype 3D museum exhibition was created based on the analysis and design phases of the theoretical model. Finally, it describes how this prototype 3D exhibition was tested based on the assessment phase of the theoretical model using the three typical types of museum visitors and expert evaluations. This section explores whether the model is valid and effective in terms of promoting a deeper engagement with the thematic content by encouraging specific visiting styles, increasing exhibits' attraction and holding power and ultimately improving learning efficiency.

Chapter 8: draws overall conclusions and summarises the main research findings, achievements and contributions to knowledge, followed by recommendations for further research.

Chapter Two: Literature Review

2.1 Introduction

This chapter presents a wide range of studies on relevant literature relating to the nature of virtual web-based museum systems. The aim of the literature review is to gather knowledge of the conceptual framework of virtual museum design and identify any existing suitable design methods in a 3D museum environment as both an informational and learning resource. The literature research also aims to formalise a research question which will be addressed at length in subsequent primary research works.

The literature review is divided into seven sections: 1) virtual museum on the Internet, 2) museum theory, 3) the role of the museum as both an informational and learning resource, 4) visitor studies, 5) educational theories for web-based learning application, 6) virtuality and simulation theory and 7) 3D web technologies and virtual museum environments.

2.2 Virtual museums on the Internet

2.2.1 Origins of the virtual museum and overall definition

The widespread development of virtual museums is being attempted to provide vast amounts of valuable museum information in electronic forms as widely as possible by exploiting emerging technologies on the Internet as a new communication medium. Although virtual museums have presented their collection artefacts and information resources on the Web ever since it became available, the notion of the virtual museum did not originate with the World Wide Web. Huhtamo (2002) summarised the origin and the concept of the virtual museum in Table 2.1.

Year	Name	Delivery systems	Features and notions
1960s	Xanadu	Online	● Ted Nelson's hypertext work ● An early specification of the cultural implications using networked hypertext
early 1990s	Virtual Museum	Offline (CD-ROM based)	● "Virtual Museum" was 'a demonstration disc for Apple's proprietary QuickTimeVR software shown at "Siggraph 92" in Chicago (Huhtamo 2002).' ● The virtual museum allowed visitors to navigate a 3D simulation of three interconnected museum spaces by using the mouse
1991	The Museum Inside the Telephone Network	Online	● The exhibition was organised by the Project Inter Communication Centre (the Japanese telecom NTT) ● The exhibition was accessible only to home users through the telephone, fax, and in a limited sense the computer network because the Internet access was not yet available in Japan
1995	The Museum Inside the Network	Online	● The museum exhibition was an amended version of the "The Museum Inside the Telephone Network"

Table 2.1 The origin and the concept of the virtual museum

The contextual notions of creating the virtual museum at each time phase involved the use of computer technology and a diversity of delivery systems. In recent years, the dramatically rapid growth of web-based virtual museums has raised one important issue of whether or not the title "web museums" replaces the term "virtual museums" as 'straightforward museum websites merit the title "virtual museum" (Huhtamo 2002).' Before addressing this issue, a definition of virtual museums would be helpful to shed some light on the notion of creating the virtual museums and the relationship between the virtual museums and web museums.

The hallmark characteristics of the virtual museum are identified by Schweibenz (1998) ‘a logically related collection of digital objects composed in a variety of media, and, because of its capacity to provide connectedness and the various points of access available, it lends itself to transcending traditional methods of communicating with the visitors;…its objects and the related information can be disseminated all over the world.’ However, the term virtual museum has recently become indistinct, since in the museum world and the realm of information science a variety of terms is utilised synonymously for associated museum information databases such as electronic museum, on-line museum, digital museum, hypermedia museum, Web museum, meta-museum, Cyberspace museum and so on, as the concept of the virtual museum has remained “under construction” on the Internet (Schweibenz 1998, 2004). Irrespective of the appellations of these museums, the primary idea behind this phenomenon is to transform authentic objects into digital objects for a digital extension of the museum on the web (Schweibenz 2004).

2.2.2 Different types of virtual museums and their relation to real museums

When using the word “virtual” related to museums, it is generally employed to indicate the web-based version of a physical museum space (Buiani 2003). A large number of museums operates in both the physical and virtual domain. However, not all of the virtual museums have a correspondent real physical site or presence. Paolini et al (2000) summarised four main conceptual frameworks of the virtual museum related to actual museums in terms of virtually visiting a virtual museum environment in Table 2.2.

Type	The categories of the virtual museum	Interpretation
A	A virtual museum website which reproduces the organisation of the museum	The construction of the virtual content simulates the physical organisation of the real content in the museum
B	A virtual museum website which does not reproduce the organisation of the museum	The construction of the virtual content is not associated with the physical organisation of the actual content in the museum
C	A virtual representation of the physical museum environment	The content of digital form is displayed in the virtual spatial environment, simulating the real museum exhibition
D	A virtual representation of an imaginary "hyper"-building	The content of digital form is displayed in an imaginary virtual environment, dissociated from the real museum

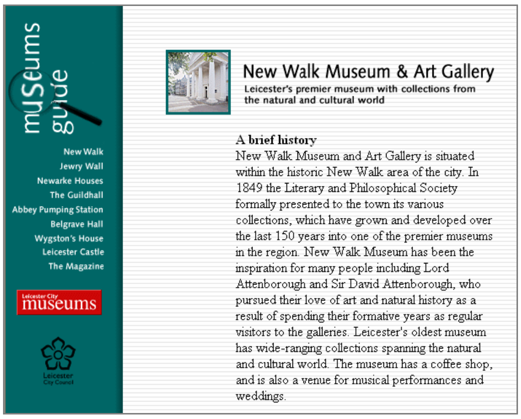
Table 2.2 The four conceptual frameworks of the virtual museums related to the actual museums

Types A and B of the virtual museums are devoted to constructing their information architecture and virtual content in a two-dimensional medium consisting of text, graphics and images; on the other hand, Types C and D of the virtual museums are dedicated to dynamically displaying their artefacts in 3D virtual reality environments with accompanying multiple media formats content for interpretation and associated information.

There are a few examples that indicate the features of these different types of the virtual museums on the web:

- Type A: *a virtual museum website which reproduces the organisation of the museum.* e.g. Leicester New Walk Museum & Art Gallery (Figure 2.1) (www.leicestermuseums.ac.uk/museums/f_newwalk.html)

The representation of its virtual content such as events, exhibitions, activities, etc., on the museum website is presented in order to reflect the organisation of the real content in the New Walk Museum and Art Gallery itself. The structure of the site looks more like a brochure of what it owns and is currently exhibiting than a museum. The museum is organised with the purpose of offering real content that is distinctly appealing to virtual visitors. The purpose of the online art gallery (Figure 2.2) highlights a collection of six artefacts by representing the essence of the galleries in order to encourage virtual visitors to view the authentic artefacts in the physical museum (New Walk Museum and Art Gallery, 2006).



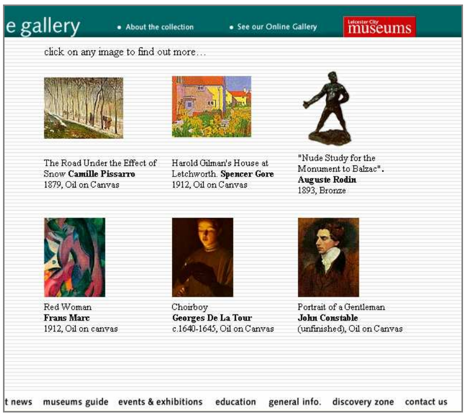
New Walk Museum & Art Gallery

Leicester's premier museum with collections from the natural and cultural world

A brief history

New Walk Museum and Art Gallery is situated within the historic New Walk area of the city. In 1849 the Literary and Philosophical Society formally presented to the town its various collections, which have grown and developed over the last 150 years into one of the premier museums in the region. New Walk Museum has been the inspiration for many people including Lord Attenborough and Sir David Attenborough, who pursued their love of art and natural history as a result of spending their formative years as regular visitors to the galleries. Leicester's oldest museum has wide-ranging collections spanning the natural and cultural world. The museum has a coffee shop, and is also a venue for musical performances and weddings.

Figure 2.1 New Walk Museum & Art Gallery



click on any image to find out more…

The Road Under the Effect of Snow **Camille Pissarro**
1879, Oil on Canvas

Harold Gilman's House at Letchworth. **Spencer Gore**
1912, Oil on Canvas

"Nude Study for the Monument to Balzac".
Auguste Rodin
1893, Bronze

Red Woman
Frans Marc
1912, Oil on canvas

Choirboy
Georges De La Tour
c.1640-1645, Oil on Canvas

Portrait of a Gentleman
John Constable
(unfinished), Oil on Canvas

Figure 2.2 The online art gallery

- Type B: *a virtual museum website which does not reproduce the organisation of the museum.* e.g. Peabody Museum of Anthropology and Ethnology (Figure 2.3) (www.peabody.harvard.edu/)

  The exhibited artefacts in the online exhibitions, according to the museum, are only displayed through the virtual space and not in the physical museum spaces (Peabody Museum of Archaeology and Ethnology, 2006), as Witcomb (2003) points out one of the on-line exhibitions: '*The Ethnography of Lewis and Clark:*

Native American Objects and the American Quest for Commerce and Science, for example, has a number of interesting features which differ from those normally found in a "real" exhibition.' (Figure 2.4)

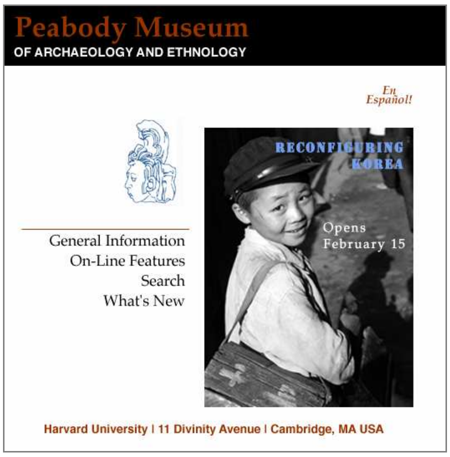


Figure 2.3 Peabody Museum of Anthropology and Ethnology

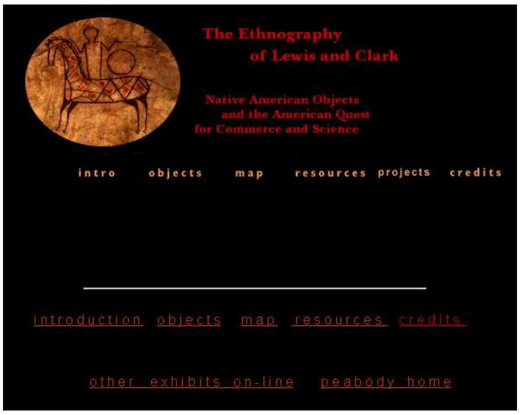


Figure 2.4 The Ethnography of Lewis and Clark: Native American Objects and the American Quest for Commerce and Science

- Type C: *a virtual representation of the physical museum environment.* e.g. National Museum of Science and Technology (Figure 2.5) (www.museoscienza.org/english/)

The National Museum of Science and Technology has presented its exhibits on display in the buildings as existing both in the actual and virtual building environment (Figure 2.6). In this type of museological creation, virtual visitors can experience walking through the three dimensional virtual buildings and viewing artefacts on display at will (Witcomb 2003). This museum uses 3D technology to recreate the actual spatial environment as realistically as possible in the form of a 3D simulation to try to give the feeling of truly being in the physical museum space itself.

National Museum of Science and Technology - Via S. Vittore 21 - 20123 Milano - Italy
Tel. +3902485551 - Fax +390248010016 - E-mail museo@museoscienza.org

Figure 2.5 National Museum of Science and Technology

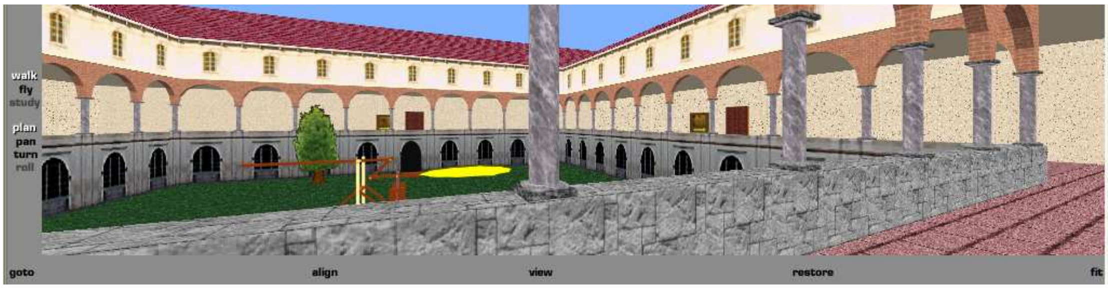
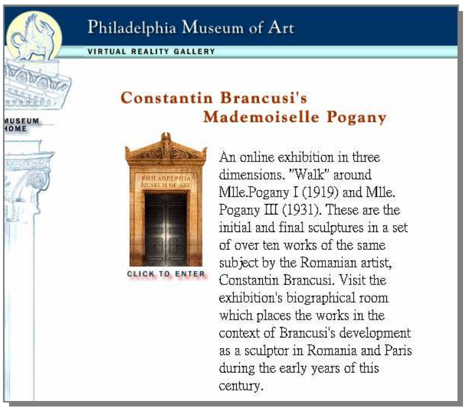


Figure 2.6 The spatial environment of 3D simulation

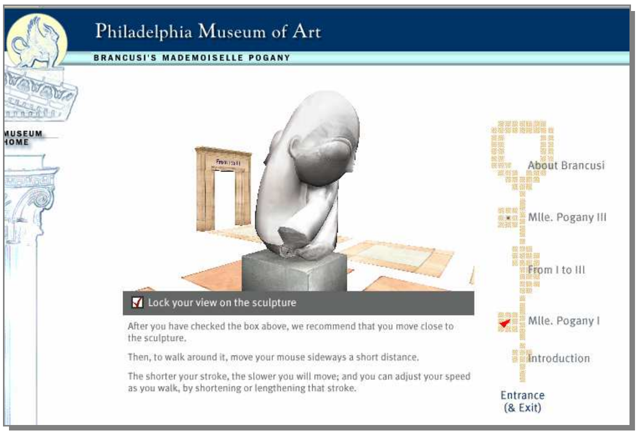
- Type D: *a virtual representation of an imaginary "hyper"-building.* e.g. Philadelphia Museum of Art (Figure 2.7) (www.narrativerooms.com/pogany/vr/index_a.html)

The Philadelphia Museum of Art has displayed an online exhibit of "Constantin Brancusi's Mademoiselle Pogany" in the virtual exhibition space (Figure 2.8) which is not a reproduction of the actual physical museum space. Using this type of information structure allows virtual visitors to easily interact with three dimensional models of the sculptures in an imaginary virtual 3D space in order to overcome the limitation of geographic and spatially physical museum exhibitions.



An online exhibition in three dimensions. "Walk" around Mlle.Pogany I (1919) and Mlle. Pogany III (1931). These are the initial and final sculptures in a set of over ten works of the same subject by the Romanian artist, Constantin Brancusi. Visit the exhibition's biographical room which places the works in the context of Brancusi's development as a sculptor in Romania and Paris during the early years of this century.

Figure 2.7 The Philadelphia Museum of Art



☑ Lock your view on the sculpture

After you have checked the box above, we recommend that you move close to the sculpture.

Then, to walk around it, move your mouse sideways a short distance.

The shorter your stroke, the slower you will move; and you can adjust your speed as you walk, by shortening or lengthening that stroke.

Figure 2.8 The virtual exhibition space

Although the classification into four types of the virtual museums is useful, this classification of current web-based museums, especially the status of the online exhibitions, is not always distinct. As Witcomb (2003) discusses, ‘are they teasers to invite the virtual visitor to see the real exhibition at the museum itself or are they truly on-line exhibition’; for example, the Canadian Museum of Civilization (www. civilization.ca). Despite this concern, the overall advantage and disadvantage of these types of the virtual museums can be shown in Table 2.3 (Paolini et al 2000; Witcomb 2003; Di Blas et al 2003; Schweibenz 2004; Gill 2001; Guynup 2003; Marable 2004):

Type	Advantages and disadvantages
A	Definition: A virtual museum website which reproduces the organisation of the museum Advantages: • Directly informing potential virtual visitors about the museum information on current exhibits, events, contact details and so on, corresponding with the physical site itself (Schweibenz 2004) • Information architecture is easy to deliver content of cultural materials through 2D media such as images, videos, graphics etc. (Paolini et al 2000) Disadvantages: • Providing merely basic information about the museum (Marable 2004) • 3D forms of artefacts are restricted to representation by 2D digital images because spatial information has been lost (Gill 2001) • Less interactive experience for virtual visitors because 'three-dimensional form of the object or space has to be flattened onto a two-dimensional view from a single perspective (Gill 2001)'
B	Definition: A virtual museum website which does not reproduce the organisation of the museum Advantages: • Providing a great amount of museum information organised in an object-oriented way, basically corresponding with collection database (Schweibenz 2004) • Presenting a detailed portrayal of museum collection for different interests such as researchers (Schweibenz 2004) • Information architecture is easy to deliver content of cultural materials through 2D media such as images, videos, graphics etc. (Paolini et al 2000) Disadvantages: • A web-based virtual exhibition which looks 'more like a well illustrated book than an exhibition (Witcomb 2003)' • 3D forms of artefacts are restricted to representation by 2D digital images because spatial information has been lost (Gill 2001) • Less interactive experience for virtual visitors because 'three-dimensional form of the object or space has to be flattened onto a two-dimensional view from a single perspective (Gill 2001)'

C	Definition: A virtual representation of the physical museum environment Advantages: ● Representations of both objects and their complex contextual environments (Gill 2001) ● The spatial environment provided by 3D simulation duplicates in the physical site which can evoke a prior physical visit already performed (Paolini et al 2000) ● Allowing visitors to experience and interact with 3D objects in a virtual environment (Paolini et al 2000) ● Allowing visitors to navigate through 3D simulation of museum space (Cerulli 1999) ● Widening access to the detailed spatial information on 3D model artefacts in the virtual world (Gill 2001) Disadvantages: ● The spatial environment of 3D simulation is not able to present either 'large quantities of information or high quality visual information (Di Blas et al 2003)' ● Complexity of 3D environment navigation because it requires visual-spatial information (Guynup 2003)
D	Definition: A virtual representation of an imaginary "hyper"-building Advantages: ● Representations of both objects and their complex contextual environments (Gill 2001) ● Allowing museums to construct their collections, structures, and architectural environments more flexibly and effectively for 'hypotheses about form and function to be explored in a shared, networked environment (Gill, 2001)' ● Allowing visitors to experience and interact with 3D objects in an imaginary environment (Paolini et al 2000) ● Allowing visitors to navigate through 3D simulation of an imaginary museum space (Paolini et al 2000) ● Widening access to the detailed spatial information on 3D model artefacts in the virtual world (Gill 2001) Disadvantages: ● The spatial environment of 3D simulation is not able to present either 'large quantities of information or high quality visual information (Di Blas et al 2003)' ● Complexity of 3D environment navigation because it requires visual-spatial information (Guynup 2003)

Table 2.3 The advantages and disadvantages of the different types of the virtual museums

As can be seen, virtual museums, regardless of their different types in relation to real museums, provide ‘an electronic media space in which images of museums, collections and displays precede or become superimposed on actual museums, objects and displays (Witcomb 2003).’ The conceptual framework for creating a virtual museum is established as an organisational structure with distinct hierarchies of information architecture on the website that any person can access from a computer and Internet connection anywhere (Witcomb 2003). This allows increasing access to their repository of digital images of artefacts which have potential for a significant democratizing effect.

2.3 Museum theory

What is museology? According to Vergo (1989), the term “museology” ‘is the study of museums, their history and underlying philosophy, the various ways in which they have, in the course of time, been established and developed, their avowed or unspoken aims and policies, their educative or political or social role.’ As can been seen, studying museums is not only concerned with their collections, but also involves how to organise and manage the institutions themselves (Hooper-Greenhill 1991).

For an institution concerned with interpreting collection assets, one of important concepts in the museum realm, particularly in museological processes which is: applying semiotic approaches to convey messages and concepts of artefacts for interpretations.

2.3.1 Applying semiotic theory when using artefacts to convey concepts

Semiotic theory is the study of sign systems and is a branch of communication theory. The general science of the sign systems is related to what definition is given to the sign. Therefore, a sign is not a natural production; it exists in the social world and produces meanings related to social and cultural context. Most studies of contemporary semiotics draw from the theory of sign systems started in the work of the Swiss linguist Ferdinand de Saussure and developed by French philosopher and linguist Roland Barthes.

Both Saussure's and Barthes' semiotics are not only analyses of the linguistic meanings, but can tackle many aspects of cultural studies such as museology. A number of museum studies has applied the concept of semiotics to analyse an artefact as a sign and symbol that conveys meanings (for example, Pearce 1990, 1992, 1995; Lidchi 1997; Tilley 1991). Furthermore, the interpretation of the meaning and historical and cultural significance of artefacts is an important aspect of museum studies.

In museology, the term "artefact" is identified as an object that has been made by people and this may have significant historical value and require cultural context validation. In the museum world, as is already known, the artefacts of a traditional museum are paramount. A museum is endowed with a unique role as a cultural institution which exists to interpret collections of objects and the relationship between the past and present associated with the museum itself. The essential features of museum objects contain physical presence and meanings (Lidchi 1997).

An object bears some objective messages in its physical presence that is obvious and intelligible at first sight. However, the difficult task of a museum is in expressing the broader meanings of the objects to visitors. The meaning of a museum object contains various layers of information related to its signifier, contextual elements, aesthetic value and historical context. The physical presence of an object, besides, cannot guarantee its decoding at the level of meaning, as Lidchi (1997) pointed out. Moreover, the meanings of objects are never intrinsic or constant: ‘it is culturally constructed and changes from one historical context to another, depending on what system of classification is used (Lidchi, 1997).’

In order to analyse an object as a symbol and a sign, its relationship to a complex of historical contexts and cultural meanings is involved. There are several semiotic studies in museology, employing linguistic analysis of communication through both Saussurian and Barthes’ semiotics as the analytic techniques to convey concepts of an artefact (for instance, Pearce 1990, 1992; Tilley 1991). A semiotic approach in a museum exhibition is a way of viewing that involves interpretation of the meaning of an artefact using a range of relevant explanatory material and other artefacts in the surrounding exhibition. Pearce (1990) suggested that the use of a semiotic approach may shed some useful light on the analysis of meaning in the communication process. She uses semiotic analysis to deconstruct a range of ideological messages of the artefact: for an officer’s red jacket worn at the battle of Waterloo, she states

> …the jacket [as] works as a message-bearing entity, acting in relationship to Waterloo both as an intrinsic sign and as a metaphorical symbol, which is capable of a very large of interpretation; and to explore how this relates to the way in which the present is created from the past. (Pearce 1990)

From this aspect of interpreting the meanings of objects as the signified, it is possible to use the semiotic concept to shed some light on the significance of collections of artefacts.

Hooper-Greenhill (2000) stated ‘if individual objects are complex in relation to meanings, exhibitions - groups of objects combined with words and images - are more complex still.’ In traditional museum settings, the design elements of exhibitions include architectural environment, exhibit lighting, texts and multimedia installations which have been established to convey specific messages of objects to viewers. A number of studies in museology has adapted theoretical frameworks based on the analysis of semiotics to interpret meanings of objects and knowledge related to objects on display in the exhibition for communication. Maroević (1995) states that from a semiotic aspect, the museum exhibition is designed as the organisation of the channel through a chain of the communication process. Pearce (1992) points out the museum exhibition is an element in the chain of the communication process, interpreting meanings and knowledge of objects and using the idea of implicit performance of the artefacts in bearing a metaphorical or symbolic relationship. At the same time, it is ‘act of imagination by which we make sense of our common pasts and presents and project these into the future (Pearce 1992).’

New technological possibilities are creating a space in which the repository of physical artefacts can migrate into the realm of a virtual museum through digitally recorded imaging. This notion of the adoption of digital images of collections of objects has transformed the nature of museum collections online to the public. One could argue whether the digital reproduction of the original artefacts can directly represent their intrinsic meanings, cultural essences and historical context as well as in a traditional museum; although a greater depth of contextual information can be given when viewing them through a computer screen. There are two key questions related to the migration of repository of physical artefacts into the realm of virtual environment: how meanings of a physical object are conveyed and interpreted in a virtual museum and what types of representational system are used to communicate information on cultural materials in a web-based virtual museum.

As has been explained earlier, in spite of the fact that the physical presence of an object is presented in a traditional museum, its decoding at the level of significant meaning cannot be guaranteed, because a physical object is constructed as meaningful only through historical and cultural contexts in which they are interpreted on display, depending on what conceptual classification schemes is used. A variety of conceptual classification schemes to order and frame objects in the museum involves a way of thinking and knowing related to cultural and historical specifics (Hooper-Greenhill 1992). For example, Foucault (1970) quotes ‘a certain Chinese encyclopaedia in which [it written] the animals are divided into:

- belonging to the Emperor
- embalmed
- tame
- sucking pigs
- sirens
- fabulous
- stray dogs
- included in the present classification
- frenzied
- innumerable
- drawn with a very fine camelhair brush
- et cetera
- having just broken the water pitcher
- that from a long way off look [like] flies’

As can be seen, the concept of mental categories used to identify and classify objects is presumably regarded as a culturally specific taxonomy and a rationality of a way of knowing (Hooper-Greenhill 1992).

In terms of a collection of artefacts on display in a traditional museum exhibition, the application of representational schemes is based on the conceptual structure of classification and the emphasis on particular artefacts: this can therefore be applied effectively to interpret meanings of physical artefacts in virtual museums. Naturally, virtual museums cannot provide physical artefacts to visitors but the virtual exhibit can be presented according to a variety of representational schemes for cultural materials. In this respect, Tang (2005) states that ‘current digital museum projects reveal a wide variety of cultural materials as well as representational schemes adopted for their online display.’ Tang (2005) summarised three current modes of representational practices from a semiotic perspective for cultural materials in virtual museums: narrative-centered, object-centered and information-centered modes as shown in Table 2.4:

Mode of representation	**Exposition**
Narrative-centered	● The objects are arranged by a narrative which is a text structured through the time sequence of the events. ● Constructing the objects in narrative-centered mode as evidence to the storyline is to convey a message by invoking historical significance.
Object-centered	● The objects are organised to highlight the intrinsic value of artefacts and closely resembles the traditional sense of museums. ● Presenting the objects in the object-centered mode is involved in interpreting aesthetic values and cultural significance.
Information-centered	● The objects are structured to illustrate the images with accompanying interpretation text suited to the information transmission model of a museum. ● Presenting the objects in the information-centered mode is used most widely in explaining visual documentation of the natural specimens of animals and insects and the demonstration of scientific process and natural

	phenomena.

Table 2.4 Three modes of representational schemes based on a semiotic perspective for cultural materials in virtual museums

(Source: adapted from Tang 2005)

Each type of representation is adopted according to certain systematic classification schemes and different categories of collections of artefacts for access to cultural information in the virtual museums online. Moreover, each mode of representational practices not only operates to convey meanings of cultural materials as symbols or signs, but also interprets versatile meanings of objects and knowledge for communication.

2.4 The role of the museum as both an informational and learning resource

2.4.1 Traditional museums as information and learning environments

Museums not only exist to house and preserve a vast number of collections of artefacts, but also play a significant role as educational institutions which interpret the versatility of meanings of their collections for communication of knowledge. Most visitors appreciate museums as places of leisure which enrich their experience and allow them to enjoy a social occasion without particular learning goals, so called leisure-learning (Hooper-Greenhill 1999). This finding has suggested that ‘museums provide a free-choice learning experience, so motivation is key in effective learning; experiences should be stimulating, enjoyable, relevant and appropriate for the visitor (Hawkey 2004).’

The educational function of museums is devoted to delivering their informational and learning resources through ‘workshop sessions providing many different kinds of experience for students in schools, colleges and universities; advisory courses for teachers; written or audio-visual material to help plan classes or for self-guided learning; loan services and mobile exhibitions; lectures, talk, demonstrations, events and other leisure activities (Hooper-Greenhill 1991).' Such learning resources and activities can be used to accomplish the experience and goals of some or all of formal and informal learning and the provision of leisure-learning for children of all ages, families of all categories, individuals, adult public, religious groups and so on. One of strengths of the museum in education is exactly this variety and flexibility (Hooper-Greenhill 1994).

An important task for a museum is to plan the learning opportunities of exhibitions and displays and demonstrating collections of artefacts as the educational value (Hooper-Greenhill 1991, 1994, 2000). Exhibitions are one of the core educational approaches in museums. The exhibitions in a museum not only provide two or three-dimensional artefacts but also comprise educational material and knowledge which are concerned with a collection of artefacts for the meaning-making process of visitors through the structure of objects and ideas. In this respect, Hooper-Greenhill (1999) pointed out that the development of effective exhibitions 'needs to take account of both what people want to know, would be interested in, and how they can come to know it – how they learn.'

The potential benefit for learning in museum environments centres on learning from objects. Knowledge of objects and associated contextual information can act as catalysts for stimulation in relation to learning process. In the museum domain, information is an essential component of knowledge and 'originates from various forms of communication between individual and objects, the information being the articulation of what has been noticed or experienced during the communication process (Maroević 1995).’ Maroević (1995) claimed that museum collections and objects are regarded as the sources of information, including scientific and cultural.

- Scientific information: using the main scientific disciplines accurately analyses categories of museums objects as ‘art history, archaeology, anthropology, ethnology or natural and technical sciences (Maroević 1995).’
- Cultural information: employing cultural and historical context or social and physical environment synthetically determines an artefact and its messages involved meaningful significance of provenance, cultural values, symbolic meanings and historical importance (Maroević 1995; Hooper-Greenhill 1991).

Despite the nature of the two kinds of information, both of them have the potential for learning context in a museum environment. For example, visitors are able to learn the many stories, the conceptual themes and interpretations (cultural information) from activities based on culture materials such as a collection of artefacts, genres of works of art, specimens of animals and insects and so on (scientific information) (Hawkey 2004).

2.4.2 The roles of the virtual museum in improving access and as an informational and learning resource

2.4.2.1 Improving access

A real museum offers a substantial resource of artefacts and educational material for people to learn knowledge about a collection of objects. Due to the limitations of public access to physical museums e.g. opening hours, location and so on, the Internet and the World Wide Web can be advantageous to museums in improving access in cyberspace. Museums on the Internet, with hyperlinks online and interactive database, can be very useful to provide a variety of information related to its objects, exhibitions and anytime anywhere. Hawey (2004) states that the development of web-based virtual museums is being established to create virtual exhibition environments which increase access to their informational and learning resources for a number of reasons:

- 'They [are] able to showcase a wider range of objects;
- they [can] mount exhibitions on different - and difficult - subjects, perhaps more specialised or more topical;
- they [can] increase outreach and access;
- they [can] attract more visitors to the physical museum. (Hawey 2004)'

Traditional museums are regarded as cultural institutions which exist to house a vast amount of collections of artefacts and cultural materials. However, only a small proportion from collections of artefacts can be displayed to the public through exhibitions because of architectural limitations of space in the physical museum. For example, the Canadian Museum of Civilization presents only 3-5 percent of collections of objects on display in the physical exhibition space (Corcoran et al 2002).

In order to present the various exhibits and collection of objects in the real museum, most of which could never be displayed due to the limited exhibition spaces of the physical or geographical museum, dynamic displays can be created using digital media to improve access. From this aspect, the use of novel information and digital technology means the virtual museum can play a variety of significant roles in improving access for people to museums as learning and informational resources through cyberspace. Cyberspace, in other words, is a limitless space. Migrating the repository of various and physical artefacts using digitally recorded imaging into the realm of a virtual museum provides a way to overcome access restrictions to the physical museum space. Furthermore, a physical visit to the museum to see the authentic objects is far more limiting, as only a portion of the artefacts may be on display and special permission may be needed to view objects more closely. The virtual museum thus undermines the exclusivity of the artefact, making it available to all, all of the time.

Another important advantage in creating the virtual museum is the possibility of achieving access to sensitive museum objects in a repository, such as a collection of educational images of artefacts which are light-sensitive or fragile. These can be readily presented online through representation of the original objects by digital images as learning resources, and thereby enhance virtual visitors' experience of viewing and learning. Images of light-sensitive material exhibits can be easily displayed online long-term without damaging them physically from exhibition lighting in a public museum exhibition. Fragile materials of artefacts or rare objects on display in a virtual museum can offer educational access without the need to physically handle or secure them. Bowen (2000) pointed out these significant roles of the virtual museums, He stated that they

> Perhaps mirror actual exhibitions in the galleries, both temporary and permanent. This also allows access to material not otherwise generally available, such as objects in store (normally the vast majority of a serious museum's collection) or those too fragile or sensitive for display. (Bowen 2000)

As a result, current constraints of the physical museum such as limited access out of normal hours, admission fees, geographic limitation, exhibits stuck in storage and the display of only a limited number of collections can be overcome (Besser 1997).

More specifically, virtual museums in an Internet environment not only provide information but also increase access by presenting the particular features of collections of artefacts effectively to a vast number of virtual visitors who may suffer from geographical limitations preventing their attendance. Bowen (2000) stated that one of the main reasons for visiting a museum website is probably the location of the physical museum which is far from where the virtual visitor lives. This outreach of access is able to attract and encourage the virtual visitors to come back to the physical museum to view real objects (Schweibenz 2004).

2.4.2.2 Informational and educational resources

As already discussed, a museum's on-line presence not only shares a common mission to inform and educate a wider range of virtual visitors, but also extends access to and improve its learning and educational resources. Varisco and Cates (2005) identified educational resources of web museums as being classified into the eleven distinct categories. The features of each learning resource are summarised as shown in Table 2.5 (Varisco and Cates 2005):

Category	**Features**
Online instruction	• Offering learning material to be completed online; such learning material must contain key elements: intended learning goal or goals, either explicit or implied. (Varisco and Cates 2005 cited from Martindale et al 2005) • 'Explicit goals generally lay out the goal or goals in a straightforward manner (Varisco and Cates 2005)' • 'Implicit goals present similar materials, but the expected goal may not be as obvious (Varisco and Cates 2005)'

Learning activities	Including text, activities and games. 1. Text is 'based [on] descriptions of activities that visitors can print and complete offline (Varisco and Cates 2005).' 2. Activities and games are usually organised with a conceptual theme or particular subject related to exhibits or part of a collection.
Lesson plans	• They are general provided as Word or PDF documents for teacher resources (materials and/or activities) to employ offline in the classroom as compared with online instruction or online learning activities resources which are available on the Internet.
Online exhibits	Including basic educational and enriched educational exhibits. 1. Basic educational exhibits present minimal information on exhibits such as 2D still images and brief interpretive content. 2. Enriched educational exhibits present a large amount of information on exhibit material as follows: • Enlargeable images for seeing more detailed artefacts. • Essay extensions for interpretations of historical context, biography of creators, conceptual themes, background, processes and techniques, etc. • Exhibition activities for enhancing learning experience using multimedia content of exhibit: virtual reality representations of artefacts, games, animations, videos, audios, etc. • Complementary links to resources with accompanying or complementing the exhibited artefacts; for instance: 'lectures, films, performing arts, festivals, catalogues, tours, public programs, classes, and so on (Varisco and Cates 2005).'
Guided tours	• Using guided tours to give virtual visitors a quick overview of the museum in a systematic way based on the intended routes.
Collections	• 'Descriptions accompany each major class of the collection along with a minimum of five images (usually clickable to enlarge) (Varisco and Cates 2005).' • Providing a variety of information about artefacts in terms of principal provenance, creators, places, genres, periods and so on.
Lectures/demonstrations	• Providing dense thematic ideas or topics through linear media accompaniment such as videos, text and audio whose presentations of such media without manipulation, visitors are expected to experience.
Research databases	• They are basically regarded as all material housed in the museum's library, including 'a variety of information, everything from artefact records, to books, periodicals, exhibition catalogues, auction catalogues, pamphlet

	files, artists' publications, and special collections materials (Varisco and Cates 2005).'
Learning links	Generally labelled "Links" or "Resources" that contain two types of sources: the external and internal links of web museums: 1. External learning links: regional, national and international resources etc. 2. Internal learning links: archives, publications, museum libraries, web projects resources.
Conversation tools	• Offering media of communication which supports the relationship between visitors and museums for interpersonal communication through chat rooms, blogs, notice boards, emails, bulletin boards, online videoconferencing and so on.
Miscellaneous other resources	• Including those learning materials which do not properly fit in the other categories but which are still educational resources such as: 'printable guidebooks, white papers, manuals, glossaries of art–related terms (either printable or online), procedural descriptions, and the like (Varisco and Cates 2005).'

Table 2.5 The eleven types of learning resources

(Source: adapted from Varisco and Cates 2005)

However, although the classification system for describing educational resources is useful, some of the learning resources such as online exhibits, research databases collections and miscellaneous other resources can also be regarded as information resources because the features of such resources have overlaps between learning and informational resources. For example, the Dover Museum (http://www.dover.gov.uk/museum/) (Figure 2.9) classified its online exhibits, research databases and collections into information resources. Despite the conceptual classification schemes for describing different types of museum resources, many museums make their digitised content as both informational and learning resources more broadly available on the Web for a wide audience.

Information Resources

The Collection information and pictures

Online exhibition - Channel Swimmers

Articles and Factsheets on Dover history subjects

- Cinque Port Pilots
- Courts Wine Merchants
- Freemen of Dover
- History of Dover Museum
- How to Research your house
- Noel Coward and Ian Fleming at White Cliffs
- Researching Family History - sources

Figure 2.9 The Dover Museum

2.5 Visitor study

2.5.1 The profile and expectations of virtual visitors

The Museum of the History of Science in the University of Oxford reports that it has been conservatively estimated that for every three virtual visitors there is one physical visitor (Sphæra 1999). Some trends are already evident with individual visits to virtual museums online gradually becoming more popular. This phenomenon has been illustrated by National Museum Directors' Conference (1999), which reports that 'the Natural History Museum website records about 150,000 individual visits monthly and the Tate Gallery [is even bigger], with a staggering 200,000 hits a day.' Additionally, the rapid growth of the number of virtual visitors to many web-based virtual museums has already overtaken the number of visitors to visit physical museums itself since early 2002 (Hawkey 2004). Table 2.6 shows museum websites online surveys which have discovered that virtual visitors now outnumber physical visitors.

Museums	**Physical visitors**	**Virtual visitors**
National Museums of Scotland	1,400,000	4,500,000
Natural History Museum	3,300,000	7,955,845
National Maritime Museum	1,532,690	6,749,917
National Portrait Gallery	1,468,875	4,500,000

Table 2.6 Physical and virtual visitors 2004-2005 (Data from the museum's own 2004-2005 annual reviews)

Both traditional and virtual museums serve the three representative groups of visitors: the general public, researchers and professionals and schools (Bowen et al 2001, Brown et al 2005). In terms of key characteristic difference in their knowledge, Marable (2004) stated that the general public may have little knowledge of the subject matter and would need help in putting exhibit content into context. Research and professional visitors not only contain scholars, experts and museum curators, but also may include high level research students, enthusiastic collectors, amateurs and so on. They are knowledgeable on specific fields or have rich experience of the areas. Schools consist of two types of visitors: school students and teachers. Brown et al (2005) pointed out that 'school students and teachers can be regarded as a hybrid of the other two groups with students closer to the general public and teachers closer to researchers in terms of their knowledge and skills'

Moreover, several virtual visitor studies have investigated what kind of content information the virtual visitors look at and use (Avaro and Godonou 2001; Cunliffe et al 2001; Canadian Heritage Information Network 2005). Virtual visitors' expectations vary according to the distinct categories of the visitors as follows:

- 'Potential visitors : to help to plan [a] visit to the Museum;
- Technical Enquirers: to provide [a] facility for detailed enquiries;

- Schools enquiries: to provide access for schools to project-based information and to plan visits; and
- Virtual visitors: to provide access to those who are unable to visit in person (Cunliffe et al 2001 using a citation by Booth 1998a, b).’

This understanding was applied to the development of specialised or particular content information in the Museo del Oro (Museum of Gold) (Figure 2.10) website based on the different types of virtual visitors’ expectations. For example, potential visitors may search general museum information or look at historical background information about pre-Columbian America collection of objects; school students probably seek the thematic subjects for their homework or assignments; teachers who perhaps need help to prepare a visit for a school activity or museum outing (Londoño L. 2000).

Figure 2.10 The Museo del Oro (Museum of Gold) website

2.5.2 The experiences of virtual visitors

Teather and Wilhelm (1999) stated that creating a web-based virtual museum involves taking advantage of the potential of the web environment to enrich the experiences of virtual visitors. This sentiment is echoed by Bowen (2000) who states that creating a virtual museum should be exploited to enhance the experience of virtual visitors; for instance, vast amounts of museum databases can be made available online that otherwise would be unavailable. Moreover, the enhancement of virtual visitor experience can be achieved by 3D digital graphics or models with accompanying interactive multimedia content for interpretation of associated knowledge as information and learning resources. This also allows virtual visitors to rotate 3D models of objects in a 360-degree plane for viewing experience (Copeland et al 2005). This can perhaps achieve a better experience virtually than through direct experience in real museums with exhibits stuck behind glass.

The research into the experiences of virtual visitors has been conducted to investigate how to add educational value to online collections and exhibits in the museum learning context. For considerations of matching the required learning experiences of virtual visitors, Brown et al (2005) have suggested that Diana Laurillard's 'conceptual framework for describing different kinds of learning activities or aspects of learning and for mapping them on to media forms, methods and technologies' can be applied to the presentation of online museums as follows (Table 2.7):

Learning experience	**Methods/technologies**	**Media forms**
Attending, apprehending	Print, TV, video, DVD	Narrative
Investigating, exploring	Library, CD, DVD, Web resources	Interactive
Discussing, debating	Seminar, online conference	Communicative
Experimenting, practising	Laboratory, field trip, simulation	Adaptive
Articulating, expressing	Essay, product, animation, model	Productive

Table 2.7 The five educational media forms and methods for the types of learning experiences

(Source: Laurillard 2002)

Laurillard (2002) states that there are five differentiated types of learning experience, including:

- Attending, apprehending: understanding knowledge through a passive learning process, such as lessons.
- Investigating, exploring: acquiring knowledge through an active learning process which is managed by learners.
- Discussing, debating: learning through discussion or debate with other learners.
- Experimenting, practising: gaining knowledge through an experimental process and practising skills
- Articulating, expressing: articulating and communicating ideas through creating 'the synthesis of some new product (Brown et al 2005).'

Brown et al (2005) summarised these five different types of learning experience which are supported through the different types of media forms corresponding with specific methods for applications of content in a virtual museum in the following (Table 2.8):

Media forms	**Features**	**Methods**
Narrative	• Linear and non-interactive media for transmission of information, ideas and knowledge	Texts, graphics, audios, videos, animations, etc.
Interactive	• Allowing virtual visitors to discovery content in an interactive way for self-directed exploration	Online museum library, catalogues, databases, search engines, hypermedia (e.g. hypertext), etc.
Communicative	• Offering media of communication supports feedback and discussion	Emails, online conferencing, online discussion boards, chat rooms, etc.

Adaptive	• Adaptive forms are similar to media forms of interaction but with the important addition of “direct intrinsic feedback” on learner’s action in learning process	Simulations, virtual environments, educational games, etc.
Productive	• Allowing virtual visitors to present creative expression of their own ideas, and to demonstrate their understanding of knowledge by creative tools	Production, modelling, etc.

Table 2.8 Diana Laurillard’s model and the use of methods for applications of content in a virtual museum

(Source: adapted from Brown et al 2005 and Laurillard 2002)

2.5.3 Visitor behaviours in physical museum and virtual museum websites compared

Much has been written about visitors’ behaviour in a physical museum in terms of their movements, pathways and time spent at exhibit components to determine how to effectively display exhibits in the museum space (Belcher 1991; Yahya 1997; Hein 1998; Diamond 1999). Observing visitor behaviours in museum environments is important to examine ability of exhibits to attract, interest and engage attention in order to understand the degree of visitors’ satisfaction and visitors’ needs.

A number of studies on visitor behaviours involves physical and virtual museum environments (Borysewicz 1998; Davies and Jefsioutine 2001; Chittaro and Ieronutti’s 2004). Veron and Levasseur (1983) have classified four categories of visitors based on paths, movements, stops at exhibits, time spent in viewing exhibits in museum exhibitions (Table 2.9) (Figure 2.11, 2.12, 2.13 and 2.14):

Type	**Features**
The ant visitor	● Spending a long time to visit most exhibited artefacts ● Moving methodically from exhibit to exhibit ● Stopping frequently and physically next to walls and exhibits ● Avoiding empty spaces
The fish visitor	● Moving preferably in the centre of the spatial environment. ● Spending a short time to superficially see exhibits without studying details ● Passing through empty spaces
The grasshopper visitor	● Viewing only exhibits interesting to them and hopping from one to another ● The majority of the visit is guided through individual interests and an understanding of the pre-existing knowledge related to the content of the exhibition ● Spending quite a long time to observe individual chosen exhibits ● Crossing empty spaces
The butterfly visitor	● Frequently changing the direction of visit ● Viewing most exhibits and pausing quite often during the visit ● Spending a variety of periods for viewing each exhibit ● Quite often avoiding empty spaces

Table 2.9 Four categories of visitors’ behaviour

(Source: adapted from Veron and Levasseur 1983 and Chittaro and Ieronutti 2004)

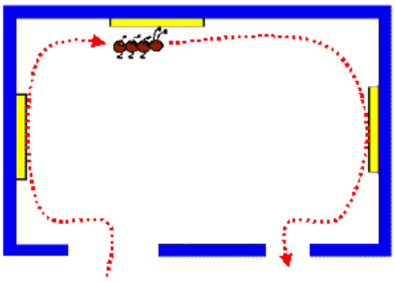


Figure 2.11 The ant visitor

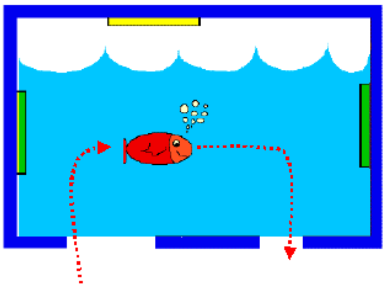


Figure 2.12 The fish visitor

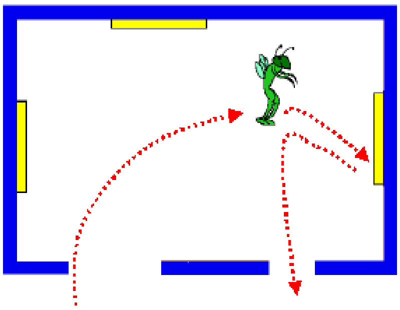


Figure 2.13 The grasshopper visitor

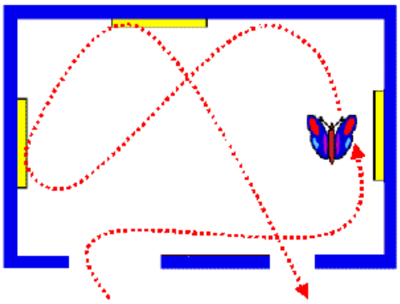


Figure 2.14 The butterfly visitor

(Source: http://giove.cnuce.cnr.it/PETRONI/PETRONI.html)

This research was conducted to investigate actual visitors' behaviour and visitor flow in 2D and 3D virtual environments. Virtual visitor behaviours are traced to identify the types of visiting style related to actual visitors' behaviour by using a virtual tool, called Visualization of Users' Flow (Chittaro and Ieronutti 2004). This measures how much time the virtual visitors spend viewing in front of a particular exhibited artefact. The position of the virtual visitors indicates their interests in the virtual environments (Chittaro and Ieronutti 2004). The categories of virtual visitors are: the visiting style of ant (Figure 2.15), fish (Figure 2.16), grasshopper (Figure 2.17) and butterfly (Figure 2.18) in the virtual environments and are shown as follows:

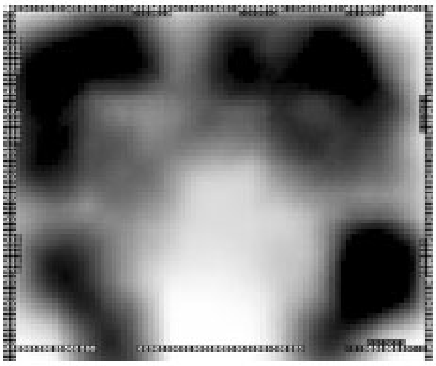


Figure 2.15 Ant visiting style

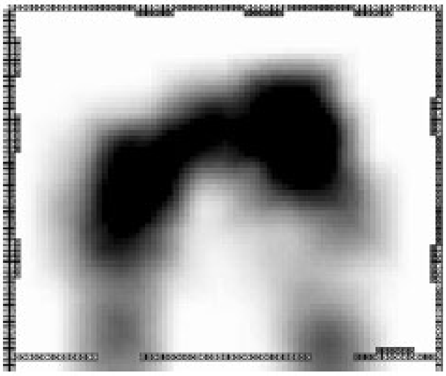


Figure 2.16 Fish visiting style

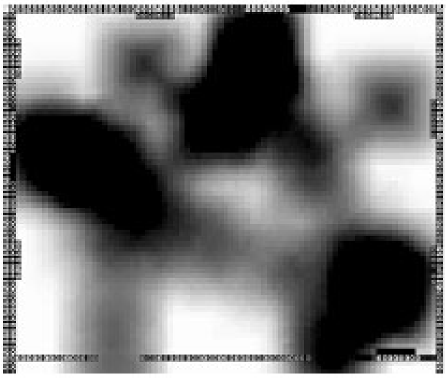


Figure 2.17 Grasshopper visiting style

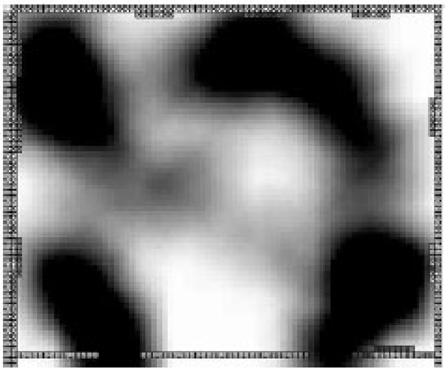


Figure 2.18 Butterfly visiting style

(Source: Chittaro and Ieronutti 2004)

In Chittaro and Ieronutti's (2004) study, they found that the virtual visitors' behaviours in the virtual environments are similar to the behaviours of real visitors when seeing the artefacts in the virtual exhibition environment. In addition, these behaviours can be applied to the consideration of the contextual environment of a virtual exhibition and used to design the information and exhibit in a more appropriate way in order to improve the degree of satisfaction of visitors (Chittaro and Ieronutti 2004). 'This information can be used to help the designer of the virtual exhibition to propose guided tours' as a learning resource (Chittaro and Ieronutti 2004).

Moreover, visitor behaviours in traditional museums have been applied to design museum websites or virtual galleries. For example, Davies and Jefsioutine (2001) created a virtual gallery of contemporary jewellery (Figure 2.19) based on Borysewicz's (1998) idea of the conceptual behaviours: '…browsing through a CD or a Web site is strikingly similar to the "grazing" behaviour that museum visitors engage in (Borysewicz 1998).' They consider visitors' behaviours in a virtual museum as being synonymous with visiting an actual museum, and therefore the virtual gallery could provide them an experience in the physical museum environment, which is synonymous with it (Davies and Jefsioutine 2001).

Maker	Jane Adam
Type	neckpiece
Date	1999
Materials	aluminium, white metal, stainless steel
Techniques	dyed and crazed anodised aluminium, fabrication
Dimensions	45cm

Through the creative adaptation of the industrial technique of anodising, Adam transforms common aluminium into beautiful and sensual jewellery. She is able to print the surface of the anodised aluminium with coloured dyes, then mill the metal which stretches it and creates a subtle sheen on its surface.

Figure 2.19 The virtual gallery of contemporary jewellery

2.6 Educational theories for web-based learning application

2.6.1 Educational theory and pedagogic design for online learning activities

Museums and galleries provide a substantial resource of artefacts and the knowledge associated with those artefacts can be used as educational materials through various types of learning activities, applications and programmes. Concerning learning in museums, there are two issues related to educational theory underpinning the educational practices of museums: the different perceptions of knowledge and what type of learning theory is involved underlying the museum learning context (Hein 1995, 1998).

Hein (1995, 1998) proposed educational theories that consist of two continua of theories crossing each other. Each educational theory places an emphasis on both theory of knowledge (epistemology) and on learning theory, as illustrated in Figure 2.20 and Table 2.10 (Hein 1995, 1998):

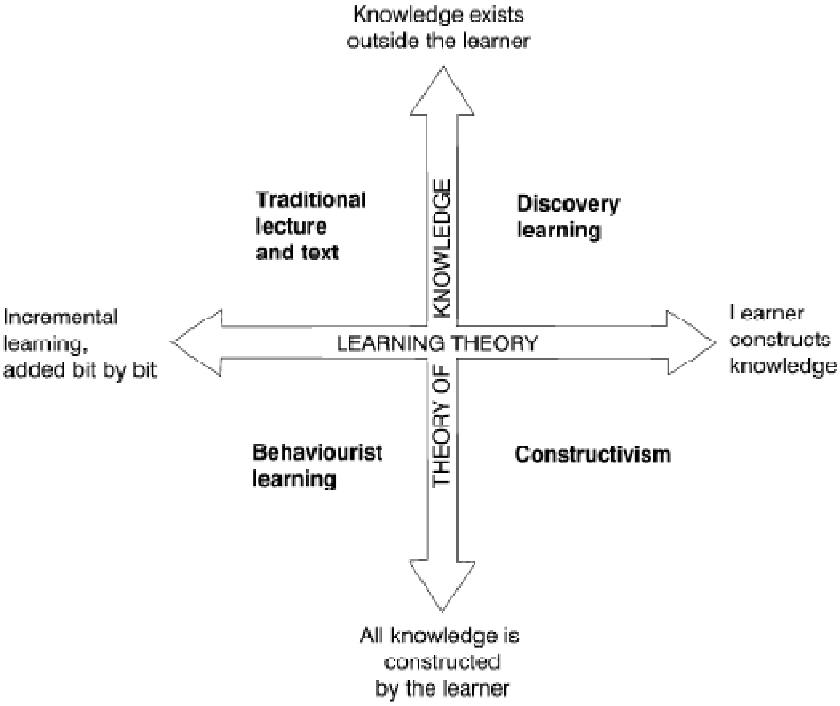


Figure 2.20 Educational theories

(Source: Hein 1995)

Categories	**Exposition**
Traditional lecture and text	• This indicates a traditional view of education, describing didactic and expository education. • The structure of lecture or lesson is organised in a logical sequential order, 'starting with simplest elements of subject and moving on [to] more complex, until the entire field is covered (Hein 1995).'
Behaviourist learning	• It shares didactic and expository method, except it makes no claim for the state of the knowledge of how to learn. • This is devoted to stimulus-response formulation of learning, referring 'only to the outcome from specific stimulus (Hein

	1998).’
Discovery learning	• It indicates the view that learning is an active process. • The integration of active learning and knowledge allows learners to explore “truth” through “learning by doing”.
Constructivism	• This includes two essential components: the active participation of learners and learner-centred model of learning. • Knowledge is constructed by learners as well as their actively organising and building up both understanding and the ability to learn when interacting with the world around them during the learning process.

Table 2.10 The nature and elements of the four dimensions of the educational positions

Each of the educational domains can be effectively applied to the learning context of the physical museums (Hein 1995, 1998; Hawkey 2001, 2004; Teather and Wilhelm 1999). For example, the Deutsches Museum (Munich), the Harvard Museum of Comparative Zoology and the National Portrait Gallery have organised their structure of content of the subject-matter based on the “traditional lecture and text” approach (Hein 1995). Traditional museums organise their learning activities based on the educational positions that contain the featured characteristics of the museums as follows (Hein 1995, 1998) (Table 2.11):

Categories	**Features**
Traditional lecture and text	• Organising an exhibition in a sequential order from beginning to end with accompanying didactic components such as labels, panels and so on for the specification of the exhibition. • A clear hierarchical organisation of subject from the simplest elements to progressively more complex. • Learning activities and programmes with specified instructional objectives determined by the content to be learned.
Behaviourist learning	• Organising museums based on behaviourist learning approach is similar in its characteristics to didactic and expository exhibition. • Arranging exhibits in a logical sequence and an intended order

	with a clear beginning to end for pedagogic purposes.
Discovery learning	• Constructing exhibitions including the concept of exploration of exhibits components suited to a variety of active learning modes. • Ability to ask questions and encourage visitors to find out for themselves through didactic labels and panels. • 'Workshops for adults that offer expert testimony and other forms of evidence for contemplation and consideration, so participants can understand the true meaning of the material (Hein 1998)'
Constructivism	• Providing a number of entry points without specific path and specified beginning and end. • Presenting a broad range of points of view for differentiated active learning modes. • Ability to offer visitors interaction with objects and construct meanings through a range of learning activities, programmes and experiences by using their prior understanding and own life experiences. • Providing 'experiences and materials [to] allow students in school programmes to experiment, conjecture, and draw conclusions (Hein 1998).'

Table 2.11 The characteristics of the museums based on each type of educational theory

In order to apply relevant educational theory to a variety of web-based learning activities in virtual museums, Hawkey (2001, 2004) has suggested that Hein's theoretical model of education can also be applied to virtual museums on the websites as well as in traditional museum exhibitions. He uses this educational model to analyse learning activities and programmes in the Natural History Museum website (UK). Each type of learning activities and programmes was designed according to particular educational dimensions based on the specified learning objectives and differentiated learning needs, as shown in Figure 2.21:

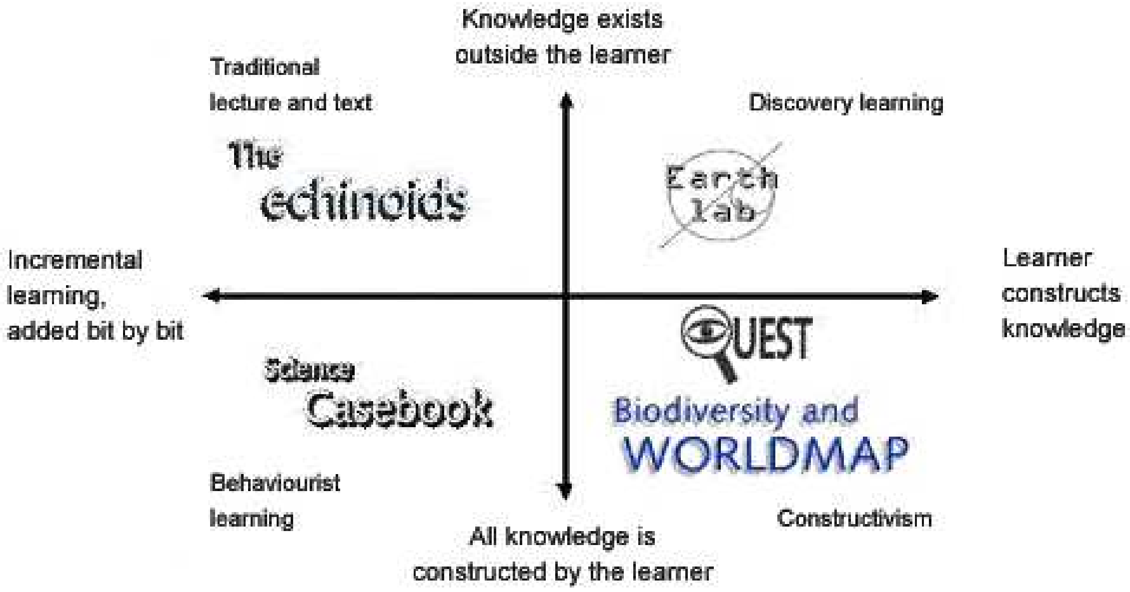


Figure 2.21 Hein’s educational theory applied to the Natural History Museum website

(Source: adapted from Hawkey 2001)

- The echinoids (traditional lecture and text): learning resources and information about echinoids in this programme are organised by the necessary steps in a sequential order for visitors to learn thematic content in a systematic manner from simple to complex.

- Earth lab (discovery learning): this learning activity provides resources regarding specimens, rocks, minerals and fossils through the concept of exploration of exhibits’ components. Visitors are allowed to learn knowledge of museum artefacts through their individual discoveries to actively select categories from the database.

- Science casebook (behaviourist learning): this programme presents a number of science cases for visitors to learn how the scientists work in the Natural History

Museum. One of the cases, “The Beast of Bodmin Moor”, investigates the skull of the Beast of Bodmin Moor with large fangs as learning content in a logical sequence from beginning to end for its intended pedagogic purposes.

- QUEST (constructivism): this programme allows visitors to learn through their own exploration and investigation of selected virtual objects in terms of size, mass, age, material and so on through using a variety of interaction learning activity. ‘It is active learning predicated on discovery rather than merely passive (Hawkey 2004).’

In the context of real museums, Hein (1998) summarised each category of the educational theory corresponding to a specific pedagogy in educational settings as shown below (Table 2.12):

Categories	**Exposition**
Pedagogy for traditional lecture and text	• Acquirement of knowledge relies on the essential structure of the subject such as lectures, programmed instruction, tapes and so on. • The lesson contents are arranged by the necessary steps in a sequential order to develop individual units that can be most easily learned.
Pedagogy for behaviourist learning	• The pedagogic strategy for behaviourist learning is the same as for didactic and expository education. • Including ‘descriptions of exhibit content that focus on linear, sequential structuring of exhibit components, defining specific learning objectives and reinforcement models (Hein 1998).’
Pedagogy for discovery learning	• The pedagogic approach ‘is to provide the appropriate environment for individual learners to be both challenged and stimulated and to partake in experiences that will move them towards the desired goals (Hein

	1998).' - Knowledge of artefacts is organised to provide sufficient openness so that learners are able reach a desired conclusion while exploring the learning environment.
Pedagogy for constructivism	- Organising museums as a learning material and resource such as an encyclopaedia or a catalogue that allows visitors to select what thematic content they want to learn. - A number of constructivist museums provide the opportunity for visitors to learn knowledge through making connections with familiar concepts and artefacts.

Table 2.12 Each educational theory corresponding to a specific pedagogy used

Despite the fact that pedagogy for each educational theory is useful, Hein offers less guidance in providing the explicit procedure for the pedagogic design and a clear identification of target audience. According to a committee of museum professionals in Archives & Museum Informatics, the committee has established a set of criteria as the standards to recognise "Best Educational Use" for museum websites with an emphasis on educational purposes every year. One of the standards, "easily identifiable target audience and clear pedagogical strategy", has indicated that instructional materials in museum websites should be clear in matching pedagogic needs to the target audience (Museums and the Web 2006). For learning in online activities on websites, Weston et al (1999) proposed a structured framework of instructional principles for designing learning materials: this can therefore be equally applied to web-based learning activities and programmes in virtual museums as follows:

- Clarity of target audience
- Clarity of instructional objectives and strategies

- Motivation and context for learning process
- Clarity of organisation and structure of content
- Provision of examples and help in how to use the application
- Provision of interactively practising task in learning process
- Provision of feedback in learning activities

This pedagogic guideline was established as a set of instructional tools with elaborations for designing web learning activities. In addition, it can be used to supplement and expand Hein's pedagogy for each educational theory in museum online activities, programmes and applications in cyberspace.

2.7 Virtuality and simulation theory

2.7.1 Levels of virtuality and simulation and museums

The term "virtuality" may have been initially used to refer to the "conceptual structure" of interactive computer systems in the networked hypertext by Ted (Theodore) Nelson (Skagestad 1998); thus it is often defined as implicit in the description of cyberculture. Lee (2005) asserts that there are two dimensions of virtuality, which are:

- Referring to 'things, events and situations that are not actual (Lee 2005).'
- Designating 'those that have the same effect as real (Lee 2005).'

The features of virtuality, in a broader sense, are not merely an exclusive prerogative of virtual reality but general to all media used. However, although virtuality can be generated by different formats of media, virtuality is strictly regarded as referring to a computer-generated and three-dimensional sensory environment. The world of virtuality can be an imaginary environment. Concerning the representation of the material world, Cerulli (1999) states that the classification of virtual environments in relation to levels of realism, cited from Bridges and Charitos (1997) in World Design Inc., as shown:

- Hyper realities: a virtual environment completely represents the complexity of the real world.
- Selective realities: a virtual environment is a simpler way of representing the real world, where some aspects of the environment are selectively created with a 'high degree of realism and others are transformed, cutting unnecessary detailed information (Cerulli 1999).'
- Abstractions: a virtual environment is represented an abstract world where the aspects of the environment are devoted to presenting 'abstract information about very complex real environments or information that cannot have a physical representation (Cerulli 1999).'

Regarding the application of laboratory and scientific research, simulation is a computer-based technique that produces 'actual events and process under experimental settings (Lee 2005).' Virtual reality is one of the most advanced technologies in creating forms of simulation; thereby simulation can be effectively accomplished through the virtual reality environment. This allows users to interact with a simulated three-dimensional environment through computer-generated modelling.

Baudrillard, a post-modernist theorist, has suggested that there are three stages of simulation in society (Baudrillard 1983, 1993), including:

- The theatre stage: simulation in the theatre stage, the imitation and counterfeit, an exact representation of appearance, needs an original or reference for its meaning, referring to the Renaissance.

- Industrial era of production: an object suffers from an increasing loss of reality in modern production society; thereby, everything can be replicated and simulated by the techniques of mechanical reproduction.
- Post-modern hyperreality: simulation in the post-modern, generated through models of a real, creates the hyperreal which is the 'meticulous reduplication of the real'; thus the distinction between real and hyperreal is not clear due to 'hallucinatory resemblance of the real to itself (Baudrillard 1993).'

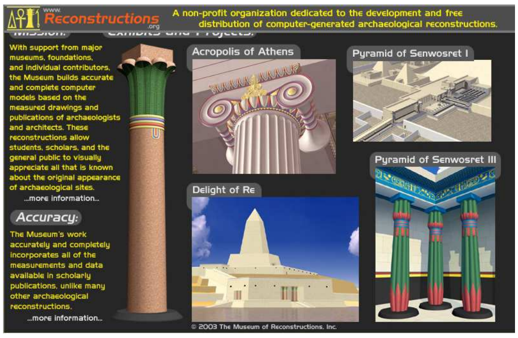
Besides these stages of simulation, there are also the orders of simulacra. Simulacrum refers to 'imitation or copy without an original or referent (Barker 2000).' Baudrillard claims that the three stages of simulation correspond with three orders of simulacra as follows (Baudrillard 1983) (Table 2.13):

The stages of simulation	**The orders of simulacra**
The theatre stage	The first order: the simulacrum of a nature (the counterfeit) • Simulacra are based on the natural law and founded on the image on counterfeit and imitation.
Industrial era of production	The second order: the industrial simulacra • Simulacra are based on the commercial law and founded on energy in the whole system of mechanical production.
Post-modern hyperreality	The third order: simulacra of simulation • Simulacra of simulation are based on the structural law and founded on information for the purpose of complete control and operationality.

Table 2.13 The three stages of simulation corresponding with the orders of simulacra

As can be seen, the stages of simulation corresponding with the orders of simulacra provide evidence for 'the obliteration of the boundary between the real and virtual (Lee 2005).' This cultural phenomenon occurs in the realm of museums. There are three dimensions of simulation in museum environments: reconstruction, reproduction, and representation.

An example is the actual-scale reconstructed imitation of a dinosaur using a dynamic mechanism on display in a natural history museum (Anderson, 1999). The imitation of a dinosaur is simulated without its reference to the real; although it was created through archival research, archaeological evidence and the physical remains etc. as scientifically systematic inferences for reconstruction. In a museum exhibition, this imitation of a dinosaur in an authentic context is simulated as realistically as possible, living in its contemporary time that the visitor may enjoy viewing it in an immersive environment rather than seeing the static skeleton of a dinosaur stuck in a showcase. However, although the skeletons of dinosaurs are of value as authentic objects which are important for a museum and in particularly for historians and researchers, the simulation of a dinosaur, a reconstruction, is hyperreal more real than real (because its colours, skin, textures and spatial information are dynamically represented in detail), which enables visitors to have a compelling experience in an immersive and sensory environment. Besides, the creation of the reconstructed cultural materials (e.g. historic sites, artefacts and archaeological structures etc.) are presented within a virtual museum environment for virtual visitors to visually appreciate the original appearance of archaeological buildings and places through accurate simulation of computer-generated models; for example, the Museum of Reconstructions (Figure 2.22) (www.reconstructions.org/mor_index_frame.html).



A non-profit organization dedicated to the development and free distribution of computer-generated archaeological reconstructions.

With support from major museums, foundations, and individual contributors, the Museum builds accurate and complete computer models based on the measured drawings and publications of archaeologists and architects. These reconstructions allow students, scholars, and the general public to visually appreciate all that is known about the original appearance of archaeological sites.

Accuracy:

The Museum's work accurately and completely incorporates all of the measurements and data available in scholarly publications, unlike many other archaeological reconstructions.

© 2003 The Museum of Reconstructions, Inc.

Figure 2.22 The Museum of Reconstructions

Concerning reproduction of original artefacts, museums present their collections in virtual form as duplication of authentic artefacts in cyberspace. This is because the aura of an original artefact, its authenticity (for example, smell, touch, feeling, etc.), has been lost when it is reproduced by a digital image but its visual expression cannot be substituted. Allison-Bunnell and Schaller (2005) state that 'given the inherent mediation of the virtual environment, an online exhibit will always be a reproduction of the object….Thus a key aspect of authenticity in the museum gallery can never be transferred online.' Therefore, reproduction of original artefacts in a virtual museum, especially for an art museum website, is always regarded as an iconic signifier as close to the original as possible. This could be through the reproduction of an artefact as authentic to the original as possible.

Advanced technology also allows for the creation of such an imaginary environment for representing the material world in a symbolic way. Davies and Jefsioutine (2001) discuss the symbolic representation of museum objects in a virtual world, referring to Zorich's contention that 'media presentations can be used to make these connections and, in this context, a representation of an object is not intended to approximate to the impact of the real thing, but is used, rather, as a visual reference.' There is a migration of an original artefact into the realm of a virtual museum through a digitally recorded image which acts as a visual reference to its original and is regarded as a symbolic signifier. For example, presenting an artefact in a science museum website is often considered as a symbolic signifier in order to focus on demonstrating the underlying scientific principle through the digital representation of the original.

2.8 3D web technologies and virtual museum environments

2.8.1 Application of virtual reality and 3D web technology in virtual museum environments

Virtual Reality (VR) and emerging 3D computer graphics technologies are widely applied to a variety of research disciplines and practical application in business. Much has been written about a number of evolving 3D technologies used in web museums for the creation of virtual reality environments that have become significant within the museum realm (Gill 2001; Ross et al 2003; Mastoropoulou 2001; Fahy 1995). Fahy (1995) has contended that ‘through computer-created worlds, visitors may be able to experience through their sense exploration of the sea bed, a Roman Colosseum or the museum stores (security considerations taken into account).’

According to Bryson (1994), the idea of Virtual Reality is an interactive simulation of a 3D sensory environment which gives an illusion of a computer-generated experience of viewing virtual objects with spatial presence. Ross et al (2003) state that virtual reality can ‘stretch from pure programming environments such as Java3D, through coding environments such as the HTML-like Virtual Reality Modelling Language [VRML] to photographic techniques such as those employed by Apple’s QuickTime Virtual Reality (QTVR).’

Gill (2001) and Ross et al (2003) have suggested that several relevant 3D web technologies (i.e. VRML, Java 3D, X3D and Quick Time VR) and Virtual Reality are effectively applied to present cultural information in the virtual museums in terms of the enhancement of viewing experience, the efficient delivery of 3D cultural content as informational resources and interactivity in the learning process in the 3D simulation of virtual reality environments. Moreover, other 3D web technologies such as Cult3D, Virtools and Second Life can be effectively applied to create virtual web-based museums with 3D environments. The various features of each technology are outlined as follows: VRML, Java 3D, X3D, QuickTime VR, Cult3D, Virtools and Second Life.

- VRML (Virtual Reality Modelling Language)

VRML is a scene description language and file format for describing interactive virtual environments, animations and movement. It was created as a standard for the creation of web-based contents in a 3D virtual form on the Internet. The innovative development of the emerging standards accomplishes the integration of the Internet access and the virtual reality technology which ‘allows 3-dimensional worlds navigable on-line in real-time, opening up a whole new set of possible applications for virtual spaces (Cerulli, 1999).’

In addition, the realistic effects of 3D virtual environment design using VRML can be beneficially combined with the structure of HTML. The objects can be programmed with specific behaviours; thus the users are able to navigate with them in a virtual world with realistic illusory effects (Gill 2001). For example, Inuit 3D (Figure 2.23) is a 3D simulation of the exhibition rooms on the Canadian Museum of Civilization website (www.civilization.ca/aborig/inuit3d/inuit_e.html).

To move:

1. Use the *"Page Up"* and *"Page Down"* keys to go to pre-set viewpoints.
2. Use the *arrow keys* on your keyboard to move.
3. Click and drag the *mouse* over the museum to move.

Figure 2.23 Inuit 3D virtual exhibition

- Java 3D

Java 3D, a scene graph-based 3D application programming interface (API), is a multimedia extension to the Java 2 platform rather than a language in its own right such as VRML (Ross et al, 2003). It delivers a suite of standard Java classes for the compiler to construct various 3D programmes for interactive 3D applets and applications (Walsh and Bourges-Sévenier 2001). Although Java 3D programs written in Java are different form VRML, it is possible to employ VRML content through Java 3D programmes.

Paquet et al (2001) have noted that the Canadian native sculptures in the creation of the 3D virtual museum (Figure 2.24) adopted Java 3D for several reasons as follows:

- Implementing any platform without modification of code.
- There is the possibility of using the benefits of both API without rewriting the code.
- Very rapid implementation, because Java 2 code is executed, rather than interpreted.
- The Java 3D API is very sophisticated and can deal with complex problems of ‘synchronisation of events, collisions, high quality rendering and

optimisation (Paquet et al 2001).'

Figure 2.24 Canadian Native sculptures in the museum environment

However, although Java3D is advanced technology, it is not appropriate for the efficient delivery of the web content on the Internet because of its shortcoming, namely, complexity (Ross et al, 2003). Besides, the creation of virtual reality environments might rely on external experts thereby 'depriving the organisation of the ability to update or extend a costly Java3D interactive in-house (Ross et al 2003).'

- X3D (Extensible 3D)

X3D was originally called VRML Next Generation (VRML-NG). The standards development for X3D are considered as being backwardly-compatible with VRML and provide compelling 3D graphics in cyberspace (Ross et al, 2003). Ross et al (2003) point out that 'the format is intended not only for storing and displaying 3D graphics but also as a middle ground between different graphics programmes, allowing them to exchange files between them.'

This technology encodes the scene using an XML (Extensible Markup Language).

X3D has the same benefits of allowing VRML content to be easily expressed and properly structured in terms of XML (Walsh and Bourges-Sévenier, 2001). Besides, an advantage of ‘the X3D specification is based on a small, lightweight core that can be easily extended with additional components as necessary (Gill 2001).’

- QuickTime Virtual Reality (QTVR)

QuickTime Virtual Reality is a type of movie file format developed by Apple Computer. It is neither a real virtual reality technique nor does it render three dimensional images (Ross et al 2003). However, it allows the creation of an interactive series of still images which are stitched together by authoring software to give the illusion of a realistic simulation (Gill 2001). This technology has been efficiently and widely used for applications of a CD-ROM based version of the virtual museums since the early 1990s. For example, the Apple Computer’s “Virtual Museum” presented ‘a 3D simulation of three interconnected museum spaces (Huhtamo 2002).’

There are two types of QuickTime VR movies, namely QuickTime VR Panoramas and Objects. Panorama VR allows the user to view a photographic panoramic environment through 360 degrees from a single viewpoint. For example, the VR panoramic exhibition of “sculpture of Angkor and ancient Cambodia” (Figure 2.25) on the National Gallery of Art website (www.nga.gov/exhibitions/camwel.shtm) allows viewers to navigate around the exhibition at will, even zoom in and out while interacting with exhibits by embedded hyperlinks to web pages for details.

Figure 2.25 The VR panoramic exhibition of sculpture
of Angkor and ancient Cambodia

In contrast with Panoramas VRs, Object VR simulates three dimensional views of the object from various viewing angles which allow visitors to interact with the object in a horizontal rotation from a variety of perspective viewpoints: for instance, an Pomo basket (Figure 2.26) from the National Museum of the American Indian exhibitions (www.nmai.si.edu/exhibitions/all_roads_are_good/FrameARAG9.htm).

Figure 2.26 A Pomo basket

- Cult3D

Cult3D is widely used to provide 3D product presentations for 3D e-Commerce, brand websites, in-store promotions and web marketing (Cult3D 2008). This technology can also be employed to create 3D model artefacts within 3D virtual museum environments. For example, the b-side-museum presents 3D model artefacts with textual descriptions. This 3D model exhibit (Figure 2.27) (www.b-side-museum.com/bsidenew/frame/teacup_a/a_Sop_3P.html) in the virtual space allows visitors to zoom in and out, rotate and move for spatial information.

Sopwith Triplane :Fighter 1916 **U.K.**

SPECIFICATIONS:

Wingspan:	8.08m
length:	5.74m
height:	3.20m
empty mass:	499kg
start mass:	699kg
engine:	One 110 hp or 130 hp Clerget rotory, radial engine.
max speed:	181.8km/h
initial climb:	3,05m/11min50sec.
ceiling:	6,250m
range w/max.fuel:	2.75hous
armament:	7.7mmMG X 1,
Crew:	1

なぜ主翼が３枚なのか？このアイディアを思いついたのはソッピース社のハーバード・スミス技師でした。その狙いは翼面荷重を下げて運動性を確保するというものでした。その設計意図通り優れた運動性を発揮してドイツのアルバトロス戦闘機に対し優位に戦いを進めることができました。しかしエンジン出力の向上もあり複葉機もより高性能になった結果その性能もすぐに色あせ短期間の活躍で終わりました。ドイツにもフォッカーDr.1という三葉機がありましたがこれもまた短命に終っています。これらの機体の欠点は主翼が３枚もあるため抵抗が大きく速度の点で見劣りするということでした。

In their search for an outstanding fighting aeroplane the Sopwith experimental department decided in early 1916 to build an entirely new design--a triplane. The completed machine had three narrow-chord wings. The combined wing area of the three mainplanes gave the aircraft plenty of lift. Ailerons were fitted to all three wings; the interplane struts were plain but strong and few bracing wires were needed. The fuselage was a typical Sopwith wooden box girder. Tail- plane, elevators, rudder and fin resembled those of the Pup , but later production models

Figure 2.27 A 3D model artefact with interpretive content

- Virtools

Virtools is entirely devoted to developing 3D experiences on computers, PC/console games, Intranets and the websites in virtual immersive environments (Virtools 2008). The key features of Virtools include five components: ‘the Graphical User Interface to develop sophisticated applications by visually assembling objects and behaviours, the Behaviour Engine to run interactive applications, the Render Engine to render graphics in real-time, the Virtools Scripting Language to create low level specific functions without any C + + line and the SDK to create custom behaviors (Virtools 2008).’ This technology was adopted by the Musée du Louvre to create an imaginary exhibition of oil paintings (http://musee.louvre.fr/expo-imaginaire/fragonard/index_en.html), Jean-Honoré

Fragonard, in a 3D walkthrough environment (Figure 2.28).

The Wrapped-Up Cat
Sepia wash over black chalk line drawing
H. : 45,4 cm ; L. : 34,5 cm
RF 42670
Musée du Louvre

Fragonard was a keen observer of the world of childhood and seems sometimes to have taken pleasure in the mischievous games invented by children. This drawing was probably a preliminary sketch for a painting exhibited in 1779, of which the description that has come down to us matches the scene represented here. A child is playing with a cat that has been carefully wrapped up. The creature

© Musée du Louvre
Angèle Dequier

Figure 2.28 The virtual exhibition: Jean-Honoré Fragonard

- Second Life

Second Life, a complex system, not only provides a 3D virtual space on the Internet, but also allows end-users to create their own 3D content using integrated authoring tools available in the world of Second Life. However, the integrated authoring tools do not follow conventional ways for the creation of 3D objects using 3D software packages such as 3D Studio Max, Maya and so on (Wieneke et al 2007). 3D objects created in Second Life can be also programmed by a physics engine and a scripting language to design 3D interactive content with rich media forms. In recent years, Second Life has been adopted to present museum content in 3D virtual environments (Wieneke et al 2007; Urban et al 2007). An example is the Fort Malaya Museum to present its cultural content in the virtual world of Second Life (Figure 2.29).

Figure 2.29 Fort Malaya Museum

(Source: Urban et al 2007)

The advantages and disadvantages of each 3D technology and QTVR are examined in detail in Table 2.14:

Technology	**Advantages**	**Disadvantages**
VRML	• Allowing the use of less powerful computers to view the dynamic 3D contents with high quality of visual information • The objects can be programmed with behaviours	• The requirement of a wider bandwidth • Low speed of data transmission • It is ‘not easy to learn, and its syntax is not so flexible or intuitive (Ross et al 2003).’
Java 3D	• Implementing any platform without modification of code (Paquet et al 2001) • Java 3D API is very sophisticated and can deal with complex problems (Paquet et al 2001) • Provision of a high level and object-oriented view of a 3D graphics model (Mastoropoulou 2001)	• It is too complex for efficient delivery of the web content on the Internet (Ross et al 2003) • The creation of virtual environments might rely on external experts, thus ‘depriving the organisation of the ability to update or extend a costly Java3D interactive in-house (Ross et al 2003).’
X3D	• Providing compelling 3D graphics in cyberspace and compatible with VRML • ‘The X3D specification is based on a small, lightweight core that can be easily extended with additional components as necessary (Gill 2001)’	• Difficulty in modifying the 3D content (Liu and Gu 2006) • High cost of creating 3D products (Liu and Gu 2006)
QTVR	• Intuitive user-friendly interface of navigation (Gill 2001) • Low cost of creating or authoring cultural information of images in the realistic	• Inability to present accurately spatial information on form and dimensions of the physical artefacts

	context of a scene (Gill 2001) • Ease of viewing the file format on less powerful PCs with the ubiquitously QuickTime browser plug-in through the Internet	• Less interactivity of manipulation through the 2D digitally recorded images of artefacts
Cult3D	• Ability to present 3D model objects with sounds and animations • High quality of visual information with a small size file • 3D model objects can be programmed by using JavaScript • Cult3D viewer plug-in will be automatically downloaded and installed	• Fewer functions for programming 3D objects with various behaviours • Some media formats are not supported
Virtools	• Ability to present accurate form and dimensions of the physical artefacts or environment with animations, sounds, videos and so on. • Compatible with JavaScript for programming • The Virtools Scripting Language is a powerful tool for editing 2D or 3D objects with various behaviours • The plug-in browser, 3D Life Player, will be automatically downloaded and installed	• The Virtools Scripting Language is difficult and complex • Inability to present high quality of visual information with the smallest details
Second Life	• 3D model objects can be programmed by using the physics engine and scripting language • Intuitive user-friendly interface of navigation • Ability to create 3D environments with other media formats such as animations, sounds, videos and so on	• The creation of 3D model objects is limited by using the authoring system • Access to Second Life is required by advanced computer hardware and broadband Internet connection (Wieneke et al 2007) • Inability to present high quality of visual information • 3D environments are accessed only by registered visitors • Inability to accommodate a large number of virtual visitors in a single environment

Table 2.14 The advantages and disadvantages of Virtual Reality and 3D technologies

As can been seen, overall Cult3D and Virtools have significant advantages over the other 3D web technologies and have already been effectively applied to 3D museum environments in terms of the presentation of 3D model exhibits with rich media formats support.

2.8.2 Immersion, presence and usability issues in virtual reality environments

A virtual environment (VE) provides the benefit of psychologically transporting its "presence" to a place which may not exist in the world of reality (Sadowski and Stanney 2002). The featured characteristics of a virtual environment are to focus "immersion" through sensory information of displays. 'VEs add a dimension of physiological immersion by removing as many real world sensations as possible while substituting the sensations that would be imparted if the VE were real (Sadowski and Stanney 2002).'

2.8.2.1 Immersion

Slater and Wilbur (1997) identified the term "immersion" as 'a description of a technology, and describes it as the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant.' Slater and Wilbur (1997) summarised these factors that contribute to immersion as follows:

- Inclusiveness: extent to which physical reality is shut out
- Extensiveness: the range of sensory modalities accommodated
- Surrounding: the extent to which this virtual reality is panoramic rather than limited to a narrow field
- Vividness: the resolution, fidelity, and variety of energy simulated within a particular modality (for example, the visual and colour resolution)

(Source: Slater and Wilbur 1997)

The level of immersion can be assessed through an objective and quantifiable description of what any particular system does provide (Slater and Wilbur 1997). It is important to note that the level of immersion is not fixed, and depends on multiple variables: 'the number of displays, the extent of inclusiveness, the quality and quantity of display information, the extent of body tracking, the richness of the body model, and the degree of temporal correlation between proprioception and sensory data (absence of lag) (Slater and Usoh 1995).'

2.8.2.2 Presence

Presence, a state of consciousness, is the psychological sense of being in the virtual environment in which one is immersed; for example, walkthroughs (Slater and Usoh 1995; Slater and Wilbur 1997; Schubert et al 1998). Heeter (1992) contends that there are three different categories of presence: personal, social and environmental.

- Personal presence: this refers to 'the extent to which and the reasons why you feel like you are in a virtual world (Heeter 1992).' The main purpose of virtual reality research is to emphasize creating a sense of personal presence through imitation of the range and intensity of stimuli of the human senses in order to measure the extent of perceiving the natural world. The reasons for creating vivid and rich artificially simulated sensory stimuli influence a comprehensive and accurate measure of presence in terms of three-dimensional models, sounds, photorealistic images, tactility and so on.
- Social presence: this refers to 'the extent to which other beings (living or synthetic) also exist in the world and appear to react to you (Heeter 1992).' The premise of social presence is simply that if many people are in the same virtual environment, the presence of others offers evidence that a virtual environment actually exists (Heeter 1992).
- Environmental presence: this refers to 'the extent to which the environment itself appears to know that you are there and to react to you (Heeter 1992).'

> A virtual environment can be created to be more responsive than the real environment in order to evoke a greater sense of presence through actively responding to users. For example, lights can be automatically turned on when users enter a room.

Immersion can influence the sense of presence which ‘is a state of consciousness where the human actor has a sense of being in the location specified by the displays (Slater and Usoh 1995).’ However, the level of presence is unlikely to be a simple linear function as the degree of immersion is due to differentiated requirements of various individuals for sensory data (Slater and Usoh 1995). Sadowski and Stanney (2002) examined the possible factors with their corresponding guidelines for enhancing the sense of presence in virtual environments (Table 2.15):

Factors	**Guideline**
Ease of Interaction	Provide seamless interaction such that users can readily orient in, traverse in, and interact with the virtual environment.
User-initiated control	Provide immediacy of system response, correspondence of user-initiated actions, and a natural mode of control.
Pictorial Realism	Provide continuity, consistency, connectedness & meaningfulness in presented stimuli.
Length of Exposure	Provide sufficient exposure time to provide VE task proficiency, familiarity with the VE, and sensory adaptation.
Social Factors	Provide opportunities to interact with and communicate with others verbally or by gestures. Provide confirmation that others recognize one's existence in the VE.
Internal Factors	Identify the types of individuals who will use a VE system and their preferred representational system (i.e., visual, auditory, kinesthetic).
System Factors	Providing stereopsis, head-tracking, a large field of view, increasing update rates, multi-modal interaction, and ergonomically sound sensors/ effectors facilitate presence.

Table 2.15 Guidelines for supporting presence

(Source: adapted from Sadowski and Stanney 2002)

With regard to the concept of presence in applications of virtual museum environments, a number of studies has suggested using different forms of immersion (e.g. high-resolution digital pictures of the scene) to enhance the sense of presence (e.g. walking through the virtual reality environment) (Mastoropoulou 2001; Paquet et al 2001; Jones and Christal 2002). The simulation of original artefacts in a virtual reality museum environment relies mainly on the quality of visual information and high-resolution digital images as a form of immersion which enhances a degree of presence in order to give the possible feeling of being truly in the physical museum space itself. Besides, the employment of forms of immersion, in some cases, provides an opportunity to maximize "the sense of cultural presence" in learning about cultural and historical spaces as a feeling of being truly there. This enables a virtual visitor to evoke awareness and understanding of the past life at certain historical sites and time periods through an immersive virtual heritage environment. Champion (2006) asserts,

> If we were trying to create a virtual heritage environment that engaged and educated people, we would be aiming at eliciting this sense of cultural presence. Therefore, in this sense, cultural presence is a perspective of a past culture to a user. (Champion 2006)

2.8.2.3 Usability issues

Much has been written on the inevitable trend of employing the presentation of 3D web pages with applications of virtual reality environments such as in 3D eCommerce, 3D web-based virtual gaming environments, etc. For any consideration of creating such websites, it is important to examine currently raised usability issues involving virtual reality and the Internet. Kerr et al (1999) have pointed out a numbers of usability issues encompassing the employment of 3D technologies in virtual reality environments within web pages, including metaphors, affordances, orientation and navigation and the use of multiple media. Equally, these key usability issues are also useful when considering the creation of a virtual museum environment with an emphasis on the informational aspect and the learning context in cyberspace.

- Metaphors

  Reid and Kazman (1996) identified the metaphor as communicating the unknown domain of knowledge (the target) by transposing it into the partial mapping of a known concept (the source). Bryson (1994) defined the three levels of metaphorical abstraction with emphasis on applications to the design of a virtual environment:

  - Overall environment metaphor(s): the metaphor which determines the overall appearance of the environment, including the types of application objects which appear in the environment. This metaphor will also impact [on] the types of behaviours in the environment.
  - Information presentation metaphor(s): the metaphor for how information about the environment is presented to the user.
  - Interaction metaphor(s): the metaphor for how the user interacts with the environment and objects in the environment (such as widgets).

(Source: Bryson 1994)

There may be a number of conceptual metaphors at each level of metaphors (Bryson 1994). For instance, text, one of information presentation metaphors, reveals in the environment through an information window as well as information presented by means of the colour of objects; the direct manipulation of objects, one of interaction metaphors, indicates a set of tools as well as being controlled by menu selection, sliders, pressed buttons, etc (Bryson, 1994).

In a 3D world, the museum includes the collection, architectural environment and contextual information, etc. The construction of contents of virtual exhibits in a 3D-based architectural environment of the museum structure is more complex in particular, representing sets of information. Several studies have suggested that applying various levels of metaphorical approaches is more effective in representing complex sets of information in a 3D virtual museum environment (Frery et al 2002; Barbieri and Paolini, 2001; Cerulli 1999). Frery et al (2002) contend that in respect of the case study research, of the development of 3D virtual Guggenheim Museum Bilbao, the following considerations need to be made:

> In order to construct these information objects, rich semantic metaphors for the modelling process should be used. According to the type of information to be represented, geographical (e.g., the location of the atrium in the Guggenheim Museum), architectural, and/or conceptual metaphors may be used. (Frery et al 2002)

- Affordances

Slater and Usoh (1995) contended that ‘an affordance of an environment is what it offers the inhabitants.’ For example, a door with a handle affords pulling. This conceptual perspective can be applied in a virtual environment, such as a button indicates the function of a pressed tool in the world of reality as it can also be pressed by the user and should be visible in a virtual environment. Besides, such affordances can be directly connected to various levels of metaphorical approaches and ‘occur at all levels of the virtual environment (Kerr et al 1999).’

- Orientation and navigation

The main problems experienced by a user in the context of a virtual environment are disorientation and navigation (Chittaro and Ieronutti 2004). Orientation is an important issue relating to the nature of a virtual visitor's involvement with the virtual reality museum environment in terms of visiting styles, visitor flows and interests (see Section 2.5.3). Orientation of a virtual visitor can be indicated through "a cognitive map" for the acquisition of spatial knowledge (Cerulli 1999). Inuit 3D, for example, consists of three 3D-based virtual reality exhibition rooms on the Canadian Museum of Civilization website (www.civilization.ca/aborig/inuit3d/inuit_e.html). A visitor can intuitively navigate virtual exhibits in the virtual environment through the provided map (Figure 2.30) at the left bottom of the screen. The map generates a red cursor that indicates an orientation of a virtual visitor and thus he or she navigates and orientates the virtual spatial exhibitions for the acquisition of spatial knowledge.

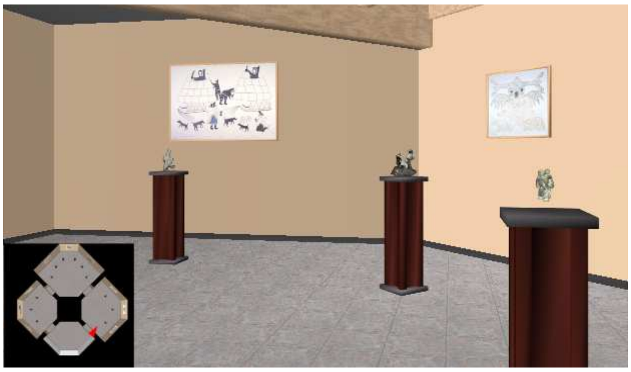


Figure 2.30 A 2D map

Besides, if a three dimensional virtual environment includes entrances and exits, it is important to provide explicitly marked indications for navigation and orientation. Thus they allow users to easily and instantly recognise where they can enter a room and exit from the rooms (Kerr et al 1999). This idea has been adopted by the Canadian Museum of Civilization website to design Inuit 3D (Figure 2.31).

Figure 2.31 A Clearly marked exit point

- Integration of multiple media formats

3D virtual museum environments can be made more attractive and more useful through the integration of multimedia content for interpretation and associated information. Paquet et al (2001) have noted that the integration of multiple media formats is very helpful in interpreting knowledge of artefacts and additional information. They state,

> One may want to access the web page corresponding to an object or a video providing additional information about the artefact like [its] excavation or a reconstitution of the period in which the artefact was in use. (Paquet et al 2001)

Regarding a virtual reality learning environment, there are several advantages of combining such media formats that can enrich learning experiences of different audiences.

2.9 Summary

A substantial amount of relevant literature in the field of virtual web-based museums in 3D environments was examined in this chapter. The key findings from the literature review in relation to the aims of the research are now summarised and the key research question is formalised.

The first section helped to identify the main purpose for creating virtual web-based museums and the advantage and disadvantage of the distinct categories of virtual museums in relation to actual museums. The second section on museum theory showed that the three current representational schemes are based on a semiotic perspective to interpret meanings of physical artefacts in virtual museums on the websites. The next section examined the role of the both traditional and virtual museums as both information and learning resources. One of the most important aims in creating virtual museums is not only to increase accessibility, but also to employ the emerging technologies to present digitised content as both informational and educational resources from which virtual visitors can learn the historical and cultural significance of museum artefacts and associated information.

The section on visitor study profile examined expectations, experiences and behaviours when interacting in virtual museum environments. Different types of virtual visitors were identified with specialised content and information requirements. The five categories of learning experience supported by the different types of media forms corresponding with specific methods for information content should be taken into consideration in the design of web-based museum systems. It is noteworthy that virtual visitor behaviours in 3D virtual environments are similar to real visitor behaviours in a real museum environment. There are four online museum visiting styles (i.e. ant, fish grasshopper, and butterfly) and that consideration is regarded as crucial for the successful and effective design of virtual exhibits and information content in a 3D exhibition environment in order to engage visitors' attention and maintain their interest.

The section on educational theories for web-based learning applications outlined Hein's educational theories that can be applied to support both real and virtual museums. Hein's educational theories and coherent pedagogic approaches should take the known museum visiting styles into account in order to create truly engaging 3D museum environments in which virtual visitors can select the most appropriate learning content in exhibitions.

The section on virtuality and simulation theory identified the relationship between the level of simulation and the degree of virtuality relating to the level of realism. The simulation of an online museum artefact should highlight the messages signified which need to be conveyed through the representational schemes, depending on what historical and cultural meanings and contextual information need to be interpreted.

The final section on 3D web technologies and virtual museum environments identified the main VR systems and 3D web technologies (i.e. VRML, Java 3D, X3D, QTVR, Cult3D, Virtools and Second Life). Advantages and disadvantages of each 3D web technology were summarised in order to determine the most appropriate technologies for the development of a 3D virtual museum environment. Cult3D and Virtools were regarded as the most appropriate technologies in terms of the effective presentation of interactive 3D objects with rich media content support and have been already successfully applied to create 3D virtual museum environments. There are four key factors which contribute immersion in 3D environments which are inclusiveness, extensiveness, surrounding and vividness. Metaphors, affordances, orientation and navigation and the use of multiple media were identified as important design elements to increase usability of 3D virtual museum environments with an emphasis on the informational aspect and the learning context.

In conclusion, virtual museums using the emerging 3D technologies can not only improve accessibility, but also allow virtual visitors to interact with 3D model exhibits using rich multimedia content from which they can learn the historical and cultural significance of museum artefacts and associated information within a 3D environment. However, although Hein's educational theories and coherent pedagogic approaches can be used to underpin virtual museums in the learning context, they are not enough on their own. To develop effective 3D virtual museum learning environments requires further consideration of virtual visiting styles. This is because consideration of the known museum visiting styles is important in the design of exhibit content, virtual or otherwise, to ensure it attracts visitors' attention and maintains their interest and allows learning to take place. Thus it can be argued that the effective design of 3D museum environments should be based on sound educational theory and a coherent pedagogic strategy grounded on a better understanding of visitor behaviour patterns. This will then ensure the learning content of the virtual exhibition is consistent with the related visiting styles, leading to a deeper engagement with the subject matters for learning efficacy.

The next chapter (Chapter Three) therefore discusses the reasons for the choice of research methods for addressing this research question: specifically what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy.

Chapter Three: Methodology

3.1 Introduction

The last chapter described the central research question of this study: what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy. In order to address this research question, this chapter will detail the rationale for choosing a set of research methods suitable for this research study.

In relation to the research question, methods triangulation (Patton 2002) was considered as an appropriate methodology to be applied in this research project combining both qualitative and quantitative methods for data collection and analysis. This research study includes a documentary review on the nature of web-based museum systems (qualitative approach), a critical review of the existing museum websites (qualitative approach), observations of virtual visitor behaviours and their learning activities combined with performance tasks and post-observation questionnaire (mixed qualitative and quantitative approaches), semi-structured interviews with experts (qualitative approach) and an evaluation of the prototype 3D exhibition (mixed qualitative and quantitative approaches) in order to achieve the formulated research objectives.

The results of the secondary and primary research findings were used to propose a theoretical design reference model that could be employed as a tool for virtual museum designers to develop effective 3D museum environments for use as both an informational and learning resource. A prototype 3D exhibition was then developed based on this theoretical design reference model. The validation of the theoretical model was conducted by evaluating this prototype through user testing and expert evaluation based on the assessment phase of the theoretical model. Moreover, issues of validity and reliability for each of the three primary research works and the prototype evaluation are further explained at the end of this chapter.

3.2 The use of research methodology

A choice of correct methods applied to a research for investigation depends on a well-defined research question (Walonick 1993). According to the research question defined by the literature review, the studies conducted in this research project involve multidisciplinary areas: 3D museum environments, virtual visitor behaviour patterns and pedagogic approaches. In terms of 3D museum environments, the study dealt with the use of 3D technology with rich media content support for the effectiveness and suitability of online information design strategies in 3D environments. Regarding virtual visitor behaviour patterns, the study dealt with the reasons that govern visitor behaviours when interacting within 3D museum environments. Moreover, concerning the application of pedagogic approaches in learning activities on the museum websites, the study dealt with the presentation and organisation of cultural content using 3D online learning environment in educational settings. In order to address the research question related to these multifaceted domains, methods triangulation[2] was therefore regarded as an appropriate methodology to be adopted in this research study using both qualitative and quantitative approaches for cross-checking the results.

Moreover, Clarke and Dawson (1999) suggested that the employment of methods triangulation enables the strengths of one method to compensate for the weaknesses of

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[2] Methods triangulation is a form of triangulation which involves collecting both qualitative and quantitative data to check the consistency of findings (Patton 2002).

another method, and then the measurement errors and the problems of intrinsic bias can be reduced to enhance the overall quality of the research data by using more than a single method. They advocated that one of the main benefits of employing methods triangulation as part of a mixed-method design rather than a single method is to allow the researcher to have confidence in the research findings (Clarke and Dawson 1999).

3.2.1 Overall research framework

The research framework which outlines all the seven stages of the research process is illustrated in Figure 3.1. The focus of the first stage lay in the identification of the research problem and determines the initial research objectives, followed by a literature review to identify a gap in knowledge and formalise the main research question. This was followed by the three primary research studies: a critical review, observation studies and semi-structured interviews. The critical review was to examine the existing problems with current museum websites which use 3D technologies for online informational and learning resources. The following observation studies were based on the four most effective museum websites which were selected from the critical review in order to determine visitors’ behaviours and their learning activities within the 3D environments. Next, the semi-structured interviews with museum project managers and multimedia experts’ experiences with developing 3D virtual environments were conducted to test the formulated hypothesis generated from the observation studies. The following stage was to develop a theoretical design reference model based on the findings of the three primary research studies and the key conclusions of the literature review. The purpose of the proposed theoretical model is to provide a design method for virtual museum designers to consider when building 3D museum environments. The next stage was to design a prototype 3D exhibition based on the theoretical model. At the sixth stage, the prototype 3D exhibition was evaluated by user testing and expert evaluation in order to validate the theoretical model on which it was based. The overall conclusions and recommendations provided the final stage of this research.

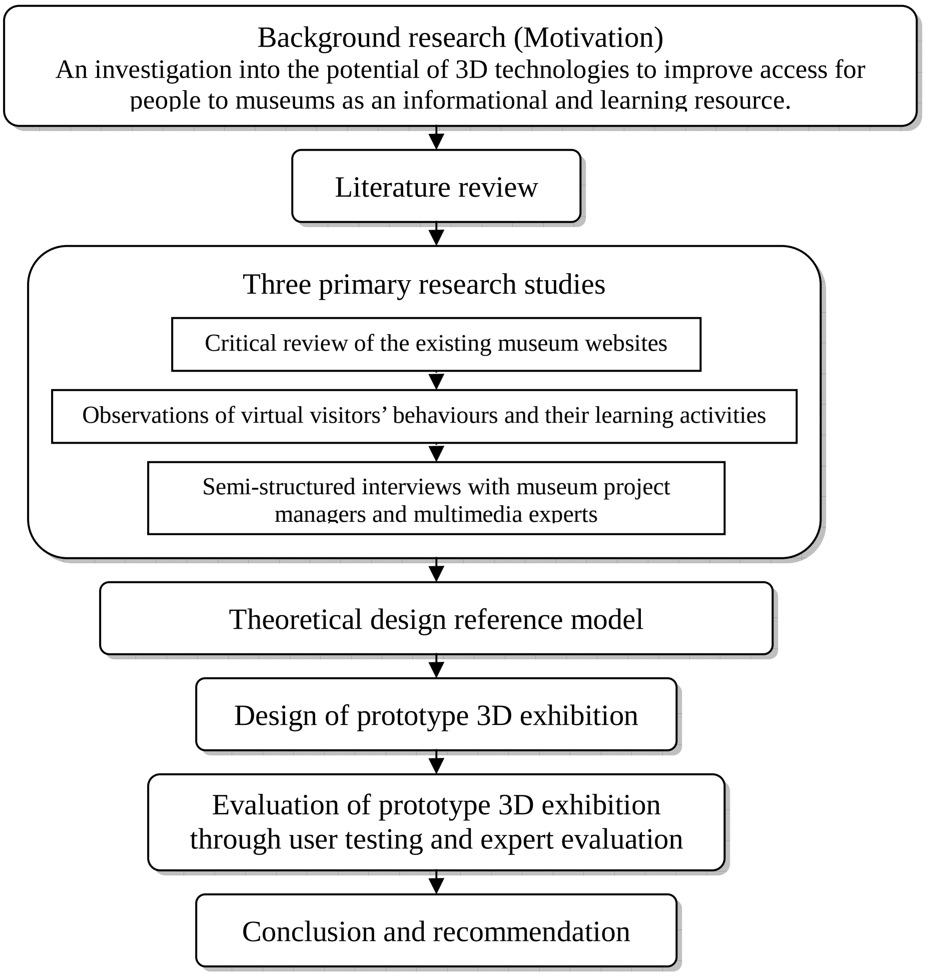

Figure 3.1 The research framework

3.2.2 Documentary research on the nature of web-based museum systems (Literature review, qualitative method)

The objective of the documentary research was to review the relevant literature on web-based museum online environments focusing on information and learning, museum theory, visitor behaviours within physical and virtual museums, education theories, virtuality and simulation theory, existing 3D web technologies, suitability and effectiveness of online information design strategies in 3D environments.

More importantly, the review of the relevant literature aimed to obviate 'the need to *reinvent the wheel* for every new research question (Walonick 1993).' Thus this exploratory documentary research in the early stage of the research framework also aimed to identify a gap in knowledge and define a research question. The research question was then addressed by the primary research methods used for this research.

3.2.3 Critical review of the existing museum websites (qualitative method)

A critical review is 'an essay or article that gives a critical evaluation (WordNet, 2003).' A critical review can be applied in different evaluation contexts in a number of research activities, such as examining usability problems and effectiveness of website design, assessing the aesthetic value and worth of artworks and so on.

It was needed because from the literature review, there has been little research into the effectiveness or the strengths and weaknesses of current museum websites which exploit 3D technologies for online informational and learning resources based on appropriate pedagogic strategies. Due to this current limited knowledge of existing museum websites and their informational aspects and the learning contexts, a critical review at the first stage of the primary research was to determine the existing problems within current museum websites and identify the elements of effective design for presenting learning content in 3D environments.

Ten current museum websites were chosen to represent the distinctive characteristics of the ten major types of museums. The ten selected museum websites were critically evaluated in terms of the three fundamental components based on Karabin's (2000) methodology, namely 1) the use of 3D technology in improving access, 2) Web-based museums as informational and learning resources and 3) The Archives & Museum Informatics Standards. Moreover, the purpose of the critical review was to identify the four most successful and effective museum websites which represent each type of pedagogic approach based on Hein's educational theory (i.e. traditional lecture and text, behaviourist learning, discovery learning and constructivism). All four pedagogic approaches were selected in order to identify which pedagogic approaches used in the design of their 3D museum environments are the most appropriate ways of presenting the learning content of exhibits to match related visiting styles, leading to a deeper engagement with the subject matter.

3.2.4 Observations of virtual visitors' behaviours and their learning activities (mixed qualitative and quantitative method)

From the results of the critical review, the strengths and weaknesses of the ten web-based museums in 3D environments and the elements for effective design for presenting information and learning content were determined. However, although the critical review was helpful to evaluate the characteristics of museum websites in 3D environments, it could be argued that the critical review results are affected by subjective bias due to the use of a self-evaluation of the museum websites without objective visitor reactions. Therefore, in order to gather objective data regarding virtual visitors' behaviours and their interactions with the learning content of exhibits, it was necessary to conduct a visitor study, making direct observations of what they are actually interacting with when using the learning content within 3D museum environments.

Visitor studies using observations of visitor behaviours as one of main primary methods were carried out in museums (Hein 1998; Diamond 1999). Hein (1998) contended that an observation method can be supplemented by combining other quantitative approaches such as questionnaires. A designed questionnaire can be used to evaluate the effectiveness of museum exhibitions and educational programmes through statistical analysis of the visitors' responses based on their post-visit experience. The observation studies (qualitative method) were complemented by the post-observation questionnaires (quantitative method) in order to obtain different types of data regarding visitors' behaviours in the four museum websites in 3D environments, namely: the London Science Museum, the Canadian Museum of Civilization, the Helsinki City Museum and the Philadelphia Museum of Art. These four museum websites were chosen from the critical review because they were indicated to effectively present their cultural content using each of the four pedagogic approaches.

The purpose of the observation method was to observe visitor behaviours (e.g. reading labels or texts, viewing images, manipulating exhibits and so on) and visiting styles (i.e. the four visiting styles) in the learning context within the 3D virtual environments on the four museum websites. Moreover, performance tasks in the 3D environments was conducted to measure how effective they are in presenting exhibit content in terms of organisation, paths and interaction metaphors (e.g. exhibit icons with clear indication of individual exhibit names can be clicked on) in educational settings.

The post-observation questionnaire covers the three key aspects of the influence on visitor interactions within the four museum websites: the use of 3D technology in improving access, exhibit information content, and learning content and activities. All the quantitative data were analysed using descriptive statistics to create an average point score per question which was calculated from a frequency distribution of responses in tabular description to describe the effectiveness of design factors in visitor interactions within the four museum websites.

3.2.5 Semi-structured interviews with museum project managers and multimedia experts (qualitative method)

In order to evaluate six research hypotheses generated from the earlier observation studies, the next stage employed expert interviews with museum project managers and multimedia developers' involved in creating 3D online museum environments in the learning context. In addition, the objective of the interviews was to identify the existing problems and limitations of current 3D virtual learning and information environments and potential needs.

The nature of research interview is to ask questions of a subject or groups of subjects through different kinds of interview such as structured interviews, semi-structured interviews, unstructured interviews and so on (Diamond 1999). The semi-structured interview has a 'sequence of themes to be covered, as well as suggested questions' in order to capture the subject's point of view through open-ended questions and a list of questions that is prepared in advance (Kvale, 1996). In addition, interviews can be used to test research hypothesis (Kvale 1996). Thus the method of semi-structured interview adopted in the research not only aimed to test the research hypotheses, but also to identify a number of issues in the design of virtual exhibits and the development of 3D museum environments.

3.2.6 Development of the theoretical design reference model

From the results of the interview studies, four hypotheses were supported by the experts' points of views. Two supported hypotheses are concerned with the relationship between attraction and holding power of exhibits and rich multimedia formats. The other two supported hypotheses are concerned with the relationship between visiting styles and the design of 3D museum environments based on pedagogic approaches. These four hypotheses were used to guide the development of a theoretical design reference model with emphasis on facilitating attraction and holding power of exhibits, visiting styles and the design of the 3D museum environment for learning efficacy.

Based on the results of the secondary and primary research findings, a theoretical design reference model was proposed for the development of a 3D virtual museum environment as both an informational and learning resource. The purpose of the theoretical model is to provide a tool for virtual museum designers to consider when building their 3D museum environments on the websites to improve learning efficacy.

An instructional design model is a design method that enables designers to organise the learning content based on appropriate pedagogic approaches in order to achieve the desired goals. The Reeves multimedia design model was considered as the most appropriate model to be adopted for the development of a theoretical design reference model for creating a 3D museum learning environment (refer to Section 7.2 for details). The Reeves model was modified to include three phases (i.e. analysis, design and assessment phase) as a basis for developing a theoretical design reference model for the design of 3D museum environments.

3.2.7 Design of the prototype 3D exhibition

A prototype 3D museum exhibition, "The Meanings behind the Patterns on Plates", was created based on the theoretical design reference model. The purpose of the prototype 3D exhibition was experimentally to validate the theoretical model as a design tool for creating 3D virtual environments which improve access to museums as both information and learning resources. Prototypes should be created as close to the final product as possible in order to evaluate how the visitors responds to the final products (Diamond 1999). Therefore, the prototype 3D exhibition was created as closely as possible to resemble the final working product in order to identify whether visiting styles and pedagogic approaches match those predicted.

The prototype was created based on the analysis and design phase of the theoretical model using several software programmes, namely, Flash, Dreamweaver, 3D Studio Max, Cult3D and Virtools. The conceptual basis for all design decisions relating to the visitor pathways, organisation of the exhibit content and the layout of exhibit displays was to encourage specific visitor styles, leading to a deeper engagement with the subject matter based on the intended pedagogic approach in the 3D exhibition environment. In addition, the design of virtual exhibit content using the different presentation methods and rich multimedia formats was to both attract and engage visitors in the 3D virtual exhibition environment.

3.2.8 Evaluation of the designed prototype 3D exhibition through user testing (observations combined with performance tasks and questionnaire) and expert evaluation (semi-structured interviews)

Karoulis et al (2006) stated that ‘the most applied methodologies are the expert-based and the empirical (user-based) evaluation.’ Both evaluation methodologies can be employed to analyse the usability and effectiveness of museum websites, such as Harms and Schweibenz’s (2001) work. A combination of both evaluation methodologies was therefore adopted to validate the theoretical model through the evaluation of the prototype 3D exhibition at the final stage of the research framework. The aim of the prototype evaluation was to test whether the prototype 3D exhibition based on the pedagogic approaches encouraged the related visiting styles, leading to a deeper engagement with thematic content for learning efficacy.

The two applied methodologies for the prototype evaluation are user testing and expert evaluation. The method used for the prototype evaluation through user testing was the same approach to that taken in the earlier observation studies. The expert evaluation using semi-structured interviews explored specialists' opinions and perspectives on the prototype in depth. The expert evaluation used the same approach to that taken in the interview studies. For more details refer to Chapter Seven.

3.3 Validity and reliability

Clarke and Dawson (1999) noted that methods triangulation 'is presented as a way of guarding against threats to both reliability and validity' based on cross examination. Methods triangulation used in this research study was to ensure the validity and reliability of the results by cross-checking data from multiple sources (i.e. a critical review, observation studies, interviews and an evaluation of the prototype 3D exhibition).

For the critical review, the methods of data collection and data analysis are more qualitative than quantitative because quantitative approaches using calculation of percentages and statistics would have been ineffective and invalid for such a subjective review. Thus the critical review used a qualitative approach to analyse data based on the three fundamental evaluative components through a self-evaluation of the museum websites.

For the observation studies, multiple data collection methods were used to assess visitors’ behaviours in the 3D museum environments, including one-to-one observation, followed by a post-observation questionnaire on the same tasks. The use of both qualitative and quantitative data and different collection methods provides a form of comparative analysis allowing cross-checking or triangulation of results to confirm the reliability and validity of the outcomes.

For the interviews, the expert participants’ factual knowledge and opinions on particular subjects regarding the research hypotheses were elicited by the series of questions to collect reliable data. The logic of the derivations and unambiguous wordings of each question were considered in the expert interviews in order to confirm the validity of the hypotheses.

Each research work will be further discussed in detail in terms of validity and reliability, rationale, procedure, and selection of sample and sample size in subsequent chapters (critical review in Chapter Four, observation studies in Chapter Five and semi-structured interviews in Chapter Six).

For the evaluation of the prototype 3D exhibition and the reference model on which it was based, the same approach was used as in the earlier observation studies employing qualitative and quantitative data collection methods through user observation, performance tasks, questionnaire and expert interview. These evaluation strategies provided a way to triangulate findings based on comparative analysis for reliability and validity.

3.4 Summary

This chapter has presented the overall research framework which consists of seven stages of research in order to address the research question: what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D museum environments to ensure learning efficacy. In order to address the research question, methods triangulation was applied to this research project through the use of both qualitative and quantitative methods for data collection and analysis. Each stage was first introduced and then each research work was discussed in terms of the selection of the qualitative and quantitative approach in order to achieve the formulated research objectives.

The findings of the secondary and primary research were used to develop a theoretical design reference model which could be used as a tool for virtual museum designers to create an effective 3D museum environment as both informational and learning resources. The prototype 3D exhibition, "The Meanings behind the Patterns on Plates", was developed to experimentally test this design model. The validation of the model was conducted through two evaluation strategies: user testing and expert evaluation. The final section of this chapter described issues of validity and reliability for each of the three primary research works and the prototype evaluation strategies.

Based on this overall research framework, the first stage of the primary research works therefore focused on a critical review of the ten current museum websites to determine the potential or existing problems within virtual museums in 3D environments with emphasis on informational aspects and the learning context. This review is discussed in the next chapter.

Chapter Four: Critical Review

4.1 Introduction

After an extensive literature review, there appears to have been little research into the effectiveness or the strengths and weaknesses of current virtual museums on the web which exploit novel 3D web technologies for online informational and learning resources in 3D environments using appropriate pedagogic strategies. As discussed earlier (Section 3.2.3), in order to overcome this current limited knowledge of existing museum websites and their informational aspects and the learning contexts, a critical review was therefore conducted to determine the existing problems within current museum websites and identify the elements of effective design for presenting learning content in 3D environments.

Ten current museum websites in 3D environments were chosen to reflect the distinctive characteristics of the ten major types of museums. As mentioned in the last chapter, the criteria to evaluate the ten museum websites were based on Karabin's (2000) methodology for the investigation of current museum websites: the three fundamental components for the overall assessment, namely, the use of 3D technology in improving access, web-based museums as informational and learning resources and the Archives & Museum Informatics Standards. The evaluation method using a qualitative approach was to examine the characteristics of museum websites concerning effectiveness and suitability in online learning and information design against the three fundamental areas of assessment.

At the end of this chapter, the important findings and design elements which are regarded as useful for the proposition of a new design method for the development of

3D museum environments are identified. Moreover, the critical review aims to determine the four most effective museum websites which employ four different types of pedagogic approaches in the 3D environments as defined by Hein (1995, 1998): traditional lecture and text, behaviourist learning, discovery learning and constructivism. The effectiveness of four museum websites will then be used for further more objective observations of virtual visitors' behaviours within the 3D environments in order to identify the relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments for learning efficacy.

4.2 Aim of critical review

The aim of this review is a critical examination of potential or existing problems with current museum websites which exploit 3D technologies for online informational and learning resources in a 3D virtual environment.

4.3 Rationale

This critical review focuses on the potential or existing problems within virtual museums on the Internet. The purpose of this research is to critically examine the use of new 3D technologies in current virtual museum websites in terms of their effectiveness and usability as a virtual learning and informational resource. The research also aims to examine the representation of information resources in a 3D virtual world. The review undertaken here aims to address the following questions:

- What innovative uses of 3D technology are being developed to improve access to virtual museums in terms of informational aspects and the learning context?
- What are the advantages and disadvantages of employing 3D digital modelling of museum objects and 3D virtual walkthrough environments (exhibitions or

heritage sites) in the web-based museums?

- What are the factors that determine the effectiveness and usability of the presentation of information and learning content associated with the museum artefacts in a 3D environment based on pedagogic approaches for educational needs?

4.4 Methodology

4.4.1 Validity and reliability

Validity refers to the means of assessment which is accurate and appropriate to research (Diamond 1999). Reliability refers to 'the degree to which the finding is independent of accidental circumstances of the research (Kirk and Miller 1985).' Using appropriate methods and techniques for this research strategy will affect the validity and reliability of the investigative results. In order to gain an in-depth understanding of the strengths and weaknesses of current museum websites in terms of informational aspects and the learning contexts in 3D environments, the methods of data collection used are more qualitative than quantitative. The employment of quantitative approaches would have been ineffective and invalid in this critical review due to its subjective nature; for instance, calculation of percentages and statistical analysis. For this research, a qualitative approach was therefore used to assess current museum websites which used 3D technologies for informational and learning resources through in-depth analysis of the results. In addition, Karabin's methodology for the investigation of current museum websites using qualitative approach was applied to this critical review in order to ensure the results were as objective as possible for validity and reliability. Karabin's methodology is discussed in the following section.

4.4.2 Methods

Karabin (2000) provides a research methodology for the investigation of current museum websites. This approach of qualitative evaluation includes three main components of assessment: 'technological, design and source considerations of the Web; characteristics of the Web and web use thought to enhance learning; and the National Visual Arts Standards (Karabin, 2000).' The general nature of the procedure of the methods is shown as follows:

1. Defining the purpose of the website analysis
2. Identifying the quality of the art museums sites using three components of the matrix:
    - 'technological, design and source considerations of the Web'
    - 'characteristics of the Web and web use thought to enhance learning'
    - 'the National Visual Arts Standards' (Karabin, 2000)

3. Defining the specific criteria for assessment of each of the three components
4. Choosing a set of art museum websites to investigate
5. Analysing the museum sites according to the stated criteria
6. Summarising the results

Using these methods an art and museum educator can evaluate the 'future exploration into the technological and educational aspects, as well as adherence to the National Visual Arts Standards, of other web sites they may want to use to meet their pedagogical needs (Karabin 2000).' As can be seen, the methods for the examination of the art education museum websites can be identified as three aspects of the fundamental components: the employment of the emerging technology, the use of web as learning and instructional resources and the standards of the art education association as guidelines.

For the purpose of this study, detailed assessment criteria were applied to the three fundamental components of Karabin's proposed methods, namely: the use of 3D technology in improving access, web-based museums as informational and learning resources and the Archives & Museum Informatics Standards. The evaluation methods using this qualitative approach are adopted to evaluate the characteristics of museum websites as learning and informational resources. Although these three components of analysis have multiple criteria, all criteria from the three foundation components are integrated into the overall assessment as in Figure 4.1

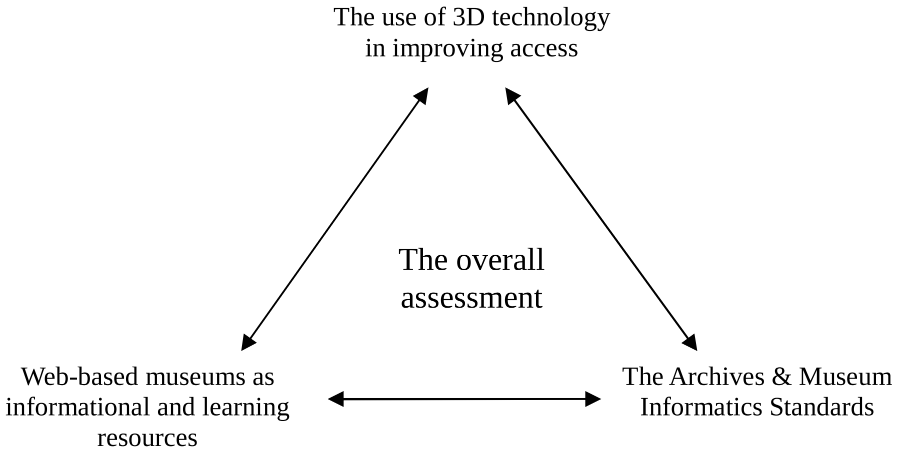

Figure 4.1 The three fundamental components for the overall assessment based on Karabin's (2000) methodology

The detailed process of this critical review based on Karabin's (2000) methodology is as follows:

1. *Specifying goals of analysis*

In this phase, the goals of this analysis are defined, based on the research question found during the literature review. This critical review begins to address the research question: what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy.

2. *Identifying the quality of virtual museum characteristics based on the three fundamental components*

   In this step, identifying the quality of the museum websites is based on the three fundamental components of assessment criteria (detailed criteria will be discussed in Section 4.4.3), including:

   - The use of 3D technology in improving access
   - Web-based museums as informational and learning resources
   - The Archives & Museum Informatics Standards

3. *Choosing a set of museum websites to evaluate*

   In this stage, ten current museum websites are selected from the diverse categories of museums which reflect the range of ways of communicating information about cultural materials using the novel 3D technologies in 3D virtual environments. The reasons for selecting the types of museum websites are discussed in Section 4.4.4.

4. *Analysing the museum websites according to the stated criteria*

   In this phase of the process, the chosen museum websites are analysed using the three fundamental components of assessment criteria for evaluation.

5. *Summarising the results*

   In the final step, the results are analysed and summarised for each of the ten museum websites. The advantages and disadvantages of those museum websites and the effective design elements are identified for contribution to the development of the proposed research.

4.4.3 Examination of virtual museum characteristics based on the three fundamental components

The three fundamental components include the use of 3D technology in improving access, web-based museums as informational and learning resources and the Archives & Museum Informatics Standards. Each fundamental component of assessment criteria can be further explained in the following subsections.

4.4.3.1 The use of 3D technology in improving access

The first of the three fundamental components involves the identification and discussion of the four criteria which are concerned with the innovative use of 3D web-based technology in improving access, including simulation, interactivity, metaphors and integration of multiple media formats. The three dimensions of simulation in relation to the levels of realism are to determine the effectiveness of presenting 3D models of museum artefacts and 3D walkthrough environments (exhibitions or heritage sites).

Interactivity (i.e. immersion, presence, manipulation, navigation and orientation) is concerned with the context of communication between virtual visitors and 3D museum environments. “Immersion” and “presence” aim to examine the sense of presence in an immersive museum environment. “Manipulation” is to identify the effective interactions with 3D models of exhibits. “Navigation” and “orientation” are to identify the clear and effective orientation when navigating in 3D virtual museum environments.

The other criteria, “metaphors” and “integration of multiple media formats”, are regarded as design elements of usability for 3D virtual museum environments within web pages. “Metaphors” are to examine the usability problems with representing the overall appearance of the 3D environment. “Integration of multiple media formats” is the effective presentation of exhibit content using rich multimedia formats for additional information. These four criteria are concerned with the innovative use of 3D technology in improving access as defined in Table 4.1:

Criteria	**Interpretation**
Simulation	The dimensions of 3D simulation (see Section 2.7) • Reconstruction • Reproduction • Representation The degree of 3D simulation in the virtual environments in relation to realism (Cerulli 1999 cited from Bridges and Charitos 1997) (see Section 2.7) • Hyper realities • Selective realities • Abstractions
Interactivity	Immersion • Using richness of the sensory information related to resolution and quality of the displays for vividness of the presentation of 3D virtual artefacts or 3D virtual exhibitions The dimensions of presence (Heeter 1992) (see Section 2.8.2.2) • Personal presence • Social presence • Environmental presence Manipulation • Allowing viewers to manipulate 3D model artefacts within the environment (Cerulli 1999) Navigation • Allowing visitors to navigate through 3D simulation of museum space (Cerulli 1999) • Effective use of navigational system with user interface Orientation

	• Virtual visitors easily recognise where they are
Metaphors	The use of the conceptual metaphors to represent the overall appearance of the 3D environment (Bryson 1994) (see Section 2.8.2.3) • Overall environment metaphor(s) • Information presentation metaphor(s) • Interaction metaphor(s)
Integration of multiple media formats	To present additional information with integrating multiple media formats (see Section 2.8.2.3) • Videos • Texts • Sounds • Images • Graphics

Table 4.1 The four criteria concerned with the innovative use of 3D technology in improving access to museums websites

4.4.3.2 Web-based museums as informational and learning resources

The second of the fundamental components for the examination of museum websites concerns their roles as informational and learning resources by means of 3D emerging technologies with embedded multimedia components. In terms of informational aspects, the three modes of a representational system based on the semiotic perspective are used to communicate information on cultural materials (Section 2.3.1). As a result, the three modes of representational scheme are applied as criteria to analyse informational resources in web museums (see Table 4.2).

In order to evaluate if the different learning resources are used to effectively enhance the learning experience of visitors, the clarity of pedagogic structures of each learning activity is important. Two pedagogic design factors, four pedagogic approaches based on Hein’s educational theories (Section 2.6.1) and the procedure of the instructional principles established by Weston et al (1999) (Section 2.6.1), were regarded as suitable criteria to evaluate the effective pedagogic design of web-based 3D virtual museum learning environments (see Table 4.3). The four pedagogic approaches aim to identify the effective application of pedagogic strategies to educational materials within the museum websites. The procedure uses instructional principles to evaluate the effective design elements of learning materials for web-based learning activities and programmes. Furthermore, the different types of learning experience can be underpinned by using media and methods based on Laurillard's model (Section 2.5.2). The employment of specific media and methods is to identify the effective learning content of exhibits and learning activities for supporting different types of learning experience (see Table 4.4).

Mode	Criteria
Narrative-centered	• Clarity of construction of the objects in conveying a message as storyline in invoking historical imagination.
Object-centered	• Clarity of organisation of artefacts in devoting to aesthetic values and cultural context of significance with accompanying literal interpretations.
Information-centered	• Clarity of the presentation of the objects in interpreting visual documentation of the natural specimens of animals and insects and the demonstration of scientific process and natural phenomena.

Table 4.2 Three modes of the representational system (Tang 2005)

Pedagogy for Hein's educational theories (Hein 1995) • Traditional lecture and text • Behaviourist learning • Discovery learning • Constructivism
The procedure of instructional principles (Weston et al 1999) • Clarity of target audience • Clarity of instructional objectives and strategies • Motivation and context for learning process

- Clarity of organisation and structure of content
- Provision of examples and help in how to use the application
- Provision of interactively practising task in learning process
- Provision of feedback in learning activities
- Evaluation of learning outcomes

Table 4.3 Pedagogic design factors

Learning experience	**The use of methods**	**Media forms**
Attending, apprehending	Texts, graphics, audios, videos, animations, etc.	Narrative
Investigating, exploring	Online museum library, catalogues, databases, search engines, hypermedia (e.g. hypertext), etc.	Interactive
Discussing, debating	Emails, online conferencing, online discussion boards, chat rooms, etc.	Communicative
Experimenting, practising	Simulations, virtual environments, educational games, etc	Adaptive
Articulating, expressing	Production, modelling, etc.	Productive

Table 4.4 The use of media and methods and the types of learning experience based on Laurillard's (2002) model

(Source: adapted from Laurillard's (2002) model)

4.4.3.3 The Archives & Museum Informatics Standards

As discussed in the literature review (see Section 2.6.1), the Archives & Museum Informatics Standards aim to identify "Best Educational Use" for museum websites with an emphasis on learning purposes. Thus the third fundamental component is to determine the effectiveness and usability of the presentation of supplementary materials with the museum objects in 3D virtual environment constructed according to the achievement standards based on the Archives & Museum Informatics Standards (Museums and the Web 2006) shown in Table 4.5.

Category	**Standards**
Best Educational Use	● Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together ● Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students ● Interaction between museum staff and students, teachers, or educational groups of any level ● Integration of experiences of 'real' visits to museum and the educational Web site ● Provision of non-curriculum-based learning experiences and support of lifelong learning activities ● Easily identifiable target audience and clear pedagogical strategy

Table 4.5 The standards of “Best Educational Use”

(Source: Museums and the Web 2006)

These standards represent a consensus of a committee of museum professionals in Archives & Museum Informatics; for example, museum directors, curators, educators and so on regarding for supporting educational use in museum websites. The standards were established as a set of criteria to recognise “Best Educational Use” for the educational roles of museum websites design every year; in particular for those museums which are small size and have limited budgets.

Furthermore, the standards are adopted not to focus on an actual education curriculum; on the other hand, they emphasize provision of educational content and activities for informal or leisure learning as ‘non-curriculum-based learning experiences’ as one of the features of educational museum websites (Museums and the Web 2006). By applying these demanding standards, it is possible to examine how museum websites meet their learning and interpretive needs for the target audiences as well as adhere to the Archives & Museum Informatics Standards.

4.4.4 Reasons for selection of the ten virtual museum websites

Museums are identified as different groups, namely: art museums, science museums, historical museums, anthropological museums, natural history museums, archaeological museums and so on (Sloof 2003). Additionally, the distinctive characteristics of museums can also be examined through a systematic scheme of classification such as its physical size and visitor figures and budget; its funding structure and management, e.g. whether the museum is managed by a university, and the characteristics of its collections, e.g. whether its collections are regionally specific or themed. Karabin (2000) evaluates art museum websites according to different categories of art museums, such as 'flagship/large art museums, regional/local art museums, university art museums, special interest/ethnic art museums, and electronic art museums.'

As shown in Table 4.6, the types of museums can be divided into ten categories based on well-known and multidisciplinary museums, genres of artworks, thematic acquisition of objects, patronage of a university and geographic or regionally specific and so on, according to their distinguishing characteristics (Sloof 2003; Karabin 2000; Encyclopædia Britannica 2006):

Category	**Characteristic**
Leading museums	● Nationally or internationally famous collections ● Occupy a large building and position ● Located in a big city ● Benefit by large endowments and funding ● A variety of events, activities, exhibitions and programmes
Art museums	● In some places, named as an art gallery ● Collections contain various genres of artworks ● Artworks bear aesthetic value and meanings

History museums	● A variety of museums (properly called general museums) ● Collections include objects of art and science encompassing nature of history ● Creating knowledge of the past to the present for visitors to rethink assumptions
Science museums	● Collections of objects associated within science ● Serving a purpose of learning via programmes, activities and events ● Encouraging visitors to learn the demonstration of scientific process and natural phenomena by touching exhibits
Natural history museums	● Concerned with the natural world ● Collections of biological specimens, rocks, minerals, fossils and so on ● Programmes and exhibitions dedicated to addressing natural phenomena
Archaeology museums	● Collections of artefacts derived from excavations ● Emphasis on the original appearance of cultural materials, historic sites, heritages, etc., through archaeological reconstructions
Regional and local museums	● Missions and collections emphasize the specifically local area ● Collections mirror local economy, history and culture ● Programmes and exhibitions are devoted to interests of the regional residents
Thematic museums	● Thematic collections of cultural or historical objects ● Programmes, events, activities and exhibitions are devoted to the presentation of the conceptual thematic content encompassing its collections
University museums	● Operation of function under a university ● Funding from a university ● Services of a research, teaching and cultural institution
Technical museums	● Collections of artefacts involved were produced by specifically technical skills, such as aircraft ● Emphasis on grasping the history of old to new technologies mirrored in the artefacts

Table 4.6 The characteristics of each category of museums

(Source: adapted from Sloof 2003; Karabin 2000; Encyclopædia Britannica 2006)

This classification of museums it is proposed should cover typical and major categories of museums. The ten museum websites which exploited 3D web technologies for informational and learning resources in virtual environments on the Internet were carefully selected to represent each category of museum in Table 4.7

Type	**Leading museums**
Name	Science Museum (London, UK)
URL	(http://www.sciencemuseum.org.uk/)
Type	**Art museums**
Name	Philadelphia Museum of Art (Philadelphia, USA)
URL	(http://www.philamuseum.org/)
Type	**History museums**
Name	Museum of National Antiquities (Stockholm, Sweden)
URL	(http://www.historiska.se/)
Type	**Science museums**
Name	National Museum of Science and Technology (Milan, Italy)
URL	(http://www.museoscienza.org/)
Type	**Natural history museums**
Name	Toucan Virtual Museum (an imaginary museum produced by Toucan Corporation, Japan)
URL	(http://www.toucan.co.jp/indexE.html)
Type	**Thematic museums**
Name	Canadian Museum of Civilization (Quebec, Canada)
URL	(http://www.civilization.ca/)
Type	**Regional and local museums**
Name	Helsinki City Museum (Helsinki, Finland)
URL	(http://www.hel2.fi/kaumuseo/)
Type	**Archaeology museums**
Name	Colchester Castle Museum (Colchester, UK)
URL	(http://www.colchestermuseums.org.uk/)
Type	**University museums**
Name	Cardiac Museum (an imaginary museum produced by Department of Physics at Hofstra University, New York, USA)
URL	(http://arrhythmia.hofstra.edu/vrml/museumn/museumn.html)
Type	**Technical museums**
Name	B-Side-Museum (an imaginary museum produced by Kite Brain Communications. Inc, Japan)
URL	(http://www.b-side-museum.com/bsidenew/index.html)

Table 4.7 The ten chosen museum websites

4.5 Analysis of the results

A Standard Operating Procedure[3] (SOP) was developed to conduct this critical review in order to ensure the computer hardware, operating system, browser and bandwidth speed in the same condition each time that the ten museum websites are evaluated. Each 3D museum environment browser 3D plug-in provided by the website was installed to ensure the 3D environment worked correctly before doing the critical review.

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[3] A Standard Operating Procedure is 'a set of instructions having the force of a directive, covering those features of operations that lend themselves to a definite or standardized procedure without loss of effectiveness (Wikipedia 2008a).'

The characteristics of each museum in terms of the use of 3D web technology for providing information and learning resources in 3D virtual environments were evaluated based on the three fundamental assessment criteria. The strengths and weaknesses of each museum website are identified in order to contribute to the development of the overall research. Moreover, the overall best and worst museum website and the initial findings are identified at the end of this section.

4.5.1 Analysis of the ten museum websites

An overview of the evaluation of the ten museum websites based on the three fundamental assessment criteria is shown in Table 4.8, 4.9 and 4.10. More details can be found in Appendix 4.

In terms of the use of 3D technology in improving access in Table 4.8, none of the ten museum websites fulfils all of the criteria. It is noteworthy that the employment of simulation (reconstruction, reproduction, and representation) in the ten virtual museum environments in relation to realism (hyper realities, selective realities and abstractions) varies depending on their function and context for the effective presentation of museum artefacts. The Canadian Museum of Civilization conforms to more criteria than any other museum websites. This museum provides high levels of interactivity through immersion, navigation and orientation. Interaction metaphors (e.g. each exhibit icon with indication of the exhibit name when the cursor is moved over individual exhibit images) are used to aid visitors in gathering more information about exhibits. Integration of multiple media formats is provided to interpret knowledge of exhibits and associated information. On the whole, this museum appears to have potential to improve access through the presentation of interactive 3D artefacts with rich media content in a 3D virtual environment.

Regarding aspects of informational and learning resources in Table 4.9, none of the ten museum websites conforms to all of the criteria. It was found that these ten museum websites approaches to information and learning interactions (aesthetic appreciation, comprehension of underlying scientific principles and understanding of object in its historical context) vary depending on the nature of the museum types. The London Science Museum succeeds in most criteria among the ten museum websites. This museum not only offers rich information about exhibits, but also provides great opportunities for learning through online exhibit content, activities and programmes and supports the five different types of learning experience. In addition, the Canadian Museum of Civilization, the Helsinki City Museum, the Museum of National Antiquities and the Philadelphia Museum of Art have a positive correlation to the majority of the criteria in the pedagogic design factors and the types of learning experience.

Concerning the Archives & Museum Informatics Standards in Table 4.10, all ten museum websites, except the London Science Museum, partly adhere to the Standards. The London Science Museum adheres to all of the Standards through the use of a variety of learning activities based on the intended pedagogic approach for a broad range of visitors. Furthermore, the Canadian Museum of Civilization, the Helsinki City Museum, the Museum of National Antiquities and the Philadelphia Museum of Art achieve the majority of the Standards and thus provides virtual visitors with relevant potential for use as a valuable learning resource. Overall, little that reflects the Standards can be found in the Toucan Virtual Museum due to lack of interpretive content and learning materials for the online exhibits and pedagogic strategies.

		Science Museum	**Philadelphia Museum of Art**	**Museum of National Antiquities**	**National Museum of Science and Technology**	**Toucan Virtual Museum**	**Canadian Museum of Civilization**	**Helsinki City Museum**	**Colchester Castle Museum**	**Cardiac Museum**	**B-Side Museum**
Simulation	Reconstruction	/	Environment	/	Artefacts	/	Environment	Both artefacts and environment	Historic buildings	Environment	/
	Reproduction	Both artefacts and environment	Artefacts	Both artefacts and environment	Environment	Artefacts	Artefacts	/	Artefacts	/	Environment (partly)
	Representation	/	/	/	/	/	/	/	/	Artefacts	Artefacts
	Hyper realities	/	Artefacts	Both artefacts and environment	Both artefacts and environment	Artefacts	Artefacts	/	Artefacts and part historic buildings	/	Environment (partly)
	Selective realities	Both artefacts and environment	Environment	/	/	/	Environment	Artefacts	Part historic buildings	Both artefacts and environment	Artefacts
	Abstractions	/	/	/	/	/	/	Environment	/	/	/
Interactivity	Immersion	Low	High	Low	Low	High	High	Low	High	Low	High
	Presence	Low	High	Low-medium	Low	High	Medium-high	Low	High	Medium	High
	Manipulation	Partly provided	Not provided	Not provided	Partly provided	Provided	Partly provided	Not provided	Partly provided	Not provided	Provided
	Navigation	Easy	Difficult	Easy	Easy	Difficult	Easy	Easy	Easy	Easy	Provided
	Orientation	Difficult	Easy	Difficult	Difficult	/	Easy	Difficult	Partly difficult	Easy	/
Metaphors		Provided	Provided	Provided	Provided	Not provided	Provided	Provided	Not provided	Provided	Not provided
Integration of multiple media formats		Provided	Partly provided	Provided	Partly provided	Little Provided	Provided	Provided	Little provided	Provided	Partly provided

Table 4.8 The analysis of the ten museum websites using 3D technology in improving access

		Science Museum	**Philadelphia Museum of Art**	**Museum of National Antiquities**	**National Museum of Science and Technology**	**Toucan Virtual Museum**	**Canadian Museum of Civilization**	**Helsinki City Museum**	**Colchester Castle Museum**	**Cardiac Museum**	**B-Side Museum**
Modes of representation	Narrative-centered	/	/	✓	/	/	✓	✓	/	/	/
	Object-centered	/	✓	/	/	/	/	/	✓	/	/
	Information-centered	✓	/	/	✓	✓	/	/	/	✓	✓
Pedagogic design factors	Clarity of target audience	✓	Not stated	Not stated	Not stated	Not stated	✓	Not stated	Not stated	✓	Not stated
	Clarity of instructional objectives and strategies	✓	✓	Partly clear	Not stated	Not stated	✓	✓	Not stated	✓	Not clear
	Motivation and context for learning process	✓	✓	✓	✓	✓	✓	✓	Not stated	✓	✓
	Clarity of organisation and structure of content	✓	✓	✓	✓	Not applicable	✓	✓	✓	Partly clear	Partly clear
	Provision of examples and help in how to use the application	✓	✓	✓	Not provided	Not provided	✓	✓	Not provided	✓	Partly provided
	Provision of interactively practicing task in learning process	✓	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	✓
	Provision of feedback in learning activities	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided
	Evaluation of learning outcomes	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided
Types of learning experience	Attending, apprehending	Supported	Partly supported	Supported	Little supported	/	Supported	Supported	Little supported	Little supported	/
	Investigating, exploring	Supported	/	Supported	Supported	Supported	Supported	Supported	Little supported	/	Supported
	Discussing, debating	Supported	Supported	Supported	Supported	Supported	Supported	Supported	Supported	Supported	Supported
	Experimenting, practising	Supported	Supported	Supported	Supported	Supported	Supported	Supported	Supported	Supported	Supported
	Articulating, expressing	Supported	/	/	/	/	/	/	/	/	/

Table 4.9 The analysis of informational and learning resources in the ten museum websites

		Science Museum	Philadelphia Museum of Art	Museum of National Antiquities	National Museum of Science and Technology	Toucan Virtual Museum	Canadian Museum of Civilization	Helsinki City Museum	Colchester Castle Museum	Cardiac Museum	B-Side Museum
Archives & Museum Informatics Standards	Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together	Provided	Provided	Provided	Provided	Little provided	Partly provided	Provided	Partly provided	Partly provided	Provided
	Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students	Provided	Partly provided	Partly provided	Partly provided	Partly provided	Partly provided	Little provided	Partly provided	Partly provided	Partly provided
	Interaction between museum staff and students, teachers, or educational groups of any level	Provided	Provided	Provided	Provided	Little provided	Partly provided	Provided	Provided	Little provided	Provided
	Integration of experiences of 'real' visits to museum and the educational Web site	Provided	Provided	Provided	Provided	Not applicable	Provided	Provided	Provided	Not applicable	Not applicable
	Provision of non-curriculum-based learning experiences and support of lifelong learning activities	Provided	Provided	Provided	Not provided	Provided	Provided	Provided	Not provided	Not provided	Provided
	Easily identifiable target audience and clear pedagogical strategy	Easy	Partly easy	Partly easy	Not easy	Partly easy	Easy	Easy	Partly easy	Easy	Not easy

Table 4.10 The evaluation of the ten museum websites based on the Archives & Museum Informatics Standards

1. Leading museums

London Science Museum (accessed on 1st May, 2006)

(http://www.sciencemuseum.org.uk/)

The London Science Museum (Figure 4.2) includes a great deal of informational and learning resources in relation to scientific principles and natural phenomena. The museum has presented a virtual exhibition called Wellcome Wing (Figure 4.3) (http://www.sciencemuseum.org.uk/wellcome%2Dwing/splash_ie.html), devoted to contemporary science and technology with an emphasis on biomedicine using both 2D and 3D virtual environments.

The construction of 3D virtual exhibition environment within web pages provides two versions: 3D high and low end site. The 3D low end site allows virtual visitors to visit the virtual exhibits with less powerful PCs and limited bandwidth speed.

find out about events exhibitions and offers by subscribing to our what's on mailing list

Pixar: 20 Years of Animation

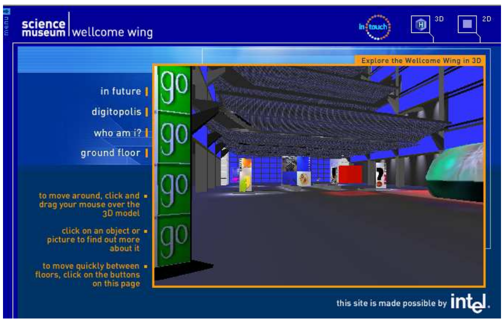
Last chance to see! Closes on 11 June 2006.

Go behind the scenes to discover the science and magic that created some of the most popular films ever made, and while you're there enter our prize draw to win a family trip to Disneyland Resort Paris!

Dead Ringers?

Every hour 1712 mobile phones are upgraded in the UK alone. The new exhibition Dead Ringers? reveals how wasteful your mobile is and what scientists and the industry are doing to combat the waste.

Figure 4.2 The London Science Museum



to move around, click and drag your mouse over the 3D model

click on an object or picture to find out more about it

to move quickly between floors, click on the buttons on this page

Figure 4.3 The Wellcome Wing 3D virtual environment

Various informational and learning resources are integrated into the virtual exhibition environment on the museum website. There are several subjects in the exhibition, including: “*Antenna*”, “*Talking Points*”, “*Pattern Pod*”, “*Who am I?*”, “*Digitopolis*” and “*In Future*”. Each subject contains interactive content providing relevant links which underlie the scientific demonstrations and principles, and current technology within biomedicine illustrated in particular online exhibits.

In addition, this museum presents a number of different levels of exhibit content for specific audience, ranging from children to adults. For these reasons, a broad range of visitors is encouraged to use the learning content based on the intended pedagogic approach and therefore they can benefit from the online learning opportunities made possible in the museum website. As a result, the London Science Museum successfully adheres to all of the Standards.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- Provides a 3D low end site which allows virtual visitors to visit the virtual exhibits in the 3D environment using less powerful PCs and limited bandwidth speed.
- Easily identifiable pedagogical strategy based on the “constructivism” approach to stimulate the learning process.
- Provides an orderly structure of online virtual exhibit components which encourages visitors to actively learn.
- Successful implementation of the Archives & Museum Informatics Standards.

Weaknesses:

- Due to lack of vivid visual information in the exhibits, the virtual exhibition environment does not effectively enhance a sense of presence.

- Without a map, virtual visitors would encounter difficulty in orienting and navigating the 3D virtual exhibition environment.

2. Art museums

Philadelphia Museum of Art (accessed on 4th May, 2006)

(http://www.philamuseum.org/)

The Philadelphia Museum of Art (Figure 4.4) houses over 225,000 artefacts which include different genres such as paintings, sculptures and so on in relation to Renaissance, Medieval times, French Impressionism, etc (Philadelphia Museum of Art 2006). This museum website launched a 3D virtual exhibition, Constantin Brancusi's Mademoiselle Pogany (Figure 4.5) (http://www.narrativerooms.com/pogany/vr/index_a.html), to present a series of Brancusi's sculptures with contextual information in a 3D virtual environment using VRML.

Thursday, May 4th 2006

As one of the largest museums in the United States, the Philadelphia Museum of Art invites visitors from around the world to explore its renowned collections, acclaimed special exhibitions, and enriching programs, both in person and online.

This exhibition features significant examples from the great age of Irish domestic silver, a period from the closing decades of the seventeenth century until the years shortly after the Act of Union of 1800.

Figure 4.4 The Philadelphia Museum of Art

An online exhibition in three dimensions. "Walk" around Mlle.Pogany I (1919) and Mlle. Pogany III (1931). These are the initial and final sculptures in a set of over ten works of the same subject by the Romanian artist, Constantin Brancusi. Visit the

Figure 4.5 Constantin Brancusi's Mademoiselle Pogany

The structure of the exhibition space comprises five distinct rooms, namely: Introduction, Mlle. Pogany I, From I to III, Mlle. Pogany III and About Brancusi. The two 3D model artefacts (Mademoiselle Pogany I and III) are dedicated to the presentation of spatially detailed information using geometrically accurate models. These two 3D models of Pogany sculptures used high quality visual information to effectively increase the sense of presence.

Although the target audience is not stated, the general public would most likely be encouraged to appreciate the evolution of aesthetic concepts of the Pogany sculptures during the learning process. Adherence to the Standards might improve with clearly defined target audience and an outreach of the different types of visitors through expanding scope of exhibit content.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- The two 3D Pogany sculptures are impressive in terms of the vividness and quality of the visual information.
- Provision of a dynamic map and clearly marked entrances and exits effectively help in the orientation of a virtual visitor.
- Easily identifiable pedagogical strategy based on the “behaviourist learning” approach to stimulate the learning process.
- Clear sequential structure of online virtual exhibit components which encourages visitors to appreciate the evolution of aesthetic concepts of the Pogany sculptures.

Weaknesses:

- Manipulation of artefacts is not provided within the virtual exhibition environment for interactions.
- A difficulty in using the mouse to navigate the exhibition throughout;

although virtual visitors are able to walk through the whole environment at will.

3. History museums

Museum of National Antiquities (accessed on 12th June, 2006)

(http://www.historiska.se/)

The Museum of National Antiquities (Figure 4.6) includes a repository of artefacts related to the history of Sweden from prehistoric times to contemporary time. One of the permanent exhibitions, Viking Exhibition, not only presents cultural materials in relation to the Northmen’s daily life, trade, etc., but also displays a collection of gold and silver artefacts and treasures derived from Viking hoards and graves. The featured exhibition has been currently presented in a 3D virtual exhibition of the “Viking” (Figure 4.7), allowing virtual visitors who are not able to actually visit the physical exhibition to virtually visit it in cyberspace (http://www.historiska.se/vr/_eng/nyfram.htm).

DEN DÄR HYCKLAREN TILL BACKPACKER!!! HON KOMMER HIT OCH SÖKER EFTER DET NATURLIGA OCH PRIMITIVA, MEN SKULLE ALDRIG KOMMA PÅ TANKEN ATT FLYTTA HIT.

Sporren från Falebro
En bild i en bok identifierar en sporre från medeltiden.
Läs mer här >>

Historiska kanalen
Se på webb-tv om Forntider, Guldrummet och Vikingar >>

Vad betyder förnamnet?
Sök i Nomina >>

Spelet om Maya
en ny utställning >>

Figure 4.6 The Museum of National Antiquities

Figure 4.7 The Viking virtual exhibition

The virtual exhibition was created as close to the original as possible; hence this may reflect the purpose of this exhibition which is to allow virtual visitors to visit the exhibition with a feeling of being truly in the actual exhibition. Although a version in English is available in this exhibition, in-depth interpretative texts for exhibition showcases are available only in Swedish. It appears to be an unfinished 3D museum exhibition environment with limited information content in the English version.

The real-time communication system using a chat platform in this museum website might encourage visitors to discuss the subject matter content during the learning process. Discussing and debating learning experience can be enhanced by the chat platform through interaction between museum staff and educational groups of any level of visitors.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- Virtual visitors are encouraged to partake in a group visit with friends or others together in the exhibition environment through a chat platform to gain knowledge of artefacts through active participation in the learning process.
- The integration of real and virtual visitor experience are effectively accomplished by the virtual exhibition duplicating the physical exhibition, allowing virtual visitors to prepare for a future visit to the actual museum or evoke an physical visit already performed.
- Provides non-curriculum-based learning experiences and supports lifelong learning activities by integrating video clips, images, photographs, texts and a chat room into the exhibition environment.

Weaknesses:

- The poor quality of visual information fails to contribute to an immersive exhibition environment.

- Lack of provision for manipulation of artefacts; therefore experience enhancement through interactivity is limited.
- Lack of a map for aiding virtual visitor orientation when navigating the 3D exhibition environment.
- A difficulty in identifying target audience through the organisation of content and information architecture.

4. Science museums

National Museum of Science and Technology (Milan) (accessed on 21st May, 2006) (http://www.museoscienza.org/)

This museum website (Figure 4.8) not only presents multidisciplinary knowledge of the natural phenomena and scientific principles, but also provides a number of informational resources about machinery and technologies. The museum has recently presented a 3D virtual walkthrough environment, Virtual Leonardo (Figure 4.9), to present the reconstructed exhibits based on Leonardo's drawings. Virtual Leonardo comprises two themed subjects in two virtual exhibition environments: "Leonardo Scientist" and "Leonardo Technologist".

Learn how it **works** and how the Museum **reconstructed** it

National Museum of Science and Technology - Via S. Vittore 21 - 20123 Milano - Italy
Tel. +3902485551 - Fax +390248010016 - E-mail museo@museoscienza.org

Figure 4.8 National Museum of Science and Technology

Figure 4.9 Virtual Leonardo

The museum used 3D technology to create both a “Leonardo Scientist” and “Leonardo Technologist” space as close to the actual spatial environments as possible. The museum website provides an opportunity for gaining information about the reconstructed exhibits in both 3D exhibition environments but there are few chances for virtual visitors to learn about them due to lack of a clearly identifiable pedagogic strategy. Furthermore, the limited auxiliary media used makes this museum website unavailable for presenting additional information about exhibit content. As a result, the learning content of the virtual exhibitions is not comprehensive enough to accomplish adherence to all of the standards and its potential for use as learning resources may be nominal.

Despite the limited learning resources provided, this museum is to demonstrate a real-time chat platform which can be used to support discussing and debating learning experience based on interaction between museum staff and educational groups of any level visitors.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- The Virtual Leonardo environment provides supplementary material, allowing teachers and schools to work together through the chat platform system.
- The integration of experiences of real and virtual visits is effectively accomplished through the virtual exhibitions duplicating the physical exhibitions, allowing virtual visitors to prepare for a future visit to the physical museum or evoke a prior actual visit already performed.

- Logical organisation of topic and structure of content is easily followed in each thematic topic.

Weaknesses:

- Lack of high quality visual information which would not contribute to a sense of presence with a feeling of actually viewing the constructed exhibits themselves in the actual museum.
- Lack of a map for aiding virtual visitor orientation when moving around the 3D exhibition environments.
- A difficulty in identifying target audience and pedagogic strategy.

5. Natural history museums

Toucan Virtual Museum (accessed on 21st February, 2006)

(http://www.toucan.co.jp/indexE.html)

The Toucan virtual museum (Figure 4.10) is an imaginary natural history museum without any physical site. The features of this virtual museum provide a diversity of 3D models of biological specimens on display in a virtual spatial environments such as fishes, flowers and insects, etc. The overall layout of the virtual museum is easy for visitors to follow in order to find information according to the main icons organised at the top of every page which is consistent throughout the site.

1 / 19 "Gifu(Luehdorfia japonica)" has been added to the VRML FieldGuide-Insect.
1 / 04 Rick Demil's picture "OVNI attack" has been added to the 3D-User's Gallery.
12 / 29 Rick Demil's picture "Cyber foetus" has been added to the 3D-User's Gallery.
12 / 28 Rick Demil's picture "Farm in summer" has been added to the 3D-User's Gallery.

The field guide using VRML(Virtual Reality Modeling Language) .

Please install any one VRML plug-in.

Figure 4.10 The Toucan Virtual Museum

This site presents 3D online exhibits using VRML for visitors to interact with the 3D artefacts. The presentation of 3D models of objects in the sites is arranged based on taxonomy as an informational resource. A large number of 3D models of artefacts is available to download providing question-answer activities and open interpretation. Due to the lack of interpretive content and learning materials for the online exhibits and pedagogic strategies in the website, such learning resources do not adhere to the Standards.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- Impressive online exhibits in terms of vividness and quality of visual information.
- Provides ample informational resources in terms of images and 3D models of artefacts.

Weaknesses:

- Lack of in-depth interpretative content for the 3D models of artefacts.
- Lack of the integration of multiple media formats; therefore may provide limited learning experiences.
- Lack of information for manipulation when interacting with the 3D model artefacts.
- Lack of clear pedagogic strategies for learning resources.

6. Thematic museums

Canadian Museum of Civilization (accessed on 24th February, 2006)

(http://www.civilization.ca/)

The Canadian Museum of Civilization (Figure 4.11) holds collections in more than one thematic subject, including archaeology, arts and crafts, civilization, cultures and so on. This museum site presents a large number of informational and learning resources except for lesson plans. The museum has recently launched a 3D online exhibition, Inuit 3D (Figure 4.12) (http://www.civilization.ca/aborig/inuit3d/inuit_e.html), to present 3D models of a selection of Inuit sculpture as a thematic collection related to Palaeo-Eskimo, Inuit History and Inuit Art (Corcoran et al, 2002).

L'institution culturelle la plus importante et la plus populaire du Canada, la Société gère le **Musée canadien des civilisations** et le **Musée canadien de la guerre**. Civilisations.ca est le site Web de la Société.

Canada's largest and most popular cultural institution, the Corporation manages the **Canadian Museum of Civilization** and the **Canadian War Museum**. Civilization.ca is the Web site of the Corporation.

Figure 4.11 The Canadian Museum of Civilization

To move:

1. Use the ***"Page Up"*** and ***"Page Down"*** keys to go to pre-set viewpoints.
2. Use the ***arrow keys*** on your keyboard to move.
3. Click and drag the ***mouse*** over the museum to move.

Figure 4.12 Inuit 3D virtual exhibition

Inuit 3D consists of 3D virtual exhibition rooms collaboratively produced by the Canadian Museum of Civilization and the National Research Council of Canada. The online exhibited artefacts are arranged in three thematically connected exhibition rooms in a circular chronological environment. The online exhibited artefacts in Inuit 3D are represented by a narrative structure interpreting the particularly conceptual themes: Palaeo-Eskimo, Inuit History and Inuit Art.

The content of the exhibits in the site offers a rich informational and learning resource. For schools and teachers, however, the exhibition environments may be compromised due to its emphasis on a particular audience, researchers and high level students. These two types of visitors might find this museum website to be an effective information and learning resource; although adherence to the Standards is incomplete.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- The integration and synergy of multiple media formats are used to enrich different learning experiences and which would be more attractive to virtual visitors in the virtual exhibition rooms.
- Easily identifiable target audience with a clear pedagogic strategy to match the required learning experiences.
- Easy to follow information structure through a clear navigation throughout the site.
- In-depth interpretive content and associated information with references in the “enriched educational exhibits”, allowing individual investigation.

Weaknesses:

- Lack of feedback and practising tasks in the learning process through the exhibition activities.
- Provides only a basic manipulation of objects through rotation.

7. Regional and local museums

Helsinki City Museum (accessed on 4th June, 2006)

(http://www.hel2.fi/kaumuseo/)

The Helsinki City Museum (Figure 4.13) conserves artworks, photographs and archive collections in relation to ‘its residents of today and yesteryear’ and is devoted to mirroring the Helsinki history, economy and culture (Helsinki City Museum 2006a). The museum provides both a 2D and 3D online exhibition environment, Virtual Museum - Time travel through history! (Figure 4.14) (http://www.virtualhelsinki.net/museum/english/), for virtual visitors to explore the virtual Henrik Govinius' site through a series of stories and the results of archaeological excavation to aid understanding the history of Helsinki.

Tervetuloa Helsingin kaupunginmuseoon
Keski-Uudenmaan maakuntamuseo

Välkommen till Helsingfors stadsmuseum
Mellersta Nylands landskapsmuseum

Welcome to Helsinki City Museum
Central Uusimaa Provincial Museum

Figure 4.13 The Helsinki City Museum

Merchant Henrik Govinius' site in the heart of Helsinki.

Familiarise yourself with the history of Helsinki with the aid of the fire inspector's story and archaeological excavation results. The 3D model will give you a glimpse of how the city looked in 1805.

The life of Johan Sederholm.

The time line will help you follow Johan Sederholm's rise to become the richest man in Helsinki. In these pages you will find objects and documents from an exhibition about Sederholm's life.

Figure 4.14 Virtual Museum - Time travel through history!

Due to lack of pictures of the buildings of the original Govinius plot, the creation of 3D reconstruction of Henrik Govinius' site (Figure 4.15) is not able to accurately present its original appearance (Helsinki City Museum 2006b). As a result, the limited visual information on the buildings used in the 3D reconstructed heritage site may result in low immersion which fails to make a contribution to the sense of presence.

Figure 4.15 The 3D reconstructed

Henrik Govinius' site

The 3D reconstructed environment provides informational and learning resources regarding the archaeological artefacts and the results of excavations. A number of media forms such as audio clips, texts, images and photographs is integrated into exhibit content in the 3D heritage environment. Virtual visitors would most likely benefit from actively learning knowledge of museum artefacts through subject matter content with in-depth interpretive texts and layers of information.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- The integration of auxiliary media formats, audios, texts, images and photographs can be easily found by hypermedia, effectively enriching the comprehending experience.
- Effectively supports non-curriculum-based learning experiences and lifelong learning activities through thematic content with in-depth interpretive texts and layers of information.
- Easily identifiable pedagogical strategy based on the "discovery learning" approach through structure of content.

- A logical organisation and structure of thematic content for virtual visitors to follow.

Weaknesses:

- Due to lack of vivid visual information of the constructed site, it does not effectively enhance the sense of presence of virtual visitors.
- Without a map, virtual visitors would encounter difficulty in orienting and navigating the 3D virtual exhibition environment.

8. Archaeology museums

Colchester Castle Museum (accessed on 24th May, 2006)

(http://www.colchestermuseums.org.uk/)

The Colchester Castle Museum houses the major repositories of archaeology collections from the late Iron Age and early Roman Britain eras (Colchester Castle Museum 2006). This museum website (Figure 4.16) has a variety of general museum information, programmes, learning activities, classes, events and so on; thus virtual visitors are encouraged to visit the physical museum. The featured characteristics of this site provide a subject, Virtual Colchester. This thematic subject presents the 3D reproduction of artefacts and the 3D archaeological reconstructions of historic buildings and cultural heritages (http://www.colchestermuseums.org.uk/Castle/castle_vr.html) devoted to the historical contexts of early Roman Britain and Norman eras.

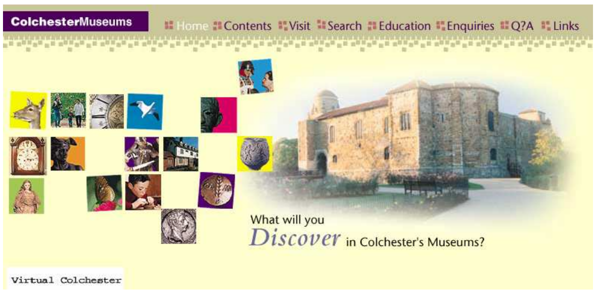


Figure 4.16 The Colchester Castle Museum

Content of 3D cultural materials in Virtual Colchester is presented by two dimensions of simulation: reproduction and reconstruction. Both a 3D reproduced museum artefact (Figure 4.17) and a 3D reconstructed historic building (Figure 4.18) are presented by using vivid visual information which contributes to immersion, enhancing the sense of presence.

Figure 4.17 The 3D reproduction of an authentic artefact

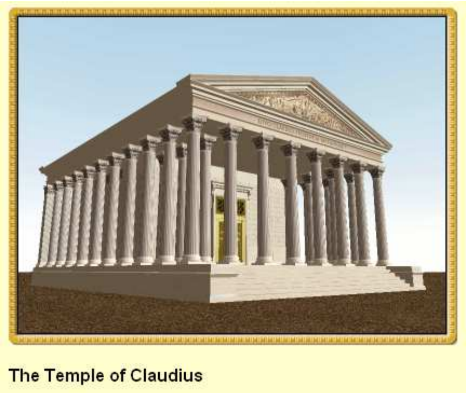


Figure 4.18 The 3D reconstruction of a historic building

The museum website provides opportunities for gaining information associated to the 3D replicas of the artefacts, reconstructed buildings and heritages but few chances for virtual visitors to learn about them due to lack of pedagogic interactions. This museum website simply presents informational resources and the 3D content of cultural materials rather than providing a learning resource. This might be due to the museum website's emphasis on general information. Consequently, little which reflects the Standards can be found.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- 3D reconstruction of the historic places and cultural heritages in panoramic environments through accurate simulated models effectively contributes to immersion.
- Effectively evokes awareness of the past life at certain historical events and time periods through the 3D reconstructed historic spaces.
- Easily identifiable target audience through structure of content.

Weaknesses:

- Lack of provision of navigation and metaphors when interacting with historic spaces and cultural heritage in virtual reality environments.
- Lack of in-depth interpretive content and learning materials to aid the learning process.
- Without a map, virtual visitors would encounter difficulty in orienting 3D virtual historic spaces and cultural heritage environments.
- Little non-curriculum-based learning experiences and support for lifelong learning due to minimum information and difficulty in identifying pedagogic strategy.

9. University museums

Hofstra University (Department of Physics)

Cardiac Museum (accessed on 24th May, 2006)

(http://arrhythmia.hofstra.edu/vrml/museumn/museumn.html)

The Cardiac Museum website (Figure 4.19) is an imaginary museum without an equivalent physical museum site. It was created by the Department of Physics at Hofstra University devoted to the 3D presentation of human atria and dog ventricles on display in various galleries. The museum consists of the lobby, the human atria gallery and the canine ventricles gallery. The university created this museum which seems to provide knowledge and information associated with arrhythmia research through the virtual exhibits.

Figure 4.19 The Cardiac Museum

The museum website presents content of virtual exhibits in 3D virtual environment using VRML technology. The virtual exhibits were created as symbolic signifiers; hence this may reflect the purpose of this site which is to emphasize the importance of medical principles and demonstrations rather than completely reproduce original artefacts. As this is a university museum, it serves a primary audience of the university-based community of students and researchers as a research and teaching institution. For this reason, the exhibit content includes terminology about human atria and dog ventricles and associated medical information in order to support research and teaching opportunities.

Concerning the Standards, the museum site seems to match the needs of researchers and high level students; thus it may not support non-curriculum-based learning experiences and lifelong learning activities.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- Easily recognisable instructional strategies were designed based on the "traditional lecture and text" approach for target audience.
- Ease of following the information structure through the use of clear navigation throughout the site employing the signs and a map.

Weaknesses:

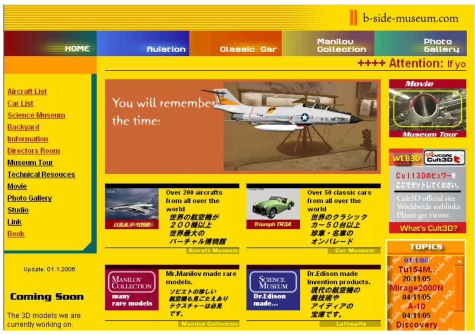
- Poor presentation of the exhibits for visitors to generally perceive the presence throughout the panoramic gallery spaces, therefore providing limited engagement.
- Lack of in-depth interpretive content and learning materials in the learning process; although the pedagogic strategy is based on the "traditional lecture and text".
- Lack of provision for the manipulation and interaction of artefacts; therefore fails to enrich viewing experience.

10. Technical museums

B-Side-Museum (accessed on 26th February, 2006)

(http://www.b-side-museum.com/bsidenew/index.html)

The B-Side-Museum (Figure 4.20) is also a virtual museum on the website without physical equivalent. This museum presents collections of both aircraft and classic cars. One of the main characteristics in the virtual museum is the 3D presentation of artefacts with associated information in the form of an encyclopaedia or a catalogue. The organisation of the 3D virtual content is easily accessed using a consistent interface design and defined navigation throughout the website.



You will remember the time:

Over 200 aircrafts from all over the world
世界の航空機が２００機以上世界最大のバーチャル博物館

Over 50 classic cars from all over the world
世界のクラシックカー５０台以上珍車・名車のオンパレード

Mr.Manilov made rare models.
ソビエトの珍しい航空機も見ごたえありテクスチャーは必見です。

Dr.Edison made Invention products.
現代の航空機の義技術やアイディアの宝庫です。

Cult3Dのビュワーをここでゲットしてください。
Cult3D official site Worldwide weblinks Please get viewer.

01/1/06 Tu154M..
20/11/05 Mirage2000N
04/11/05 A-10
04/11/05 Discovery

Update: 01.1.2006

The 3D models we are currently working on.

Figure 4.20 The B-Side-Museum

Although an English version is available on this site, interpretation of meanings and historical and contextual significance for the collections of 3D models of artefacts cannot easily be found in English. This might be because its exhibit content is under construction. Despite the fact that the learning activities include learning components which are logically organised, its content is not comprehensive enough to accomplish adherence to all of the Standards.

According to the three fundamental assessment criteria, the overall strengths and weaknesses of this virtual museum website were as follows:

Strengths:

- High-resolution and fidelity of 3D model artefacts effectively contributes to the immersive and sensory environments.

- Easy to follow information structure with clear navigation throughout the site.

Weaknesses:

- Ineffective integration of multiple media formats for the learning experience in the process of knowledge acquisition.
- Provides minimum information about artefacts in terms of history of aviation and technical principles.
- Lack of clear pedagogic strategies for learning resources.

4.5.2 The overall best and worst museum websites

The results of critical review indicated key features and problems for identification of the overall best and worst museum website.

The overall best museum website: London Science Museum

The key features in this museum website include the following:

- Successful use of 3D technology to improve access regarding interactivity (i.e. manipulation and navigation), metaphors and integration of multiple media formats.
- Effective use of the representational system: information-centered scheme. A series of scientific and technological subjects is conveyed through texts, images, photographs, learning activities and educational games with contextual information related to interpretation of the underlying online virtual exhibits.
- Clear pedagogic strategies are based on “constructivism” approach suited for the target audiences.
- Various methods used (i.e. multimedia components, hypermedia, emails,

educational games and the creation of personal website) effectively enhance the different types of learning experience.

- Successful implementation of all of the Archives & Museum Informatics Standards.

The overall worst museum website: Toucan Virtual Museum

The key problems in the museum website include the following:

- Lack of textual information and interpretative content for the 3D model artefacts.
- Lack of a description for the manipulation when interacting with the 3D model artefacts.
- Lack of the integration of multiple media formats (videos, graphics, textual information cannot be found); therefore provides limited learning experiences.
- Lack of any clear pedagogic design (e.g. instructional objectives and strategies, motivation and context, examples and help on how to use the application, interactively practicing task and so on) to support learning.
- Only a few of the Archives & Museum Informatics Standards achieved.

4.5.3 The main findings and four most effective museum websites

Overall, a number of important research findings and design elements, regarded as helpful to the proposition of a new design method for the development of a 3D museum environment were identified. The key research findings are listed as follows:

- The use of simulation (reconstruction, reproduction, and representation) in museum websites depends on their function and context for the effective presentation of museum artefacts, and thus museum websites’ approaches to information and pedagogic interactions (aesthetic appreciation, comprehension of underlying scientific principles and understanding of object its historical context) vary depending on the museum types.

- High levels of vividness and interaction are important to achieve immersion in order to contribute to a sense of presence.
- The ability to manipulate 3D model artefacts is important for visitors to view the detailed spatial information.
- The interaction metaphor is helpful to show exhibit names when the mouse cursor is moved over individual exhibit icons, allowing visitors to click them for more information on the contents.
- The provision of a map is useful for visitors to acquire spatial information for easily moving within the 3D museum environments and recognising where they are for orientation and navigation.
- The learning content of exhibits using rich multimedia formats and methods is useful for supporting visitors' different kinds of learning experiences.
- The target audience (s) needs to be clearly defined with appropriate pedagogic approaches for the effective presentation of learning content.
- Supplementary learning material and associated information on museum objects should have different levels of information content for the educational and interpretive needs of different target audiences.

In addition, the results of the critical review (also see Table 4.8, 4.9 and 4.10) indicate that the London Science Museum, the Philadelphia Museum of Art, the Canadian Museum of Civilization and the Helsinki City Museum are the most successful museum websites in terms of their effectiveness and usability as learning and informational resources. They each employed an alternative pedagogic approach in the 3D environments to effectively present their learning content of exhibits as defined by Hein (1995, 1998): traditional lecture and text (Canadian Museum of Civilization), behaviourist learning (Philadelphia Museum of Art), discovery learning (Helsinki City Museum) and constructivism (London Science Museum).

The London Science Museum uses an information-centered scheme to effectively present a series of scientific and technological subjects through texts, images, photographs, learning activities and educational games with contextual information related to interpretation of the underlying virtual exhibits. Moreover, the museum provides a large number of informational resources and different types of learning resources using multiple media formats integrated into the thematic content based on the "constructivism" approach, supporting different kinds of learning experiences. The orderly structure of online virtual exhibit components encourages virtual visitors to actively learn knowledge through a range of learning activities and programmes.

The Philadelphia Museum of Art presents the two impressive 3D models of Pogany sculptures using high quality visual information to effectively increase the sense of presence. Provision of a dynamic map and clearly marked entrances and exits effectively helps the orientation of a virtual visitor when navigating in the virtual exhibition space. This exhibition provides clear sequential structure of online virtual exhibit components and the virtual exhibits encourages visitors to appreciate the evolution of aesthetic concepts of the Pogany sculptures based on the "behaviourist learning" approach to stimulate the learning process.

The Canadian Museum of Civilization arranges its learning and information resources integrating multiple media formats into exhibits. The exhibit content using rich multimedia content can enrich different kinds of learning experiences and is more attractive to virtual visitors in the three virtual exhibition rooms. It was easy to navigate throughout the environment based on provision of a dynamic map. Moreover, the exhibition presents interpretive content and associated information in a systematic way with the traditional lecture and text approach to meet the educational needs of target audience.

The Helsinki City Museum interprets Helsinki history underlying particular objects with additional information in a narrative structure. A logical organisation and structure of thematic content are easy to follow. The museum provides a number of media forms: audios, texts, images and photographs integrated into exhibit content in the 3D environment. Virtual visitors are encouraged to actively learn knowledge of museum artefacts through thematic content with in-depth interpretive texts and layers of information based on the “discovery learning”.

4.6 Summary

The critical review conducted in this chapter presented a range of museum websites which employ 3D technologies for online informational and learning resources in a 3D virtual environment. Each museum website was assessed against the three fundamental components. The use of 3D web-based technologies in improving access for virtual visitors to a museum was commented on. The pedagogic strategies and the use of representational schemes in each museum website were analysed and interpreted. The presentation of supplementary materials within the 3D virtual environments of the selected museum websites for their target audience was examined based on the Archives & Museum Informatics Standards.

There are several key research findings and design elements regarded as important to the proposed design method for the development of a 3D museum environment as both information and learning resources, including 1) the relationship between simulation and the museum context for information and pedagogic interactions, 2) high levels of vividness and interaction for achievement of immersion to contribute to a sense of presence, 3) the ability to manipulate 3D model artefacts for viewing the detailed spatial information, 4) interaction metaphor (e.g. an exhibit icon with indication of the exhibit name when the cursor is moved over individual exhibit images) for more information on the exhibit contents and 5) provision of a map for orientation and navigation, 6) learning content using rich multimedia formats and methods to support visitors' different learning experiences, 7) clearly defined target audience (s) with appropriate pedagogic approaches for the effective presentation of learning content and 8) supplementary learning materials and different levels of information on museum objects provided for the educational and interpretive needs of the target audiences.

Moreover, the results of critical review indicated that the London Science Museum, the Philadelphia Museum of Art, the Canadian Museum of Civilization and the Helsinki City Museum were effective in presenting their exhibit content based on the intended pedagogic approaches in 3D virtual environments for the educational and interpretive needs of the target audiences. These four museum websites will be used to further conduct observational studies of virtual visitor behaviours in the next chapter (Chapter Five) to determine a potential relationship between virtual visitors' behaviours and their associated learning activities within the examined museum websites based on the pedagogic approaches used in 3D environments. In addition, part of the observational study is to confirm, as objectively as possible, some of the more subjective findings from this critical review.

Chapter Five: Observation Studies

5.1 Introduction

As discussed earlier (Chapter Four), the critical review results tended to be subjective due to the use of a self-evaluation of the museum websites without any real visitor reactions. Therefore, in order to gather objective data regarding virtual visitors' behaviours and their interactions with the learning content of exhibits, it was necessary to also conduct a visitor study through making direct observations of what they are actually interacting with when using the learning content within 3D virtual museum environments. The purpose of these observation studies is to address the research question raised earlier: what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy.

This chapter presents observational research into the four most effective and successful virtual museum websites which were discussed in the critical review (Chapter Four). These four virtual museum websites were chosen from the critical review because they were shown to effectively and clearly present their content in 3D virtual environments for the educational and interpretive needs of the target audiences. In addition, they were selected to represent each type of pedagogic approach based on Hein's educational theory (i.e. traditional lecture and text, behaviourist learning, discovery learning and constructivism). All four pedagogic approaches were selected in order to identify which pedagogic approaches should be used in the design of their 3D museum environments and the most appropriate ways of presenting the learning content of exhibits to match related visiting styles, leading to a deeper engagement with the subject matters for learning efficacy. The following sections discuss the use of the methods for conducting observations on the four selected virtual museum websites, namely, the London Science Museum, the Canadian Museum of Civilization, the Helsinki City Museum and the Philadelphia Museum of Art.

Three typical types of museum visitors (i.e. general public, researchers and schools) were selected as subject samples based on Bowen et al's (2001) classification. All three types of visitors represent the real users as the target audience in virtual museums in order to gather as much variability as possible. Ten subjects in each group were recruited according to Diamond's (1999) suggestions, giving a total number of subjects needed as thirty subjects in order to test all four museum websites to ensure the reliability of the investigative results.

Observation studies (qualitative method), as mentioned in Chapter Three, can be supplemented by combining other quantitative approaches such as questionnaires (quantitative method) in order to gather information and insight about what visitors interact within exhibits and learn in museums. Therefore, two kinds of data, qualitative and quantitative, were collected during the observation research. Qualitative data were gathered from part one – a free exploration of museum websites through the main performance test, eliciting an identification of changes in visiting styles in 3D museum environments. Quantitative data were collected from the background and post-observation questionnaire, and the main performance test, to determine a basic demographic and web usage profile, and an evaluation of learning-related behaviours in 3D environments on the museum websites.

The observation result will be analysed to identify the potential relationship between visiting styles and learning activities at the end of this chapter. The findings through these observations will be important for the development of a theoretical design reference model as part of the overall research.

5.2 Aim of observation studies

The aim of these studies is to conduct observations of visitor behaviours interacting with current virtual museums as both an online informational and learning resource in a 3D virtual environment.

5.3 Objectives of observation

This observation focuses on the identification of a potential relationship between the visiting styles and learning activities by the examination of museum websites using three-dimension virtual reality environments. Observing virtual visitors' behaviours is important for identifying the nature of interactions within museum websites with 3D virtual environments when used as informational and learning resources. The purpose of this research is to observe visitor behaviours (e.g. reading labels or texts, viewing images, manipulating exhibits, watching videos and so on) and visiting styles (i.e. the four known visiting styles: ant, fish, grasshopper and butterfly) in the learning context within the four selected museum websites which are based on the four different types of pedagogic approaches. The observation undertaken aims to address the following specific questions:

- How does the organisation and layout of the exhibition and content of online virtual exhibits influence the types of visiting styles, leading to learning activities in 3D virtual museum environments?
- How can the types of pedagogic approach be adapted to match visiting styles and the needs of different visitor groups in terms of the presentation of information and organisation of learning materials in exhibits in a 3D virtual

environment?

5.4 Methodology

5.4.1 Validity and reliability

Employing appropriate methods and techniques is important for observation studies because it will affect the validity and reliability of the observation results. Diamond (1999) has identified that the validity of observation studies in the museum environments relies on several instruments:

- ‘Conduct informal observations to determine the nature and complexity of the environment.’
- ‘Generate categories of behaviour from the environment.’
- ‘Make periodic review of the environment.’

Each instrument which is applied to these observational studies is discussed as follows:

- *‘Conduct informal observations to determine the nature and complexity of the environment’*

  The informal observations were achieved through the critical review (see Chapter Four) to determine the nature and complexity of the museum websites in terms of informational aspects and the learning context in their 3D virtual reality environments.

- *‘Generate categories of behaviour from the environment’*

  The categories of visitor behaviour were clearly defined as the ant, the fish, the grasshopper and the butterfly in virtual museum environments (Chittaro and Ieronutti 2004); these categories were discussed in the literature review

(Section 2.5.3).

- *‘Make periodic review of the environment’*

  The critical review has identified the strengths and weaknesses of the web-based virtual museums with a focus on the 3D presentation of the virtual spatial environments as both informational and learning resources (see Chapter Four). The museum websites were checked before observation to confirm there were no changes to the websites during period of observations.

Reliability refers to the quality of measurement based on the consistency of a research method. Diamond (1999) has proposed guidelines for reliability of data collection from observation with an emphasis on museum environments as follows:

- ‘Make sure that the observer is in a similar condition each time the observations are made.’
- ‘Don’t let too much time pass between observations.’
- ‘Make sure your behavioural categories are clear and unambiguous.’
- ‘If your raw data is to be transferred into another format (transcribed from tape, typed into a computer), be sure you make the transfer as soon after the original observations as possible.’
- ‘Keep your recording method the same each time you observe.’

These research instruments and guidelines are employed to observe visitors’ behaviours involved with programmes and exhibits in educational settings in museum environments for validity and reliability. However, although the instruments and guidelines are used in the traditional museum environments, it is argued they are also applicable to the domain of the virtual museum as well as the conceptual behaviours of virtual visitors are similar to the actual visitors' behaviours when viewing the artefacts in a virtual exhibition environment (Chittaro and Ieronutti 2004). Besides, the validity of the instruments and the reliability of the guidelines were considered and used in former studies of web-based virtual museum environments, such as Park's work (Park 2003).

5.4.2 Methods

As mentioned in Chapter Three, these observations were combined with performance tasks and post-observation questionnaire. The observations were conducted to determine visitor behaviour patterns and their interests while interacting with the learning content of online exhibits within the 3D museum environments.

Rubin (1994) has proposed a framework for the usability testing of computer-based products and systems (e.g. software products, Web products and so on) for evaluations of the usefulness, effectiveness and so on through observations of end users. This framework is effective and suitable for any type of Web product, including museum websites.

The procedure for this observational research was based on Rubin's framework, including a main performance test and post-observation questionnaire. The design of the main performance test is to obtain data regarding visitor behaviours, visiting styles and learning activities and performance tasks via direct observation. The post-observation questionnaire is to gain data based on participants' experience regarding the web-based museum systems after the observation.

As well as employing Rubin's methodology, the considerations of validity and reliability described by Diamond were implemented in the following steps:

1. *Specifying goals of analysis*

   In this step, the goals of this observation analysis are identified based on the research question posed during the literature review (Section 2.9) that need to be addressed as well as a methodology suitable for the research aims.

2. *Identifying the categories of virtual visitor behaviours and participant profiles to develop behavioural codes*

   In this phase, the categories of virtual visitor behaviours (i.e. the four categories of visitors relating visiting styles: the ant, fish, grasshopper and butterfly visitor) are based on the literature review (see Section 2.5.3). Identification of participant profiles is based on the typical types of virtual visitors (Bowen et al 2001; Brown et al 2005), including:

   - General public (non-specialists)
   - Researchers and professionals (specialists, scholars, curators, amateur enthusiasts, high level students, etc.)
   - Schools (students in the range 11-18 years of age and teachers, etc.)

   The types of virtual visitor behaviours and participant profiles will be used to develop behavioural codes (discussed in Section 5.5.1) for describing participants' interaction within the 3D virtual museum environments.

3. *Designing the main performance test and setting up a test environment and*

equipment

The planning and design of the main performance test includes the following four sections (Rubin 1994):

- Participant greeting and background questionnaire
- Orientation
- Performance test
- Participant debriefing

Each section will be discussed in detail in Section 5.4.2.1. The testing environment and equipment will consist of a simple room setup, including a personal computer with Internet access and a video camera, and two seats for the participant and the test monitor. The purpose of a video camera is to capture participants' behaviours in the environments on the computer screen. A diagram of the simple room setup is shown in Figure 5.1.

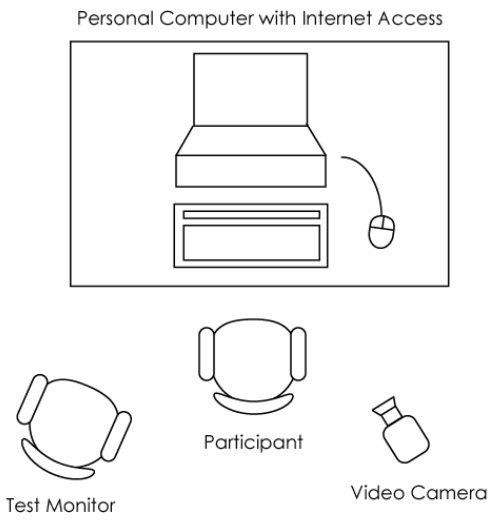


Figure 5.1 The testing environment with the required equipment

4. *Developing the background and post-observation questionnaire to gather extensive data*

In this stage, a subject background and a post-observation questionnaire are designed (discussed in Section 5.5.2) in order to gather information about the participators' prior experiences and post-observation data from participations.

5. *Selecting a set of museum websites from the critical review for observations*

   In this phase, a set of museum websites was chosen based on the pedagogic approaches indicated in Hein's educational theories (Section 2.6.1) as shown in Table 5.1:

Name	**Pedagogic approach**
Science Museum (London)	Constructivism
Canadian Museum of Civilization	Traditional lecture and text
Helsinki City Museum	Discovery learning
Philadelphia Museum of Art	Behaviourist learning

Table 5.1 The four selected museum websites

   Moreover, from the critical review, the four selected museum websites were shown to effectively and clearly present their cultural materials content in 3D spatial architectural environments for the educational and interpretive requirements of the target audiences; thereby these museum websites can be used to determine the relationship between visiting styles and learning context within 3D virtual museum environments for different groups of virtual visitors through observations.

6. *Determining methods for analysing the observation results*

   In the final step, methods for analysing the observation results were determined to examine visitor behaviour patterns while interacting with the learning content of online exhibits within 3D virtual museum environments.

5.4.2.1 The design of the main performance test

For this observational research, the main user performance test will include the following four sections:

- Participant greeting and background questionnaire

  Every participant will be greeted by the test monitor and given a background questionnaire to fill in to obtain their basic information. Participants will be clearly notified of their rights during the observation process. Moreover, participants will be given an ID number to replace their name to maintain user anonymity.

- Orientation

  Participants will be given a script introduction and orientation (Appendix 5A) to explain the aims and objectives of this observational research. Participants will be notified that they are being observed and recorded through a video camera.

- Performance test

  The main performance test consists of two parts: part one, a free exploration of museum websites and part two, performance of a range of tasks.

  i. Part one – a free exploration of the museum websites focuses on observing the nature of participants' behaviours involved in examining exhibit content and the influence of interactivity factors on visiting styles in the 3D environments. Participants will be allowed to freely explore museum websites in order to observe their actions and behaviour in the virtual environments until the time expires (10 minutes). The nature of visitor behaviours involved in the 3D environments will be recorded through a video camera and by making notes of interaction. Making notes is helpful to identify types of behaviours such as “shows frustration on navigation”, because it is difficult to define this type of behaviour from just watching videos. Therefore, this behaviour can be observed through participants’ verbal behaviour from a groan of frustration with navigation or nonverbal behaviour from the head-shake during the observations and noted.

ii. Part two – performance of a range of tasks aims to observe their performance in a range of tasks within the 3D environments in order to measure how effective they are in presenting exhibit content in terms of organisation, paths and interaction metaphors (e.g. exhibit icons with clear indication of individual exhibit names can be clicked on). The task lists are given in Section 5.5.3.2. Each task will be given from a script by the test monitor. The details of the tasks to be performed will be videotaped, including amount of time spent, relevant participant behaviours, movements and success or failures.

- Participant debriefing

Each participant will be debriefed by the test monitor and then asked to fill in a post-observation questionnaire after all tasks are completed or the time expires. The participant debriefing includes the following:

i. Participant’s perceptions of interactivity factors (e.g. immersion, presence, manipulation and so on) in the 3D virtual environments.

ii. Participant’s comments on his or her visit and performance test on the museum websites.

iii. Participant’s response to perceptions of the content and learning in the 3D environments.

iv. Participant’s response to how easy it is to follow information architecture and paths in terms of the organisation of exhibit content to progress over time and across learning programmes.

The participant debriefing session serves a number of functions which allow the participants to state their preferences for the presentation of information and learning resources and frustrations when performing the tasks. Furthermore, it not only offers useful information on each participant’s rationale for performing specific actions in the tasks, but also allows the collection of subjective preference data about the museum website.

5.4.3 Reasons for selecting subjects and the size of subject sample

For qualitative research (e.g. observations) into museums, Diamond (1999) has proposed that subject selection should rely on a variety of different types of visitors in order to gather as much variability as possible. The types of museum visitors can be classified into three main groups: general public, researchers and schools (Bowen et al 2001). Therefore, these groups will be selected as subject samples in the observation research.

The sample size is important for the reliability of the investigative results (Diamond 1999). She has suggested that ‘about five to ten subjects may be useful for exploratory evaluations (Diamond 1999).’ Thus ten subjects in each group (i.e. general public, researchers and professionals, and schools) will be recruited based on non-proportional stratified random sampling method, giving total number of subjects needed as thirty (see Table 5.2) (refer to Section 3.2.4). The thirty subjects are required to test all four museum websites for an overall comparison between the types of pedagogic approaches and visiting styles.

Visitor group	Sample size	Total sample size
General public	10	30
Researchers and professionals	10	
Schools	10	

Table 5.2 Ten subjects from each group and the total number of thirty subjects

5.5 Establishment of behavioural codes, background and post-observation questionnaires and evaluation measurements

5.5.1 Behavioural codes

Diamond (1999) contended that ‘the list of behavioural codes is the vocabulary of behavioural observations.’ Behavioural codes can be used to record visitor interactions at museums exhibits during the observation process. Based on the literature review and the critical review, a number of behavioural codes (Appendix 5B) was established for observing the expected visitor behaviours and the four visiting styles in 3D museum environments. These codes will be used to record participants’ behaviours interacting with exhibits, learning activities and games in the chosen museum websites in terms of frequency and duration in order to identify the associated behaviours for the development of learning about a subject.

5.5.2 A background and post-observation questionnaire

A background questionnaire (Appendix 5C) is designed to gather the participants’ profiles in order to understand their background and experience (e.g. name, occupation, Internet experience, virtual visitor experience in museum websites and so on). In addition, a pre-designed post-observation questionnaire (Appendix 5D) is used to gain data based on the participants' experience of the four chosen museum websites after the observations. Their responses to the questionnaire along with the results of observations and performance tasks will be analysed in order to attempt to address the research question.

5.5.3 Evaluation measurements

5.5.3.1 Observational measures

Boisvert and Slez (1995) point out that in a museum learning environment, 'exhibits must attract visitor attention as well as compel the visitor to become engaged with the exhibit for a sufficient amount of time so that learning can occur.' Diamond (1999) notes that learning experiences in museums can include 'the subjects interacting with a specific exhibit, and when the subject manipulates the exhibit correctly, reads the labels aloud, or makes a specific comment that refers to the content of a label.'

With regard to the learning process in museums, Wolf (1985) and Boisvert and Slez (1995) identified attraction, holding power, and visitor engagement as necessary steps to learning: attraction (visitors who stop at the exhibit), holding power (time spent by visitors at the exhibit) and visitor engagement (visitors pay attention to the exhibits). Wolf (1985) and Yahya (1997) suggested that attraction and holding power are important variables in understanding the museum learning environment. Besides, holding power can affect the visitor engagement factor in the duration of exhibit visits.

However, although these two measures tend to be more effective in assessing educational settings in an actual space than in a virtual space, it is also possible to take into account a number of physical aspects such as the frequency of stops at the exhibits and the duration of viewing exhibits in 3D virtual museum environments. These two observational measures were collected in order to measure the prerequisite behaviour for learning to occur:

- Attraction: the number of participants who stop at exhibit images or click on exhibit images for additional information about them.
- Holding power: amount of time spent by participants interacting with exhibits and learning activities or games.

These measures focus on assessing participants' learning-associated behaviours involved with exhibits, learning activities and games in 3D museum environments. This can be useful to guide the organisation of learning materials in exhibits and pedagogic approaches in educational museum environments to match visitor behaviour patterns.

5.5.3.2 Task lists

Diamond (1999) contends that it is helpful to ask subjects to perform a series of tasks in an activity in order to measure how best to present directions and concepts of exhibit content in a museum space. This can be helpful to determine the effectiveness of information architecture and which type gives virtual visitors the most clear orientation to progress over time and across learning activities and games in the 3D environments. The rationale of establishing a series of tasks is based on two parts:

1. Interaction metaphors (e.g. an exhibit icon with indication of the exhibit name when the cursor is moved over individual exhibit images) used in navigation paths.

2. Information architecture and different media presentation formats (e.g. combinations of texts, images, photographs, videos, audios, 3D models, games and so on) used in exhibit content.

In the first part of testing performance, the participants are asked to find the specified exhibits in the 3D museum environments in order to measure the effectiveness of interaction metaphors used in navigation paths. In the second part of testing performance, the participants interact with individual exhibits and additional information using different media presentation formats during learning experience in order to evaluate the effectiveness of information architecture.

Each task includes both two parts of testing performance. The tasks for the four chosen museum websites (i.e. the London Science Museum, the Canadian Museum of Civilization, the Helsinki City Museum and the Philadelphia Museum of Art) are listed and explained in Table 5.3-5.6:

- Science Museum (London) (http://www.sciencemuseum.org.uk/)

Task No.	**Task description**
1	Look at the exhibit, **Pattern Wall,** on display in "***Pattern Pod*"** in the ground floor, and additional information about it.
2	Find the educational game: **Networking People** from the gallery, "***Digitopolis*"**.
3	Find the exhibit: **Wheatstone printing telegraph** and additional information from the gallery, "***Digitopolis*",** on second floor.
4	View the picture, **Live science,** on display in the gallery, ***"Who am I?"*** and associated information about it.

Table 5.3 Performance task lists for the Science Museum (London)

- Canadian Museum of Civilization (http://www.civilization.ca/)

Task No.	**Task description**
5	Find the 3D exhibit, **Dancing Bear,** and additional information.
6	Look at the picture, **Two Inuit**, and then find more information on it.
7	Find the **Inuit history** video clip for information on the history of the Inuit.

Table 5.4 Performance task lists for the Canadian Museum of Civilization

- Helsinki City Museum (http://www.hel2.fi/kaumuseo/)

Task No.	**Task description**
8	Find **Gate and shop** and associated information.
9	Look at the photographs and textual information about **Yard paving**.

Table 5.5 Performance task lists for the Helsinki City Museum

- Philadelphia Museum of Art (http://www.philamuseum.org/)

Task No.	**Task description**
10	Look at the 3D sculpture, **Mademoiselle Pogany I**, and then lock your view on the 3D sculpture.
11	Find the picture of **Mademoiselle Pogany I** (bronze), **II** (bronze) and **III** (bronze)**.**

Table 5.6 Performance task lists for the Philadelphia Museum of Art

5.6 Analysis of observation results

Each 3D museum environment browser 3D plug-in[4] provided by the website was installed to ensure the 3D environment worked correctly before doing the observations. Although the Philadelphia Museum of Art website provides a plug-in for

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[4] Plug-in 'is a computer program that interacts with a host application (a web browser or an email client, for example) to provide a certain, usually very specific, function "on demand" (Wikipedia 2008b).'

the 3D environment, it was found that the 3D museum environment was not able to be presented after the installation of the plug-in. This is because the plug-in had not been updated to be compatible with the later version of browser software as mentioned in the Philadelphia Museum of Art website. Therefore, an alternative 3D plug-in was installed in the 3D environment for the Philadelphia museum website. However, some subjects pointed out the difficulty in using the mouse to navigate the environment. This factor may influence the observation results. For example, the participants may feel frustration in moving to view the exhibits which were set out over a long distance in the 3D exhibition or perhaps spend a long time to complete the assigned tasks.

The analysis of observation results includes three parts: participant profile, the main performance test (a free exploration of museum websites and performance of a range of tasks) and their views on the museum websites according to the post-observation questionnaire.

5.6.1 Participant profile

As mentioned earlier (see Section 5.4.3), the subject selection for this observation research was based on three typical types of visitors (i.e. general public, researchers and professionals, and schools). Ten subjects in each group were recruited, giving the total number of subjects as thirty in line with Diamond's (1999) recommendation.

Observations of thirty participants were made while they freely visited and performed the tasks on the four museum websites during the period September 2006 to December 2006. A typical observation lasted from one and a half hours to two hours. The numbers and percentages of the participants are shown in Table 5.7. The original data of the observation can be found in Appendix 5E.

Category	Item	Number / Percentage (%)
Gender	Male	13 (43%)
	Female	17 (57%)
Age	11-18	4 (13.3%)
	19-30	19 (63.3%)
	31-40	4 (13.3%)
	41-50	3 (10.0%)
	51+	0 (0%)
Education	GCSE	1 (3%)
	A level	3 (10%)
	First degree	18 (60%)
	Master's degree	6 (20%)
	Doctoral degree	0 (0%)
	Other	2 (7%)
Internet experience	Yes	30 (100%)
	No	0 (0%)
	Every day	25 (83.3%)
	3-6 times per week	3 (10.0%)
	Once or twice per week	1 (3.3%)
	Once or twice per month	1 (3.3%)
	Once or twice per year	0 (0%)
Museum website experience	Yes	21 (70%)
	No	9 (30%)
	Every day	0 (0%)
	Once or more per week	2 (10%)
	Once or twice per month	6 (29%)
	Once or twice per year	12 (57%)
	Less than once per year	1 (5%)
3D web-based environment experience	Yes	15 (50%)
	No	8 (27%)
	Unsure	7 (23%)
	Every day	0 (0%)
	Once or more per week	2 (13%)
	Once or twice per month	5 (33%)
	Once or twice per year	8 (53%)
	Less than once per year	0 (0%)

Table 5.7 The numbers, profiles and percentages of the participants

When asked about their Internet experience, all thirty participants have experience of using the Internet. 83.3% of the participants usually use the Internet every day. In terms of the participants' museum website experience, 70% of them have visited virtual museums on the web before. The results also indicated that most participants

(57%) visit museum websites once or twice per year. Concerning the participants' 3D web-based environment experience, half of the participants have online 3D environment experience such as 3D environments on E-Commerce, museum, game and E-Learning websites. 53% of them visit these types of websites once or twice per year. However, only two participants (13%) visit such websites once or more per week.

Their reasons for visiting museum websites, sections examined in museum websites and opinions about 3D environments on the Internet are presented in Table 5.8 below:

Category	**Item** ***multiple selection possible**	**Mentioned (frequency)**
Reasons for visiting museum websites	For general interest	13
	For research	13
	For entertainment	9
	For occupational need	7
	For schoolwork and homework	4
	For buying books, CDs, gifts, etc.	2
Sections on a museum website in general	General information	19
	Schedule of events	17
	Images of artefacts in the collections	9
	Virtual exhibitions	7
	Learning resources	5
	Online shopping	2
	Online question or requirement sections with museum staff	1
	Forum or discussion board	0
Opinions of the 3D environments on the Internet	Fun	13
	Easy to use	5
	Useful	4
	Attractive	4

Table 5.8 The reasons for visiting museum websites, sections examined in museum websites and opinions about 3D environments on the Internet

The participants responded that the top four reasons for visiting museum websites were “general interest” (13), “research” (13), “entertainment” (9) and “occupational need” (7). When asked which sections the participants normally looked at on the museum websites, “general information” (19) and “schedule of events” (17) were the two dominant sections. However, “online question or requirement sections with museum staff” (1) and “online shopping” (2) had fairly low percentages and “forum or discussion board” (0) was not chosen by any participant. These results support the findings of the CHIN’s 2004 Survey of Visitors to Museums that virtual visitors most frequently look for the two items (i.e. “general information about the museum” and “schedule of special events”) and least frequently look at “online question sections with museum staff” and “discussion forum with other visitors” on a museum website (Canadian Heritage Information Network 2005).

In terms of the participants’ opinions about the 3D environments on the Internet, those participants who had 3D environment experience considered the online 3D environments as easy to use (5), fun (13), useful (4) and attractive (4) when they were asked their opinions and attitudes.

The numbers, profiles and percentages of the participants in each group are shown in Table 5.9.

Category	**Item (Number / Percentage (%))**	**General public**	**Researcher and professional**	**Schools**
Gender	Male	5(17%)	5(17%)	3(10%)
	Female	5(17%)	5(17%)	7(23%)
Age	11-18	0(0%)	0(0%)	4(13%)
	19-30	8(27%)	5(17%)	6(20%)
	31-40	2(7%)	2(7%)	0(0%)
	41-50	0(0%)	3(10%)	0(0%)
	51+	0(0%)	0(0%)	0(0%)
Education	GCSE	0(0%)	0(0%)	1(3%)

	A level	0(0%)	0(0%)	3(10%)
	First degree	9(30%)	3(10%)	6(20%)
	Master’s degree	0(0%)	6(20%)	0(0%)
	Doctoral degree	0(0%)	0(0%)	0(0%)
	Other	1(3%)	1(3%)	0(0%)
Internet experience	Yes	10(33%)	10(33%)	10(33%)
	No	0(0%)	0(0%)	0(0%)
	Every day	7(23%)	9(30%)	9(30%)
	3-6 times per week	3(10%)	0(0%)	0(0%)
	Once or twice per week	0(0%)	1(3%)	0(0%)
	Once or twice per month	0(0%)	0(0%)	1(3%)
	Once or twice per year	0(0%)	0(0%)	0(0%)
Museum website experience	Yes	6(20%)	8(27%)	7(23%)
	No	4(13%)	2(7%)	3(10%)
	Every day	0(0%)	0(0%)	0(0%)
	Once or more per week	0(0%)	1(5%)	1(5%)
	Once or twice per month	1(5%)	2(10%)	3(14%)
	Once or twice per year	5(24%)	4(19%)	3(14%)
	Less than once per year	0(0%)	1(5%)	0(0%)
3D web-based environment experience	Yes	7(23%)	6(20%)	2(7%)
	No	2(7%)	2(7%)	4(13%)
	Unsure	1(3%)	2(7%)	4(13%)
	Every day	0(0%)	0(0%)	0(0%)
	Once or more per week	1(7%)	0(0%)	1(7%)
	Once or twice per month	3(20%)	2(13%)	0(0%)
	Once or twice per year	3(20%)	4(27%)	1(7%)
	Less than once per year	0(0%)	0(0%)	0(0%)

Table 5.9 The numbers, profiles and percentages of the participants in each group

Most researchers and professional participants (8 participants) have museum website experience, followed by school participants (7 participants) and general public (6 participants). The majority of the general public and researchers and professional participants have 3D web-based environment experience. Four of the researchers and professional participants visit this type of 3D environments once or twice per year. Only two school participants have 3D web-based environment experience. However, four school participants are not sure whether they have such 3D web-based environment experience.

Each participant groups' reasons for visiting museum websites, sections examined in museum websites and opinions about 3D environments on the Internet are presented in Table 5.10.

Category	**Item Mentioned** ***multiple selection possible**	**General public**	**Researcher and professional**	**Schools**
Reasons for visiting museum websites	For general interest	3	5	5
	For schoolwork and homework	0	1	3
	For research	3	4	6
	For occupational need	1	2	4
	For entertainment	4	3	2
	For buying books, CDs, gifts, etc.	1	0	1
Sections on a museum website in general	General information	5	7	7
	Schedule of events	5	7	5
	Images of artefacts in the collections	2	4	3
	Virtual exhibitions	0	1	6
	Learning resources	1	1	3
	Forum or discussion board	0	0	0
	Online question or requirement sections with museum staff	0	1	0
	Online shopping	2	0	0
Opinions of the 3D environments on the Internet	Easy to use	3	2	0
	Fun	4	6	3
	Useful	3	0	1
	Attractive	1	3	0

Table 5.10 Each group's reasons for visiting museum websites, sections examined in museum websites and opinions about 3D web environments

For the general public participants, the most common reason for visiting virtual museums is entertainment (4); for the researchers and professional participants, the most common reason for visiting virtual museums is general interest (5); for the school participants, the most common reason for visiting virtual museums is research (6). These findings indicated that each groups' reasons for visiting museum websites varied depending on the features, interests and needs of individual groups. In terms of the most frequent sections looked at on the museum websites, the general public and the researchers and professional participants stated that “general information” and “schedule of events” were the two dominant sections; the school participants regarded “general information” and “virtual exhibitions” as two main sections. When asked their options of 3D web-based environments, the most frequently mentioned by all three groups of the participants was fun.

5.6.2 The results of the main performance test

Thirty participants’ behaviours were observed interacting with the 3D environments on the four museum websites. In this part of observation results, there are two types of data that will be illustrated: behaviour-related data and time-related data. Behaviour-related and time-related data were collected through a free exploration of museum websites; time-related data were also gathered from the performance of a range of tasks among the four museum websites.

5.6.2.1 A free exploration of museum websites

Thirty participants were observed to record their behaviours using the behavioural codes for frequency in the four museum websites. In this study, frequency is defined as the total number of occurrences of behaviours of all thirty participants. The overall frequencies and percentages of the participants’ behaviours in the 3D museum environments of the four museum websites are illustrated in Table 5.11 and are graphically presented in Figure 5.2.

Behaviours	**Frequency**	**Percentage**
Manipulate artefacts	145	4.1%
Manipulate incorrectly	17	0.5%
Look for help or instructions for manipulation	1	0.0%
Look for help or instructions for navigation	30	0.9%
Show frustration on navigation	29	0.8%
Read labels and texts	1006	28.6%
Listen to audios	5	0.1%
Watch videos	54	1.5%
Look at images	1070	30.4%
Look at animations	8	0.2%
Click on the exhibit images for further information	1073	30.5%
Interact with learning activities or games	64	1.8%
Look for help or examples in programmes and activities	18	0.5%

Table 5.11 The overall frequencies and percentages of the participants' behaviours in the 3D environments of the four museum websites

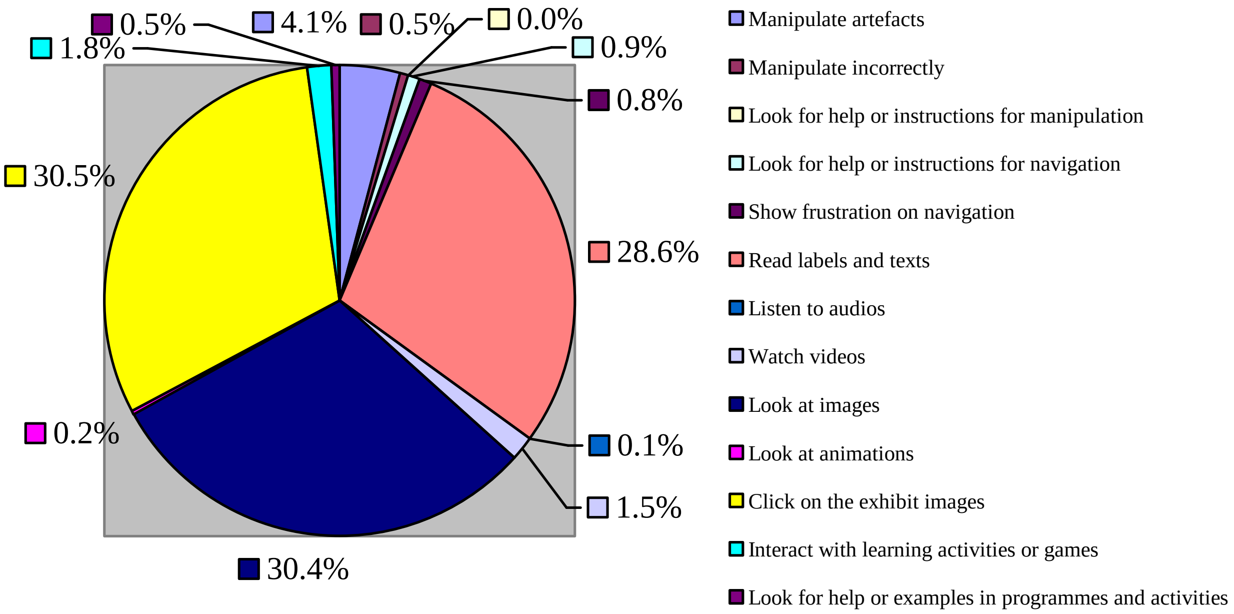


Figure 5.2 The percentages of distribution of participants' behaviours in the 3D environments of the four museum websites

"Read labels and texts" (28.6%), "look at images" (30.4%) and "click on the exhibit images for further information" (30.5%) were identified as the three most dominant behaviours for all the behaviours observed among the four museums websites. These three main behaviours were used as indicators or prerequisities for the development of the participants' learning about a subject in the 3D museum environments.

"Manipulate artefacts" (4.1%) was low in terms of all the behaviours. This was possibly because only two museums (i.e. London Science Museum and Canadian Museum of Civilization) allowed the participants to manipulate the virtual exhibits. This finding supports Diamond's (1999) idea of learning experiences taking place when visitors interact with a specific exhibit, and they manipulate the exhibit correctly, read the labels and look at images.

The frequencies and percentages of the participants' behaviours in each 3D museum environment are presented in Table 5.12.

Museums	**London Science Museum**	**Canadian Museum of Civilization**	**Helsinki City Museum**	**Philadelphia Museum of Art**
Behaviours	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**
Manipulate artefacts	27(2.8%)	118(7.3%)	N/A	N/A
Manipulate incorrectly	7(0.7%)	10(0.6%)	N/A	N/A
Look for help or instructions for manipulation	N/A	1(0.1%)	N/A	N/A
Look for help or instructions for navigation	10(1.0%)	4(0.2%)	15(2.2%)	1(0.4%)
Show frustration on navigation	0	0	7(1.0%)	22(7.8%)
Read labels and texts	247(25.7%)	450(28.0%)	198(29.6%)	111(39.2%)
Listen to audios	N/A	N/A	5(0.7%)	N/A
Watch videos	N/A	54(3.4%)	N/A	N/A
Look at images	240(25.0%)	455(28.3%)	226(33.8%)	149(52.7%)

Look at animations	8(0.8%)	N/A	N/A	N/A
Click on the exhibit images for further information	340(35.4%)	515(32.0%)	218(32.6%)	N/A
Interact with learning activities or games	64(6.7%)	N/A	N/A	N/A
Look for help or examples in programmes and activities	18(1.9%)	N/A	N/A	N/A
Total	961(100%)	1607(100%)	669(100%)	283(100%)

Table 5.12 The frequencies and percentages of the participants' behaviours in each 3D museum environment of the website

N/A=Not available

As shown in Table 5.12, some museums did not provide the functions e.g. manipulation and hyperlinks, instructions, media formats or games. In these cases, "N/A" is used to indicate that the behaviours involved for such items were not available.

The **London Science Museum** had the second highest frequency total of participants' behaviours (961) but it was less than the Canadian Museum of Civilization (1607). This was possibly because the layouts of the galleries were designed for different floors. This resulted in the participants spending a long time travelling to the different floors. "Click on the exhibit images for further information" (35.4%) was the most frequent behaviour. The next two behaviours, "read labels and texts" (25.7%) and "look at images" (25%), accounted for more than half of all the behaviours. "Interact with learning activities or games" (6.7%) and "manipulate artefacts" (2.8%) constituted nearly 10% of all the behaviours. These four behaviours (i.e. reading, looking, interacting and manipulating) were more than 60%. "Look at animations" was a fairly low percentage of all the behaviours (0.8%). This was possibly because the content was not interesting. Thus the animation was not very effective in attracting the participants to look at it.

The **Canadian Museum of Civilization** had the highest total frequency of participants' behaviours (1607) among the four museum websites. This was the highest possibly because of its simple navigation in the environment through a map. The three dominant behaviours, "click on the exhibit images for further information" (32%), "read labels and texts" (28%) and "look at images" (28.3%), were the most frequent behaviours which were observed. The frequencies for these three behaviours were the highest among the four museum websites. They were higher because the participants seemed much more engaged in looking at the texts and images and because of the logical organisation of content connecting the individual exhibits. The two behaviours, "manipulate artefacts" (7.3%) and "watch videos" (3.4%), accounted for more than 10% of all the behaviours.

The **Helsinki City Museum** had the third highest total frequency of participants' behaviours (669). The three dominant behaviours were "click on the exhibit images for further information" (32.6%), "read labels and texts" (29.6%) and "look at images" (33.8%). "Listen to audios" had the lowest percentage (0.7%) behaviour. Although "listen to audios" is a learning-related behaviour, almost all participants did not find the audios because the audio icons were not self-explanatory as they were located at the bottom of the web page. "Look for help or instructions for navigation" (2.2%) was the highest percentage for this behaviour among the four museum websites. This was because of the complicated interaction metaphors using the green and yellow balls and the silhouette figures to present information. Such metaphors confused the participants and resulted in them looking for instructions for navigation in the 3D environment.

The **Philadelphia Museum of Art** had the lowest total frequency of the participants' behaviours (283). "Look at images" (52.7%) and "read labels and texts" (39.2%) were the most frequent behaviours. This museum had the highest percentage (7.8%) of "show frustration on navigation" much more than the other three museum websites. This was because the participants had difficulty using the cursor (the mouse) to navigate the 3D environment.

In conclusion, the three dominant behaviours (i.e. "read labels and texts", "look at images" and "click on the exhibit images for further information") suggest that a museum website needs to interpret its individual exhibits using multiple media formats (e.g. texts, photographs, graphics, images and so on) with relevant links in order to match visitors' behaviours and lead visitors to a deeper engagement with the exhibit content in a 3D environment.

5.6.2.1.1 Assessing the occurrence of the necessary behaviour for learning

The occurrence of the prerequisite behaviour for learning in the virtual museum environments of the four museum websites was assessed using two observational measures: attraction and holding power. Screven (1976), Boisvert and Slez (1995), and Yahya (1997) defined attraction as the number of those people who stopped at an exhibit for at least five seconds. In this observational study, attraction is calculated by the number of participants who stopped to look at the exhibit image or clicked on the exhibit image for viewing information for five seconds or more.

Holding power is defined by Boisvert and Slez (1995) and Yahya (1997) as the mean duration of exhibit visits. It is calculated by dividing the total time spent by those participants who stopped at the exhibit or clicked on the exhibit image for viewing information about it by the number of the participants who stopped at the exhibit as presented in Figure 5.3.

$$\text{Holding power} = \frac{T\#}{P\#}$$

T# = total time spent by those participants who stopped at the exhibit or clicked on the exhibit image for viewing information about it

P# = the number of the participants who stopped at the exhibit

Figure 5.3 Holding power

The learning-related behaviours involved with exhibits, activities or games in the four museum websites based on attraction and holding power are shown in Table 5.13 - Table 5.16.

The exhibits in the **London Science Museum** attracted various numbers of the participants' attention (between 1 to 22 participants). "Antenna" attracted 22 participants' attention which is ranked in the second place behind "old buildings" (which attracted 23 participants' attention) in the Helsinki City Museum. Although this exhibit did not attract the greatest number of the participants, it held the participants for a longer time (28.5 seconds) than "old buildings" (12.9 seconds).

Gallery	Name of exhibits	Attraction (no people) (stopped at exhibits < 5 seconds excluded)	Holding power (in seconds)
Antenna & Pattern Pod	IMAX and Virtual Voyages	8	17.4
	Pattern Wall (game)	15	59.2
	Growing Patterns (game)	16	35.3
	Pattern Pod	9	15.8
	Antenna	22	28.5
	Talking Points	11	20.4
	Deep Blue Cafe	7	10.0
Who am I	Who am I	12	26.7
	Radio Babel (game)	7	37.7
	Bleadon Man (artefact)	6	19.3
	Bleadon Man (game)	4	59.0
	Live Science	6	16.7
	Cryogenic Head Freezer (artefact)	9	28.2
	White Peacock (artefact)	10	34.7
	Personality (game)	5	46.0
	Tell us what you think	5	10.8
	Teletubbies Favourite Things	7	18.4
	Art Guild	2	5.0
	Highlights (x2) *	11	20.1
Digitopolis	Networking People (game) (x2) *	4	34.8
	Musical Jacket (artefact)	4	17.8
	Highlights (x2) *	1	8.7
	Wheatstone Printing Telegraph (x2) *	8	20.2
	Tell us what you think (x2) *	4	7.3
	Sound Editor (game) (x2) *	4	19.0
	Audio Tutu (artefact) (x2) *	5	32.8
	Art Guild	5	10.8
	Pixel Revolutions (game) (x2)*	5	12.0
	Frigate 2000 (artefact) (x2) *	3	14.7
In Future	In Future (x2) *	11	21.2
	Screensavers	7	17.0

Table 5.13 The attraction and holding power of each exhibit in the Science Museum (London)

* The two exhibit icons represent the same exhibit on display in the same gallery

The majority of the exhibits (87%) held the participants for more than 10 seconds and nearly half the exhibits (48%) held the participants for more than 20 seconds. Most exhibits illustrated their information using games which provided immediate responses and opportunity for interactions. Those interactions which engaged the participants who were held for long periods were “Pattern Wall” (59.2 seconds), “Bleadon Man” (59 seconds) and “Personality” (46 seconds). However, these high values for the holding power of the exhibits did not match the frequency of attraction. In other words, these exhibits did not attract the largest number of the participants. In the case of attraction for these three exhibits, “Pattern Wall” attracted the highest number of participants’ attention (15 people), followed by “Personality” (5 people) and “Bleadon Man” (4 people). “Pattern Wall” was the highest because it (Figure 5.4) used a big exhibit image which was much more attractive to the participants compared with “Personality” (Figure 5.5) and “Bleadon Man” (Figure 5.6) both of which employed small exhibit images on display in the environment. In addition, some participants pointed out that “Pattern Wall” was an interesting game and provided clear instructions for playing the game at the beginning. Such game instructions were useful to understand how to play.

Figure 5.4 Pattern Wall image

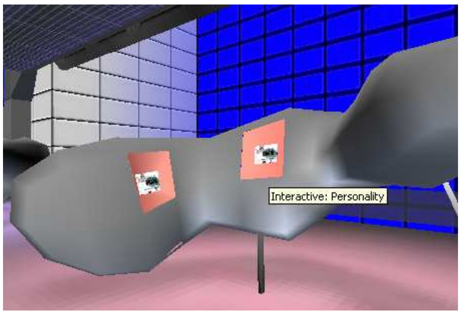


Figure 5.5 Personality image

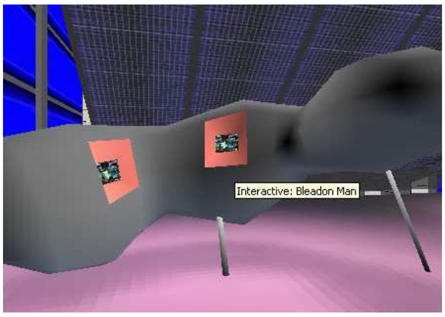


Figure 5.6 Bleadon Man image

As shown in Table 5.14, the majority of the exhibits in the **Canadian Museum of Civilization** attracted more than ten participants' attention (76%) and held the participants for more than 10 seconds (72%).

Name of exhibits	**Attraction** **(no people)** **(stopped at exhibits < 5 seconds excluded)**	**Holding power** **(in seconds)**
Palaeo-Eskimo (video)	13	52.3
Ivory Swans (artefact)	19	13.1
Floating or Flying Bear (artefact)	16	19.2
Tyara Maskette (artefact)	17	17.3
Challenger Mountains	10	9.5
Discovery Harbour	13	12.2
Archer Fiord	8	9.3
Inuit Art (video)	15	49.7
Hunter in Kayak (artefact)	16	12.9
Fish (artefact)	19	17.3
Fish Jigger (artefact)	15	12.5
Snow Goggles (artefact)	15	17.1
Caribou (artefact)	14	13.6
Ring & Pin Game (artefact)	13	14.6
The Travellers	13	14.1
Two Inuit	6	10.4
Caribou Skin Tent	5	5.1
Inuit History (video)	11	41.1
Dancing Bear (artefact)	19	13.7
Bear Hunt (artefact)	19	17.4

Woman with Child on Back (artefact)	21	13.4
Building the Winter Camp	11	7.4
Owl & Bears	15	8.0
Festive Bird	10	6.4
The Archer	6	6.0

Table 5.14 The attraction and holding power of each exhibit in the Canadian Museum of Civilization

In the case of holding power, three exhibits, “Palaeo-Eskimo”, “Inuit Art” and “Inuit History”, which used videos held the participants for the longest periods of time (41.1 seconds to 52.3 seconds) compared with the other exhibits. The exhibits (i.e. they are marked as “artefacts”) which used 3D models with rich information content such as “Ivory Swans”, “Fish”, “Woman with Child on Back” held the participants longer than the exhibits which provided only textual and photographic information without employing 3D models. This was due to the 3D model artefacts engaging the participants through increased interaction and greater spatial information.

The majority of the exhibits in the **Helsinki City Museum** attracted less than six participants’ attention (71%) and held the participants less than 10 seconds (71%) as shown in Table 5.15.

Name of exhibits	**Attraction (no people)** (stopped at exhibits < 5 seconds excluded)	**Holding power (in seconds)**
Govinius plot	8	6.4
Gate and shop	18	13.6
A house on the square*	1	16.5
Warehouse and wood stone*	2	6.5
Pig sty and privy*	2	6.0
Bakehouse and sauna*	5	12.4
Shed, stable, cowshed and granary*	4	5.3

A house on Suurkatu*	5	8.4
Well*	2	6.2
Profile*	5	4.6
Clay pipes*	5	8.9
Yard paving*	10	9.7
Old buildings	23	12.9
Cellar*	5	6.2

Table 5.15 The attraction and holding power of each exhibit in the Helsinki City Museum

* These exhibits were arranged inside the square behind the door but there was no indication that the door could be opened

Two exhibits, “gate and shop” (18 participants) and “old buildings” (23 participants), attracted a higher number of participants. Moreover, “old buildings” exhibit was found to attract the highest number of participants’ attention among the four museum websites. These figures were high because these two exhibits were situated in highly visible positions compared with the other exhibits (i.e. the latter were inside the square behind the door but there was no indication that the door could be opened).

Concerning the **Philadelphia Museum of Art** website, there may be exhibit images on display in the 3D environment when viewing them at the same time on the computer screen. Participants may look at each of exhibit images for a variety of periods of time. However, it is impossible to identify how long they spend precisely for individual exhibit images in the environment at the same time. Therefore, the total time of looking at the individual exhibit images is the same. In these cases, # and ## are used to indicate those participants who stopped to look at such exhibit images on the common screen at the same time in Table 5.16.

Name of exhibits	**Attraction (no people)** **(stopped at exhibits < 5 seconds excluded)**	**Holding power (in seconds)**
Constantin Brancusi (x2) *	4	3.4
Margit Pogany	3	2.6
Mademoiselle Pogany [I] (artefact)	13	11.7
Mlle. Pogany I (bronze)	3	4.0
Mlle. Pogany II (bronze)#	1	2.0
Mlle. Pogany II (veined marble)#	0	1.8
Mlle. Pogany III (bronze)##	4	4.5
Mlle. Pogany III (white marble)##	2	3.3
I1912 II1919 III 1931	1	5.0
Mademoiselle Pogany [III] (artefact)	2	8.3
Grave Markers	0	0.0
Peasant House	1	4.0
Brancusi’s Studio	1	8.0
Eternal Springtime	0	0.0
Head of Balzac	0	2.0
The Visitation	0	0.0
Fang Guarsian	0	0.0
Avalokiteshvara	0	1.0
Brancusi, The kiss	0	0.0
Brancusi, Maiastra	0	0.0
Bird in space	0	0.0
Brancusi, Newborn	0	1.0
Mlle. Pogany I (white marble)	1	5.0

Table 5.16 The attraction and holding power of each exhibit in the Philadelphia Museum of Art

* The two exhibit icons represent the same exhibit on display in the same exhibition

One participant stopped to look at these two exhibits (4 seconds), Mlle. Pogany II (bronze) and Mlle. Pogany II (veined marble), on the common screen

Four participants stopped to look at these two exhibits, Mlle. Pogany III (bronze) and Mlle. Pogany III (white marble), on the common screen (The total time spent by them to look at the exhibits was 13 seconds).

As presented in Table 5.16, nearly all the exhibits (22 out of all the 23 exhibits) attracted the lowest number of the participants' attention (less than 5 participants) and had the most exhibits (20 out of all the 23 exhibits) which held the participants for shortest time (less than 6 seconds) among the four museum websites. This was because there were no links to provide additional information about the individual exhibits which could attract the participants' attention and hold them, although textual panels are provided. This resulted in most participants spending very little time looking at the individual exhibit images.

Besides, as mentioned earlier, an alternative plug-in, which caused some participants difficulty in using the mouse to navigate the environment, was employed in this website. Thus this may have influenced navigation as they felt frustration in moving to see the exhibits, such as "Eternal Springtime", "The Visitation", "Fang Guarsian", etc., which were set out over a long distance in the exhibition.

"Mademoiselle Pogany [I]" using a 3D model artefact attracted the highest number of the participants' attention (13 participants) and held the participants for long periods (11.7 seconds) compared to the other exhibits which used photographic panels. This high number of the participants' attraction and long period duration was because this exhibit used a 3D model artefact to provide the participants with different views of the 3D model for interaction. It is suggested that the 3D model artefact engaged the participants through increased interaction and greater information.

The six most effective and successful exhibits

After measuring individual exhibits' attraction and holding powers, the top three exhibits for the highest level of attraction were “Old buildings”, “Antenna” and “Woman with Child on Back” and the top three exhibits for the highest level of holding powers were “Pattern Wall”, “Bleadon Man”, and “Palaeo-Eskimo” and are therefore the most effective among the four museum websites as shown in Table 5.17 and Figure 5.7.

Exhibits	**Name of museum**	**Attraction (no people)** (stopped at exhibits < 5 seconds excluded)	**Holding power** (in seconds)
Old buildings (multiple media formats)	Helsinki City Museum	23 (77%)	12.9
Antenna (multiple media formats)	London Science Museum	22 (73%)	28.5
Woman with Child on Back (3D model combined with rich information)	Canadian Museum of Civilization	21 (70%)	13.4
Pattern Wall (game)	London Science Museum	15 (50%)	59.2
Bleadon Man (game)	London Science Museum	4 (13%)	59
Palaeo-Eskimo (video)	Canadian Museum of Civilization	13 (43%)	52.3

Table 5.17 The successful exhibits in terms of either high level of attraction or high level of holding power

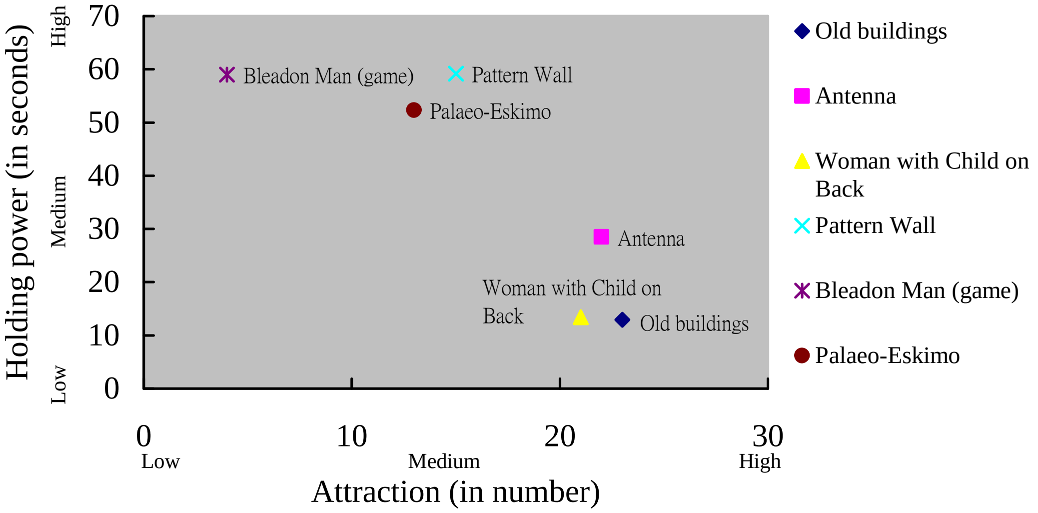


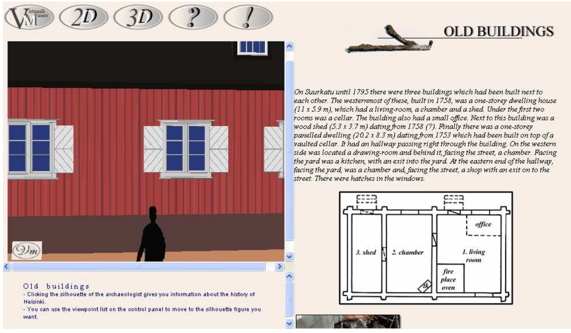
Figure 5.7 A scatter plot indicating the rating of the six exhibits through holding power and attraction

These results indicate that attraction levels were highest for the exhibits which employed multiple media formats or 3D models combined with rich information content while holding power was highest for the exhibits which used games or a video with high levels of interaction. On the whole, the high values for the holding power of the exhibits were matched by low levels of attraction and the high values for attraction of the exhibits coincided with relatively low values for the holding power. It is important to note that no exhibit combined high values for both.

These exhibits provide information using different media formats or games, including the following key features in terms of success and effectiveness:

- Old buildings: Helsinki City Museum (High level of attraction and Low level holding power)

  This exhibit (Figure 5.8) is dedicated to presenting detailed information on the construction of the old buildings through photographs and texts. Compared with the 3D model buildings in the museum environment, visitors can easily see contextual information about the destroyed old buildings. Besides, this exhibit was designed in a highly visible position within the environment. This exhibit was found to attract the highest number of visitors (77%) among the four museum websites.



On Suurkatu until 1795 there were three buildings which had been built next to each other. The westernmost of these, built in 1758, was a one-storey dwelling house (11 x 5.9 m), which had a living-room, a chamber and a shed. Under the first two rooms was a cellar. The building also had a small office. Next to this building was a wood shed (5.3 x 3.7 m) dating from 1758 (?). Finally there was a one-storey panelled dwelling (20.2 x 8.3 m) dating from 1753 which had been built on top of a vaulted cellar. It had an hallway passing right through the building. On the western side was located a drawing-room and behind it, facing the street, a chamber. Facing the yard was a kitchen, with an exit into the yard. At the eastern end of the hallway, facing the yard, was a chamber and, facing the street, a shop with an exit on to the street. There were hatches in the windows.

Old buildings

- Clicking the silhouette of the archaeologist gives you information about the history of Helsinki.
- You can use the viewpoint list on the control panel to move to the silhouette figure you want.

Figure 5.8 Old buildings

- Antenna: London Science Museum (High level of attraction and Medium level holding power)

This exhibit (Figure 5.9) presents science news connecting to different subjects by links to scientific knowledge through texts, images, photographs and graphics. Logical organisation of subject is easily followed from each thematic topic by the structured paths (Figure 5.10). This exhibit provides in-depth information and learning resources to encourage visitors to learn. This exhibit attracted the second highest number of participants (73%).

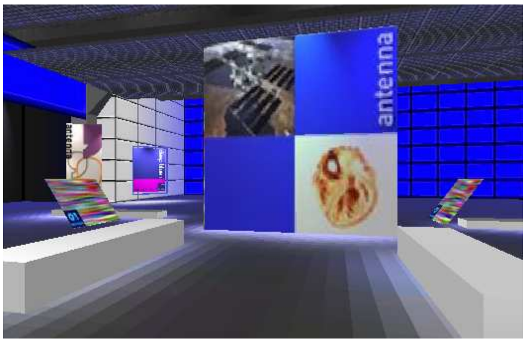
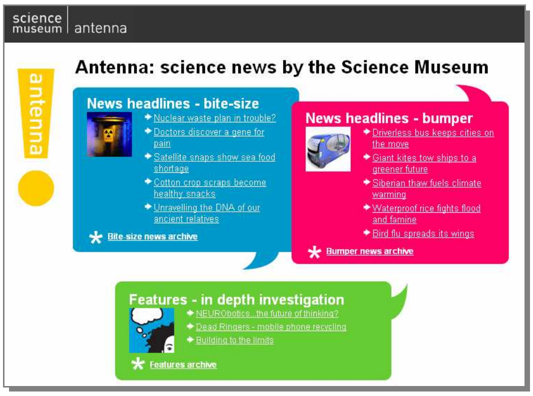


Figure 5.9 Antenna



Antenna: science news by the Science Museum

News headlines - bite-size
- Nuclear waste plan in trouble?
- Doctors discover a gene for pain
- Satellite snaps show sea food shortage
- Cotton crop scraps become healthy snacks
- Unravelling the DNA of our ancient relatives

* Bite-size news archive

News headlines - bumper
- Driverless bus keeps cities on the move
- Giant kites tow ships to a greener future
- Siberian thaw fuels climate warming
- Waterproof rice fights flood and famine
- Bird flu spreads its wings

* Bumper news archive

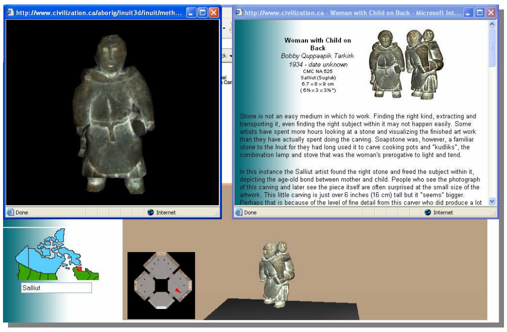
Features - in depth investigation
- NEURObotics...the future of thinking?
- Dead Ringers - mobile phone recycling
- Building to the limits

* Features archive

Figure 5.10 Antenna presenting thematic topics by relevant links

- Woman with Child on Back: Canadian Museum of Civilization (High level of attraction and Low level holding power)

This exhibit (Figure 5.11) provides a 3D model combined with in-depth interpretive content using a photograph and texts. The textural and spatial information is available for visitors to rotate for viewing various angles of the 3D model artefact. Such a 3D model engaged participants through increased interaction and greater spatial information. This exhibit attracted (70%) participants' attention.



Woman with Child on Back
Bobby Quppaapik Tarkirk
1934 - date unknown
CMC NA 525
Salliut (Sugluk)
6.7 × 8 × 9 cm
(6½ × 3 × 3½")

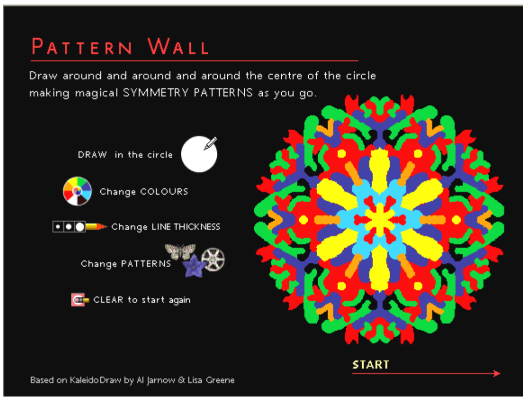
Stone is not an easy medium in which to work. Finding the right kind, extracting and transporting it, even finding the right subject within it may not happen easily. Some artists have spent more hours looking at a stone and visualizing the finished art work than they have actually spent doing the carving. Soapstone was, however, a familiar stone to the Inuit for they had long used it to carve cooking pots and "kudliks", the combination lamp and stove that was the woman's prerogative to light and tend.

In this instance the Salliut artist found the right stone and freed the subject within it, depicting the age-old bond between mother and child. People who see the photograph of this carving and later see the piece itself are often surprised at the small size of the artwork. This little carving is just over 6 inches (16 cm) tall but it "seems" bigger. Perhaps that is because of the level of fine detail from this carver who did produce a lot

Figure 5.11 Woman with Child on Back

- Pattern Wall: London Science Museum (Medium level of attraction and High level holding power)

The aim of this exhibit (Figure 5.12) is to interpret how symmetry patterns can be produced by the butterfly, flower and wheel with different turns and flips that mirror themselves as viewing the patterns in a kaleidoscope. The exhibit presents its information about patterns in an educational gaming environment, generating the different patterns with colours by drawing from individual visitors. Instructions for interacting with the game are provided, using both illustrations and texts at the beginning so that visitors can play game without difficulty. This exhibit used a game which held the participants for the longest periods of time (59.2 seconds) among the four museum websites.



Draw around and around and around the centre of the circle making magical SYMMETRY PATTERNS as you go.

Based on KaleidoDraw by Al Jarnow & Lisa Greene

Figure 5.12 Pattern Wall

- Bleadon Man (game): London Science Museum (Low level of attraction and High level holding power)

This exhibit (Figure 5.13) attempts to demonstrate the reconstruction of the face of Bleadon Man built by medical artist Caroline Wilkinson using new scientific techniques. This exhibit presents its content through an educational game which enables visitors to drag the pieces of skull and pick up the lumps of clay for the reconstruction. Due to the use of the small exhibit image on display in the 3D environment, this exhibit attracted only four participants. Although this exhibit did not attract a large number of participants, it held the participants for a long period (59 seconds). The exhibit arouses visitors' curiosity and offers visitors the opportunity for interaction.

Figure 5.13 Bleadon Man

- Palaeo-Eskimo: Canadian Museum of Civilization (Medium level of attraction and High level holding power)

  This exhibit (Figure 5.14) presents the history of Palaeo-Eskimo and additional information using a video. The exhibit was identified as holding the participants for a long period of time (52.3 seconds). This was long because the video gave participants an introduction to the history and associated information on exhibits. In addition, the video enabled the participants to manipulate the bar to look at the specific information based on their personal preference.

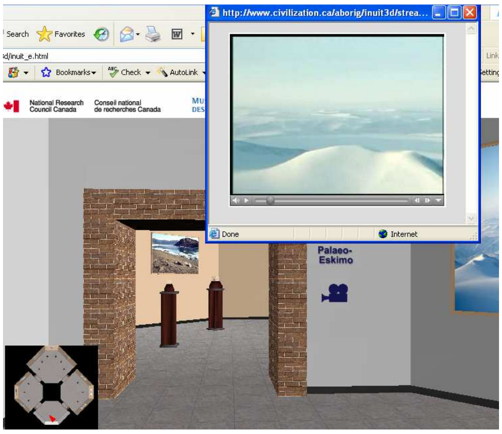


Figure 5.14 Palaeo-Eskimo

In summary, these exhibits contain one or more of the key features for successful and effective exhibits, namely, arousing curiosity, offering in-depth interpretive content and contextual information, employing logical organisation of content, using multiple media formats, providing opportunities for interaction and having visible positions.

5.6.2.1.2 Relationship between visiting styles and pedagogic approaches

Having observed 30 participants' behaviours, almost all participants had more than one visiting style when visiting the four museum environments, even if they spent less than ten minutes. The participants' visiting styles in each museum were classified into the four categories based on their visit pathways, movements, time spent in front of each exhibit and the number of stops (Veron and Levasseur 1983; Marti 2001; Chittaro and Ieronutti 2004). Due to lack of information on movement or time spent looking at the exhibits, a small number of participants' visiting styles was not classified into the four categories. The proportion of the participants' visiting styles in each museum is classified in Table 5.18 and is graphically illustrated in Figure 5.15.

Visiting style / **Name of museum**	**Ant**	**Fish**	**Grasshopper**	**Butterfly**	**Not classified**	**Total**
London Science Museum	3 (10%)	3 (10%)	10 (33%)	13 (43%)	1 (3%)	30
Canadian Museum of Civilization	13 (43%)	3 (10%)	4 (13%)	10 (33%)	0 (0%)	30
Helsinki City Museum	0 (0%)	15 (50%)	6 (20%)	7 (23%)	2 (7%)	30
Philadelphia Museum of Art	2 (7%)	19 (63%)	7 (23%)	1 (3%)	1 (3%)	30

Table 5.18 The frequencies of visiting styles which occurred in the 3D museum environments

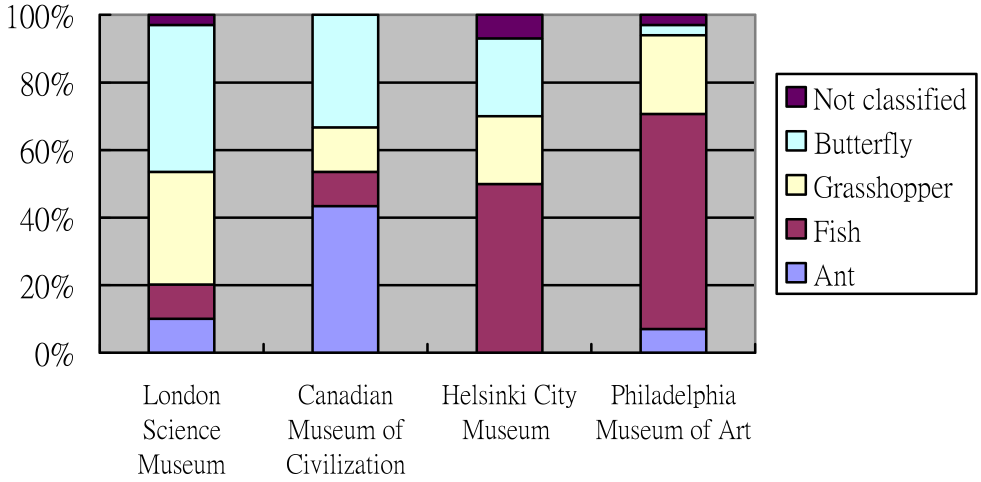


Figure 5.15 The percentage of the four visiting styles in the 3D museum environments

Significantly, it was found that almost all individual participants' visiting styles were not consistent and they had more than one visiting style in the four museum environments. Their visiting styles varied depending on the design of the 3D museum environments and the pedagogic approaches for organisation of content and layout of the exhibitions (i.e. exhibit displays and visitor's pathways).

The **London Science Museum** using the constructivism approach had a high proportion of the grasshopper visiting style (33%) and the highest proportion of the butterfly visiting style (43%). These styles were so high because the museum displays its exhibits without any preferred path suited to the characteristics of the two visiting styles. For example, the grasshopper visitors look only at exhibits they are interested in and do not follow any proposed path; the butterfly visitors frequently change the direction of visit without following any specified path in the environment. In addition, such an approach provided an opportunity for the grasshopper visitors to select what thematic exhibits they wanted to learn.

The museum had low proportions of ant (10%) and fish (10%) visiting styles. The ant figure was low because of the lack of a specified path in the museum environment which did not match ant visitor behaviours which need to be clearly guided. With regard to the low percentage of the occurrence of the fish visiting style, as the exhibits could hold most participants' for long periods of time, this did not suit the nature of the fish visiting style (i.e. the fish visitors have a rapid look at the exhibits for a short time).

The **Canadian Museum of Civilization** using the traditional lecture and text approach had the highest percentage of participants with an ant visiting style (43%) and a high percentage with a butterfly visiting style (33%). The ant behaviour was the highest because the exhibits were arranged in displays next to walls along the visitor's pathway. This matched the key characteristic of the ant visiting style as they moved close to walls and methodically viewed each exhibit. Moreover, the 3D virtual exhibition rooms were organised in a sequential order from beginning to end using an overview of the historical period which connected the exhibited artefacts and by providing relevant links to associated information. This encouraged the ant like visitors to systematically look at the exhibits from beginning to end during the learning process. However, ten participants (33%) tended to frequently change their orientation of visit to a butterfly visiting style, ignoring the implicit visitor's pathway in the museum environment.

The fish (10%) and grasshopper visiting styles (13%) were low in this museum. This is probably because most exhibits could equally attract the participants' attention and this did not match the characteristics of the two visiting styles (i.e. the fish and grasshopper visitors both rarely stop to look at the exhibits).

The **Helsinki City Museum** using the discovery learning approach had the highest proportion of fish visiting style behaviour (50%) with lower proportions for the grasshopper (20%) and butterfly visiting style behaviour (23%). This was because the organisation and structure of the thematic content were not easy to follow in this environment. This resulted in half the participants taking one quick look around and viewing information about the exhibits for only a very short time, thus exhibiting the features of the fish visiting style.

The **Philadelphia Museum of Art** using the behaviourist learning approach had the highest proportion of fish visiting style behaviour (63%). This was the highest because all the exhibit images could not be clicked on for further information about them in the 3D environment. Thus the participants looked only briefly at exhibits without stopping frequently.

The proportion of grasshopper visiting style behaviour (23%) was higher than the other visiting styles such as the ant (7%) and butterfly (3%). The grasshopper visitors spent a long time looking at one of the two 3D model sculptures which provided an opportunity for them to look at different views of the 3D sculpture. These visitors spent more time looking at the 3D model than the other exhibits using photographs. However, although the exhibits were arranged in a logical sequence and provided an intended order with a clear beginning to end, only two ant visitors (7%) stopped to look at the exhibit images following the path. This was due to the minimal text information and small size of exhibit images, and limited visual information.

In summary, the results revealed that the patterns of visitor behaviour were indicators of the degree of visitors' interaction with the learning content of exhibits within the 3D museum environments. The occurrence of ant and butterfly visitors' behaviours indicated that the museums held a greater potential for learning because the visitors interacted with a majority of exhibits. In contrast, the occurrence of fish visitors' behaviours revealed that the museums provided less potential for learning because visitors rapidly visited exhibits without stopping frequently.

The findings also showed that there is a relationship between the visitor styles and the design of the 3D environments. They indicate that there are more suitable ways of presenting exhibits by following pedagogic approaches which can support engagement. The organisation of exhibits based on the constructivism approach without any specific exhibition route seem to be more suitable for grasshopper and butterfly visitors to create their own individual and exploratory routes to learning a subject such as in the London Science Museum. The arrangement of exhibits based on the traditional lecture and text approach with the proposed visitor's pathway is more appropriate for ant visitors to move systematically from exhibit to exhibit for incremental learning from beginning to end, for example, in the Canadian Museum of Civilization.

5.6.2.1.3 Demographic analysis on the visiting styles of the different visitor groups

Having identified the relationship between visiting styles and pedagogic approaches, the analysis of demography also revealed the visiting styles of different visitor groups in terms of their personal interests and expectations in each museum website. Ten participants in each group were analysed to indicate differences in individual interests and expectations. The percentage of the participants' visiting styles in each museum is classified according to the three groups of visitors as shown in Table 5.19

and Figures 5.16-5.18.

Visitor group	**Name of museum**	**Visitor style**				
		Ant	**Fish**	**Grasshopper**	**Butterfly**	**Not classified**
General public	London Science Museum	0(0%)	1(10%)	5(50%)	4(40%)	0(0%)
	Canadian Museum of Civilization	4(40%)	1(10%)	1(10%)	4(40%)	0(0%)
	Helsinki City Museum	0(0%)	4(40%)	3(30%)	3(30%)	0(0%)
	Philadelphia Museum of Art	1(10%)	6(60%)	3(30%)	0(0%)	0(0%)
	Total (no people)	5	12	12	11	0
Researchers and professionals	London Science Museum	1(10%)	0(0%)	1(10%)	7(70%)	1(10%)
	Canadian Museum of Civilization	4(40%)	1(10%)	2(20%)	3(30%)	0(10%)
	Helsinki City Museum	0(0%)	6(60%)	0(0%)	3(30%)	1(10%)
	Philadelphia Museum of Art	0(0%)	9(90%)	0(0%)	1(10%)	0(10%)
	Total (no people)	5	16	3	14	2
Schools	London Science Museum	2(20%)	2(20%)	4(40%)	2(20%)	0(0%)
	Canadian Museum of Civilization	5(50%)	1(10%)	1(10%)	3(30%)	0(0%)
	Helsinki City Museum	0(0%)	5(50%)	3(30%)	1(10%)	1(10%)
	Philadelphia Museum of Art	1(10%)	4(40%)	4(40%)	0(0%)	1(10%)
	Total (no people)	8	12	12	6	2

Table 5.19 The percentages of the participants’ visiting styles from each group in the four museum websites

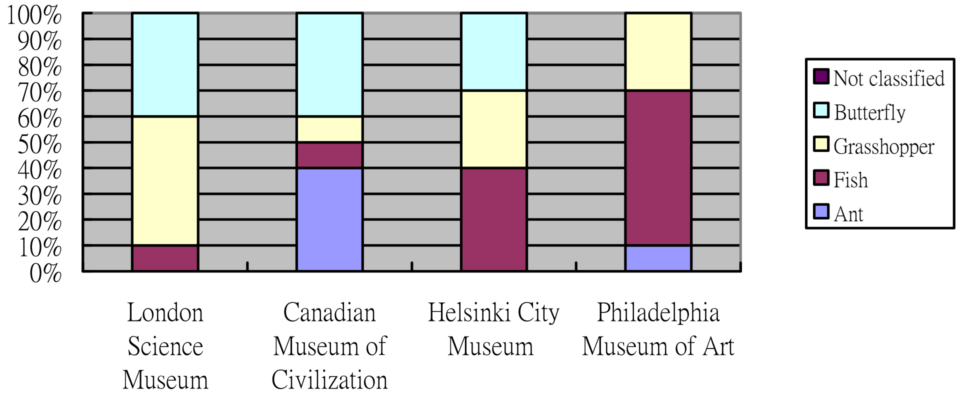


Figure 5.16 The percentage of general public's visiting styles in the 3D environments

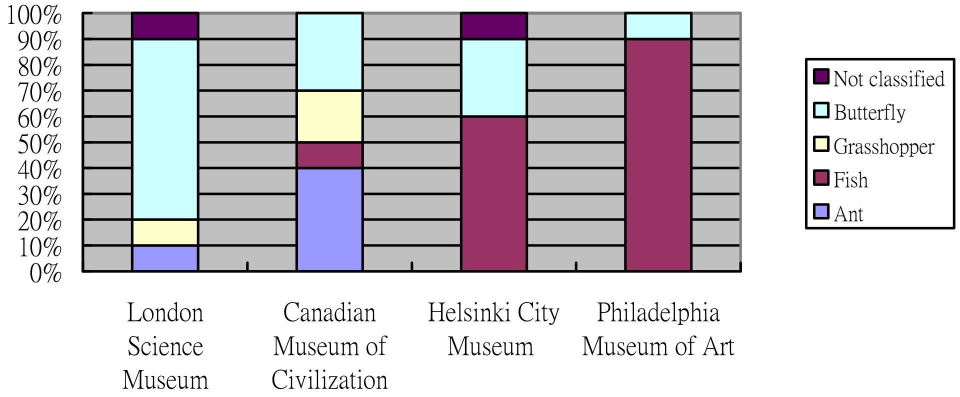


Figure 5.17 The percentage of researchers and professionals' visiting styles in the 3D environments

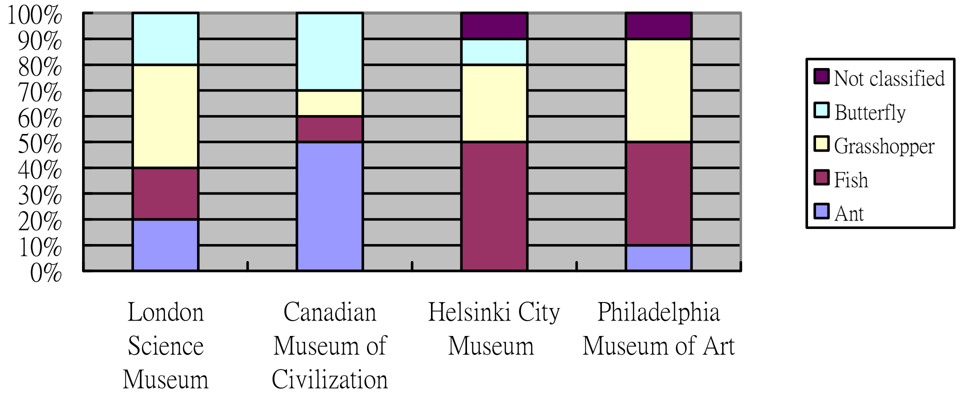


Figure 5.18 The percentage of schools' visiting styles in the 3D environments

The overall visitor styles for the three visitor groups in the four museum environments are shown in Table 5.19. The general public had the highest number of fish and grasshopper visiting styles (12 participants each), closely followed by butterfly visiting style (11 participants). Researcher and professional participants had the highest number of fish visiting style (16 participants). It is noteworthy that this group had a high number of butterfly visiting style (14 participants). This is because this group was interested in detailed and in-depth information about individual exhibits, showing butterfly visiting style. However, without rich information content about exhibits, it rapidly visited exhibits with few stops, exhibiting fish visiting style. The participants of the schools had the highest number of grasshopper visiting style (12 participants), the same as the general public. This is because these two groups tended to view specific exhibits and associated information they were interested in. This result indicated that the different visitor groups' visiting styles were influenced by their motivations (i.e. individual interests and preferences, and expectations), supporting Falk and Dierking (1998) findings that personal interest is one of the major factors which affect a virtual visit to a museum website.

As shown in Table 5.19, the **London Science Museum** had the highest number of participants from the general public (five participants) and schools (four participants) with a grasshopper visiting style. The participants of these two groups tended to view specific artefacts and associated information for a long time as they were interested in these particular aspects. It is noteworthy that this museum had the highest number of researcher and professional participants (seven out of all the ten participants) with a butterfly style. This group is more knowledgeable about specific aspects of collections of artefacts than the other two visitor groups. The key tenet of the constructivism approach used in the London Science Museum seems to have provided an opportunity to encourage this group to construct the meanings of the exhibits through their pre-existing knowledge. This might be the reason for the highest percentage of researcher and professional participants with a butterfly style in the museum among the three groups.

The **Canadian Museum of Civilization** had similar percentages for the four visiting styles for each of the three groups. The ant visiting style was the most common among researchers and professionals (four participants) and schools (five participants), and equal top for the general public group (four participants). These findings show that the participants from each group tended to see information about the exhibits and follow the visitor’s pathway even if they had different interests and expectations.

For the **Helsinki City Museum,** the fish visiting style was the most popular for all the three groups, the general public (four participants), researchers and professionals (six participants) and schools (five participants). Due to the confusing environment with inconsistent information architecture, the participants could not find the information they wanted. There was no occurrence of the researcher and professional participants’ grasshopper visiting style in the museum compared with the other two visitor groups. The reason might be that the content of exhibits did not provide sufficient information to hold their attention for long periods of time.

The **Philadelphia Museum of Art** had the highest number of researcher and professional participants (nine out of all the ten participants) with the fish visiting behaviour among the three groups. Some participants reported that they wished to see more detailed and in-depth information about the exhibits. Due to the minimal text information and limited visual information, the museum certainly disappointed this group’s personal interests and expectations.

The overall conclusion is that the participant group’s visiting styles were not only affected by their personal interests and expectations but also by the design of the 3D environments. Moreover, the results relating to the visiting behaviour of different groups i.e. that all three groups tended to behave in a similar way in each museum, would indicate that the design of the 3D environment was a more important factor than the groups themselves in terms of visitor behaviours. The results showed that the Canadian Museum of Civilization employing the traditional lecture and text approach was appropriate for all the three visitor groups. The London Science Museum using the constructivism approach to organise the structure of exhibit content was most effective in encouraging the researcher and professional group to construct meanings from the exhibits through using prior knowledge of museum collections. The results also suggest that when a museum website chooses a pedagogic approach it needs to be concerned about creating an effective 3D environment that enables it to match particular visitor styles for specific visitor groups for learning efficacy.

5.6.2.2 Performance of a range of tasks

In the next stage of the observations, the thirty participants were asked to perform a series of the tasks in each museum website after freely exploring them. The three measures, percentage of success, average time and range of completion times, are employed in order to judge and compare each task in museum websites.

The percentage of success is used to explain the total number of those participants who completed the assigned tasks by dividing by all thirty participants. In order to establish task timings, Rubin (1994) has proposed that the range of completion times for each task is useful to identify a large or small difference between the shortest and longest time. Besides, the range of completion times can be used to compare the average time as an indication of how the participants performed as a whole.

The performance results of tasks throughout the evaluation in terms of the percentage of success, average time spent and range of completion times are shown in Table 5.20 – Table 5.23.

The **London Science Museum** had a high percentage of the participants performing the four tasks successfully, as all the tasks had a completion rate of over 70%; for example, 76.7% for task 2 and 73.3% for task 4 and as high as 80.0% for task 1 and 86.7% for task 3 in Table 5.20.

Task descriptions	**Percentage of success**	**Average time (in seconds)**	**Range of completion times (in seconds)**
1. Look at the exhibit, **Pattern Wall,** on display in "***Pattern Pod"*** in the ground floor, and additional information about it.	80.0%	104.5	13–281
2. Find the educational game: **Networking People** from the gallery, "***Digitopolis"***.	76.7%	107.3	7–308
3. Find the exhibit: **Wheatstone printing telegraph** and additional information from the gallery, "***Digitopolis",*** on second floor.	86.7%	61.3	6–187
4. View the picture, **Live science,** on display in the gallery, ***"Who am I?"*** and associated information about it.	73.3%	119.5	35–253

Table 5.20 The performance results of tasks from the Science Museum (London)

In this museum website, each of virtual exhibits on display in the different galleries used interaction metaphors represented by an icon with additional indication of the exhibit name when the cursor was moved over individual exhibit images. Therefore, most of participants easily and quickly recognised each exhibit for completing the tasks.

However, based on the notes of the test monitor, nine participants out of the thirty did not know there were four galleries on the different floors within the 3D environment until they were asked to perform the four tasks. This was because the information panels provided both information about the galleries and links to each gallery. Such an information architecture scheme certainly confused the participants while performing task 2, 3 and 4, although the percentage of success of the three tasks was fairly high.

The average time for the four tasks was lower than the times for task completion on the Canadian Museum of Civilization and Helsinki City Museum website. This delay was because most participants needed to spend extra time to travel between the three floors for completion of the assigned tasks. The participants could finish task 2 and task 3 which were all on the same floor more quickly than the rest of the tasks on this website. As a result, the range of completion times for task 3 had the smallest difference between the shortest and longest time (6–187 seconds) among the four museum websites.

The **Canadian Museum of Civilization** had the highest percentage of participants successfully performing the three tasks as presented in Table 5.21. All the assigned tasks had a completion rate of over 89 % such as task 5 (100%), 6 (93.3%) and even task 7 (90.0%).

Task descriptions	**Percentage of success**	**Average time (in seconds)**	**Range of completion times (in seconds)**
5. Find the 3D exhibit, **Dancing Bear,** and additional information.	100.0%	54.0	7–268
6. Look at the picture, **Two Inuit**, and then find more information on it.	93.3%	47.1	7–192
7. Find the **Inuit history** video clip for information on the history of the Inuit.	90.0%	53.9	4–253

Table 5.21 The performance results of tasks from the Canadian Museum of Civilization

These were the highest because the simple layout of the exhibitions with the provision of map made it easy for them to finish the tasks. Despite the highest completion rate, there was a usability problem with the informational architecture using the interaction metaphor. Some participants mentioned that each virtual exhibit should have been represented as an icon with indication of the exhibit name when the cursor was moved over individual exhibit images. This resulted in some participants spending extra time clicking on the exhibit images.

The average completion times for these tasks, task 5 (54.0 seconds), 6 (47.1 seconds) and 7 (53.9 seconds) (except task 8, 50.0 seconds, on the Helsinki City Museum website) were lower than the other three museum websites, especially task 6, which was the shortest average time among all the four museum websites. Besides, the range of completion times for the three tasks was the smallest, such as task 5 (7–268 seconds), task 6 (7–192 seconds) and task 7 (4–253 seconds). This result indicates that this museum environment was the best to find information among the four museum websites because of the simple layout of the exhibition and provision of a map.

As shown in Table 5.22, the **Helsinki City Museum** had a fairly high completion rate for task 8 (83.3%) but a low percentage completion rate (56.7%) for task 9.

Task descriptions	**Percentage of success**	**Average time (in seconds)**	**Range of completion times (in seconds)**
8. Find **Gate and shop** and associated information.	83.3%	50.0	4–321
9. Look at the photographs and textual information about **Yard paving**.	56.7%	81.1	6–313

Table 5.22 The performance results of tasks from the Helsinki City Museum

In spite of having a high success rate for task 8, there was a problem in presenting information about the exhibit using audio for additional information. Most participants did not find the additional audio information, even if they correctly completed the task. They pointed out that the icon was not clear.

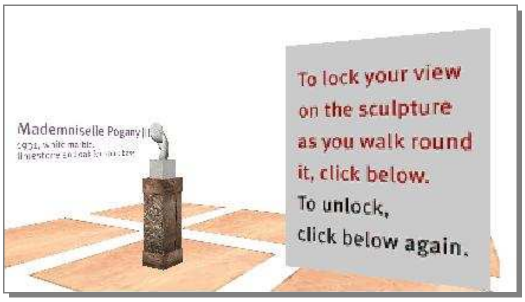
Only 56.7% of the participants succeeded in performing task 9. This was low because “Yard paving” was arranged inside the square behind the door but there was no indication that the door could be opened. Such an approach confused thirteen out of all the thirty participants and led to failure of the task. Consequently, the average time for this task, 81.1 seconds, was longer than task 8, at 50.0 seconds. This was due to some participants spending more time looking for the way to the square for completion of task 9.

The **Philadelphia Museum of Art** had a reasonably high percentage of participants finishing task 10 (63.3%) correctly, but the lowest percentage of participants performing task 11 (46.7%) successfully as shown in Table 5.23.

Task descriptions	**Percentage of success**	**Average time (in seconds)**	**Range of completion times (in seconds)**
10. Look at the 3D sculpture, **Mademoiselle Pogany I**, and then lock your view on the 3D sculpture.	63.3%	156.5	51–310
11. Find the picture of **Mademoiselle Pogany I** (bronze), **II** (bronze) and **III** (bronze).	46.7%	146.0	45–279

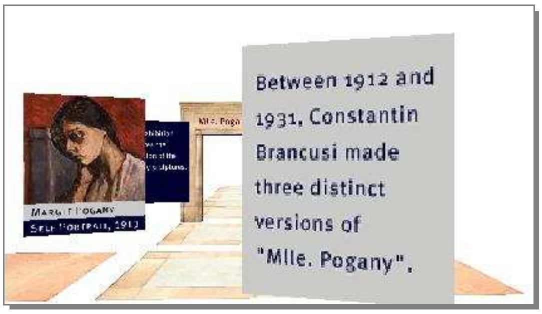
Table 5.23 The performance results of tasks from the Philadelphia Museum of Art

In task 10, there was a problem with the instructions for interaction with the 3D model sculpture when asking the participants to lock their view on the 3D sculpture. Some participants did not know how to lock their view of the sculpture. This was because of the use of the inconsistent information architecture to present both the instructions (Figure 5.19) and illustrations of the exhibits (Figure 5.20) using textual information panels. Such practice certainly upset the participants and led to failure with the task.



To lock your view on the sculpture as you walk round it, click below.
To unlock, click below again.

Figure 5.19 The instruction employing a textual information panel



Between 1912 and 1931, Constantin Brancusi made three distinct versions of "Mlle. Pogany".

Figure 5.20 The illustration of the exhibit using a textual information panel

Task 11 had the lowest success rate among the four museum websites. This is because the three exhibits, Mademoiselle Pogany I (bronze), II (bronze) and III (bronze), were separately arranged to display in the area of “From I to III” in the environment. Such an arrangement caused participants difficulty in looking for each exhibit and led to failure of the task.

In addition, as mentioned earlier, an alternative 3D plug-in was used in this website which some participants complained caused difficulty in using the mouse to navigate the environment. Thus they spent a long time to finish the tasks compared with the other tasks in the other three museum websites. This resulted in the average time (task 10, 156.5 seconds, and task 11, 146.0 seconds) and the range of completion times of the two tasks (task 10, 51–310 seconds, and task 11, 45–279 seconds) being more time than the tasks for the other three museum websites.

In spite of inconsistent information architecture and difficulty in using the mouse to navigate the environment, the test monitor reported that some participants reported provision of the map gave a clear indication of their orientation to complete the two tasks within the 3D environment.

An overall comparison of the four museum websites is presented in Table 5.24. The Canadian Museum of Civilization had the highest percentage of success (94.4%), the lowest average time (51.7 seconds) and the smallest difference between the shortest and longest time in the range of completion times (6-238 seconds). These results show that almost all participants finished the tasks within the 3D environment in a timely manner among the four museum website.

Website comparison	Overall average		
	Percentage of success	**Average time (in seconds)**	**Range of completion times (in seconds)**
London Science Museum	79.2%	98.2	15-257
Canadian Museum of Civilization	94.4%	51.7	6-238
Helsinki City Museum	70.0%	65.6	5-317
Philadelphia Museum of Art	55.0%	151.3	48-295

Table 5.24 A comparison of performance task results

5.6.3 Post-observation questionnaire

After performing the tasks on each museum website, the participants were required to fill in the post-observation questionnaire for the four museum websites. Each question was constructed using a five-point Likert Scale: "strongly agree" (5 points), "agree" (4 points), "neither" (3 points), "disagree" (2 points), and "strongly disagree" (1 point). The average point score per question was calculated from a frequency distribution of responses. None of the 30 participants to the four museum environments visited all exhibit components. Those participants who did not look at some exhibit components responded "Not Applicable" to the questions. Table 5.25-5.27 presents the results of the post-observation questionnaire according to the participants' subjective evaluation of the four museum websites.

The aspects for the use of 3D technology in improving access:

Legend: 5=Strongly Agree 4=Agree 3=Neither 2=Disagree 1=Strongly Disagree

N/A and N/R=Not Applicable and Not Responded

Question	**Museum website**	**Likert Scale**					**N/A and N/R**	**Average scores**
		5	**4**	**3**	**2**	**1**		
1. The quality of the 3D model artefacts was satisfactory.	Science Museum (London)	3%	40%	40%	17%	0%	0%	3.3
	Canadian Museum of Civilization	30%	57%	10%	3%	0%	0%	4.1
	Helsinki City Museum	3%	27%	17%	33%	20%	0%	2.6
	Philadelphia Museum of Art	0%	33%	30%	17%	20%	0%	2.8

2. The quality of the 3D museum environment was satisfactory.	Science Museum (London)	3%	40%	33%	23%	0%	0%	3.2
	Canadian Museum of Civilization	27%	60%	10%	3%	0%	0%	4.1
	Helsinki City Museum	0%	13%	33%	27%	27%	0%	2.3
	Philadelphia Museum of Art	0%	23%	27%	20%	30%	0%	2.4
3. The 3D model artefacts gave you a sense of presence with a feeling of seeing the physical artefacts themselves.	Science Museum (London)	7%	30%	20%	40%	3%	0%	3.0
	Canadian Museum of Civilization	17%	47%	27%	10%	0%	0%	3.7
	Helsinki City Museum	0%	17%	33%	20%	30%	0%	2.4
	Philadelphia Museum of Art	0%	27%	23%	27%	23%	0%	2.5
4. The 3D museum environment gave you a sense of presence with a feeling of being truly in the actual museum.	Science Museum (London)	7%	27%	27%	33%	7%	0%	2.9
	Canadian Museum of Civilization	10%	43%	30%	17%	0%	0%	3.5
	Helsinki City Museum	0%	20%	17%	30%	33%	0%	2.2
	Philadelphia Museum of Art	3%	20%	23%	37%	17%	0%	2.6
5. It was easy to manipulate the 3D model artefacts (e.g. zoom in, out, move and rotate).	Science Museum (London)	17%	27%	20%	33%	3%	0%	3.2
	Canadian Museum of Civilization	23%	60%	17%	0%	0%	0%	4.1
	Helsinki City Museum*	Not provided						
	Philadelphia Museum of Art*	Not provided						
6. Instructions given for manipulation were easy to understand.	Science Museum (London)	7%	43%	23%	27%	0%	0%	3.3
	Canadian Museum of Civilization	23%	57%	13%	7%	0%	0%	4.0
	Helsinki City Museum*	Not provided						
	Philadelphia Museum of Art*	Not provided						
7. It was easy to navigate the 3D museum environment.	Science Museum (London)	10%	27%	33%	20%	10%	0%	3.1
	Canadian Museum of Civilization	37%	47%	13%	3%	0%	0%	4.2
	Helsinki City Museum	0%	3%	20%	43%	33%	0%	1.9
	Philadelphia Museum of Art	0%	0%	10%	27%	63%	0%	1.5
8. The map provided helped you to acquire spatial knowledge of the 3D museum environment.	Science Museum (London) *	Not provided						
	Canadian Museum of Civilization	47%	37%	10%	0%	0%	7%	4.4
	Helsinki City Museum*	Not provided						
	Philadelphia Museum of Art	13%	33%	13%	17%	17%	7%	3.1
9. The videos provided you with additional information on exhibits.	Science Museum (London) *	Not provided						
	Canadian Museum of Civilization	30%	70%	0%	0%	0%	0%	4.3
	Helsinki City Museum*	Not provided						
	Philadelphia Museum of Art*	Not provided						
10. The audios provided you with additional information on exhibits.	Science Museum (London) *	Not provided						
	Canadian Museum of Civilization*	Not provided						
	Helsinki City Museum	0%	13%	3%	23%	0%	60%	2.8
	Philadelphia Museum of Art*	Not provided						

11. The images provided you with additional information on exhibits.	Science Museum (London)	13%	60%	20%	7%	0%	0%	3.8
	Canadian Museum of Civilization	27%	60%	13%	0%	0%	0%	4.1
	Helsinki City Museum	7%	30%	33%	20%	3%	7%	3.2
	Philadelphia Museum of Art	3%	30%	37%	13%	7%	10%	3.1
12. The animations provided you with additional information on exhibits.	Science Museum (London)	13%	27%	13%	17%	0%	30%	3.5
	Canadian Museum of Civilization*	Not provided						
	Helsinki City Museum*	Not provided						
	Philadelphia Museum of Art*	Not provided						

Table 5.25 The results on the use of 3D technology in improving access

* The museum did not provide the function or media format

In terms of the use of 3D technology in the museum environments, for each question, the **Canadian Museum of Civilization** had the highest average score from the participants for all the aspects of use of 3D technology, such as the quality of the 3D model artefacts and environment, manipulation of the 3D model artefacts, instructions, navigation, a map, multiple media formats and so on as the most effective among the four museum websites, followed by the London Science Museum, Philadelphia Museum of Art and Helsinki City Museum.

The **London Science Museum** had only a low percentage of the participants (37%) who felt (i.e. strongly agreed or agreed) that the 3D model artefacts gave them a sense of presence with a feeling of seeing the actual artefacts themselves. Additionally, 34% of the participants regarded the 3D museum environment as having a sense of presence as if they felt they were really in the actual museum. Concerning the use of the media formats in the museum websites, a higher percentage of the participants (73%) considered the images to be more effective than the animation (40%) in providing additional information on exhibits.

The **Helsinki City Museum** had a fairly low percentage of the participants (3%) who considered (i.e. strongly agreed or agreed) navigation in the 3D environment was easy. Although this museum offered the additional information on the exhibits using audios**,** 60% of the participants commented that the audios were inapplicable because they did not find the buttons of audios located at the bottom of the web page.

The **Philadelphia Museum of Art** had the highest percentage of participants (90%) who stated that it was difficult to navigate the 3D environment compared with the other three museum websites. In spite of difficult navigation, nearly half of the participants who responded said that the map provided was useful to acquire spatial knowledge of the 3D museum environment.

Informational aspects:

Legend: 5=Strongly Agree 4=Agree 3=Neither 2=Disagree 1=Strongly Disagree

N/A and N/R=Not Applicable and Not Responded

Question	Museum website	Likert Scale					N/A and N/R	Average scores
		5	4	3	2	1		
13. It was easy to find information.	Science Museum (London)	10%	43%	20%	27%	0%	0%	3.4
	Canadian Museum of Civilization	33%	53%	7%	3%	3%	0%	4.1
	Helsinki City Museum	0%	10%	20%	37%	33%	0%	2.1
	Philadelphia Museum of Art	3%	3%	10%	40%	43%	0%	1.8
14. It was easy to understand the information.	Science Museum (London)	3%	43%	43%	10%	0%	0%	3.4
	Canadian Museum of Civilization	37%	50%	13%	0%	0%	0%	4.2
	Helsinki City Museum	0%	23%	43%	20%	13%	0%	2.8
	Philadelphia Museum of Art	3%	27%	27%	30%	10%	3%	2.8
15. The amount of information on exhibits was adequate.	Science Museum (London)	7%	40%	33%	17%	3%	0%	3.3
	Canadian Museum of Civilization	23%	50%	20%	7%	0%	0%	3.9
	Helsinki City Museum	0%	30%	33%	27%	10%	0%	2.8
	Philadelphia Museum of Art	3%	13%	30%	33%	17%	3%	2.5
16. The 3D model artefacts provided you with more	Science Museum (London)	13%	30%	27%	27%	3%	0%	3.2
	Canadian Museum of Civilization	37%	33%	17%	13%	0%	0%	3.9

	information than texts, images, etc.	Helsinki City Museum	0%	13%	37%	23%	20%	7%	2.5
		Philadelphia Museum of Art	0%	17%	37%	30%	13%	3%	2.6
17.	The 3D model artefacts provided you with sufficient information.	Science Museum (London)	3%	43%	33%	20%	0%	0%	3.3
		Canadian Museum of Civilization	20%	60%	13%	7%	0%	0%	4.0
		Helsinki City Museum	0%	13%	40%	23%	20%	3%	2.5
		Philadelphia Museum of Art	0%	17%	33%	33%	13%	3%	2.6

Table 5.26 The results on informational aspects

According to Table 5.26, the **Canadian Museum of Civilization** had an average score of over 3.8 for all questions. Most participants responded “strongly agree” and “agree” to these questions about the informational aspects in this museum. For example, more than 85% of the participants considered information on the 3D environment to be easy to find and understand. 73% of them stated that the amount of information on exhibits was adequate. The majority of the participants thought the 3D model artefacts provided more information than texts, images, etc., and offered sufficient information.

The **London Science Museum** had average scores ranging between 3.2 and 3.4 points. 53% of the participants thought that the information was easy to find. Nearly half of the participants responded that the amount of information on exhibits was adequate and the 3D model artefacts offered sufficient information.

In general, the **Helsinki City Museum** had lower percentages of participants who considered the information on the website easy to understand, the 3D model artefacts offered more information than texts and images and provided sufficient information more than the Philadelphia Museum of Art as shown in questions 14, 16 and 17 respectively. However, it is noteworthy that a higher percentage of the participants

(30%) agreed with the amount of information on exhibits to be adequate more than in the Philadelphia Museum of Art. This was because the Helsinki City Museum offers additional information on the exhibits using texts, images and audios through hypertext links, compared with the Philadelphia Museum of Art that provides minimal text and visual information.

The **Philadelphia Museum of Art** had the lowest percentages of participants who considered the information to be easy to find (6%) and the amount of information on exhibits to be adequate (16%) compared with the other three museum websites. On the other hand, this museum had the highest percentages of participants who responded “disagree” and “strongly disagree” to all the questions in this section, except question 16. The reasons are given in Section 5.6.2.2.

Learning aspects:

Legend: 5=Strongly Agree 4=Agree 3=Neither 2=Disagree 1=Strongly Disagree

N/A and N/R=Not Applicable and Not Responded

Question	**Museum website**	**Likert Scale**					**N/A and N/R**	**Average scores**
		5	**4**	**3**	**2**	**1**		
18. Content of exhibits was easy to understand.	Science Museum (London)	3%	60%	30%	7%	0%	0%	3.6
	Canadian Museum of Civilization	33%	50%	13%	3%	0%	0%	4.1
	Helsinki City Museum	0%	33%	23%	27%	17%	0%	2.7
	Philadelphia Museum of Art	10%	20%	30%	27%	13%	0%	2.9
19. The organisation and structure of content were easy to follow.	Science Museum (London)	3%	43%	30%	20%	3%	0%	3.2
	Canadian Museum of Civilization	23%	60%	17%	0%	0%	0%	4.1
	Helsinki City Museum	0%	13%	20%	30%	37%	0%	2.1
	Philadelphia Museum of Art	0%	23%	27%	33%	17%	0%	2.6
20. It was useful to click on the exhibit images for learning activities or games.	Science Museum (London)	20%	47%	17%	17%	0%	0%	3.7
	Canadian Museum of Civilization*	Not provided						
	Helsinki City Museum*	Not provided						
	Philadelphia Museum of Art*	Not provided						
21. The learning	Science Museum (London)	27%	40%	20%	10%	0%	3%	3.9

	activities or games were useful to understand more information about exhibits.	Canadian Museum of Civilization*	Not provided						
		Helsinki City Museum*	Not provided						
		Philadelphia Museum of Art*	Not provided						
22.	The example and help were useful for you to know how to use the learning activities or games.	Science Museum (London)	10%	47%	27%	10%	0%	7%	3.6
		Canadian Museum of Civilization*	Not provided						
		Helsinki City Museum*	Not provided						
		Philadelphia Museum of Art*	Not provided						

Table 5.27 The results on learning aspects

* The museum website did not provide any learning activities or games

The **Canadian Museum of Civilization** had the highest average point score of 4.1 for questions 18 and 19. Most participants (83%) who regarded the content of exhibits as being easy to understand and the organisation content as being easy to follow among the four museum websites. The **Helsinki City Museum** had a fairly low percentage of the participants (33%) who considered the content of exhibits to be easy to understand and the lowest percentage of the participants (13%) who stated that the organisation and structure of the content were easy to follow. The **Philadelphia Museum of Art** also had a low percentage of participants who responded that the content was easy to understand (30%) and that the organisation of the content was easy to follow (23%) compared with the London Science Museum and Canadian Museum of Civilization.

From the preference data concerning learning activities and games, only the **London Science Museum** provided such learning games for the participants to play. 67% of the participants thought that the exhibit images were useful to click on for learning games and the learning games were useful to help them understand more about the exhibits. In addition, more than half of the participants responded that the example and help were useful to understand how to play the games.

A comparison of total average point scores in all three aspects is shown in Table 5.28. The highest average point score was the Canadian Museum of Civilization (4.0), followed by the London Science Museum (3.4) and the Philadelphia Museum of Art (2.6). The Helsinki City Museum had the lowest score (2.5) and was in the last place among the four museum websites.

Museum website	**Total average point scores**
Science Museum (London)	3.4
Canadian Museum of Civilization	4.0
Helsinki City Museum	2.5
Philadelphia Museum of Art	2.6

Table 5.28 Total average point scores

Overall impression of the museum website

On a scale of 1 to 10, 1= the worst; 10= the best

Question	**Museum website**	**Average score**
How would you rate this museum website as both informational and learning resources?	Science Museum (London)	6.4
	Canadian Museum of Civilization	8.0
	Helsinki City Museum	3.8
	Philadelphia Museum of Art	3.0

Table 5.29 The overall impression of the four museum websites

In the final section, the participants were asked to evaluate the overall impression of the four museum websites as shown in Table 5.29. The **Canadian Museum of Civilization** scored an average of 8.0 and was ranked in the first place, followed by the **London Science Museum** (6.4) and **Helsinki City Museum** (3.8). The **Philadelphia Museum of Art** had the lowest score (3.0) and was in the last place among the four museum websites.

5.7 Summary

This chapter presented observational research into the relationship between virtual visitors' behaviours and their associated learning activities within 3D virtual museum environments. The behaviour of thirty participants interacting with the four different museum websites was examined. The museum websites were selected as they each employed an alternative pedagogic approach in the design of their 3D environments: traditional lecture and text, behaviourist learning, discovery learning and constructivism.

"Read labels and texts", "look at images" and "click on the exhibit images for further information" were identified as the three dominant behaviours of all the behaviours observed among the four museums websites. These three dominant behaviours were shown as the observable forms of the process for the development of a participant's learning about a subject in 3D museum environments.

Each exhibit in the individual museum websites was assessed based on using the two measures: attraction and holding power. Six exhibits were identified as the most effective and successful among the four museum websites. The relationship between level of attraction and holding power and the key features of these exhibits was discussed. The results indicated that attraction levels were highest for the exhibits which employed multiple media formats or 3D models that can be manipulated, combined with the presentation of in-depth interpretive and rich information content; holding power was highest for the exhibits which used games or a video with high levels of interaction.

Two key factors, motivation (i.e. personal interests and preferences, and expectations) and the design of the 3D environment, were shown to influence the style of visitor behaviour regarding categories proposed by Veron and Levasseur (1983) i.e. ant, fish, grasshopper and butterfly. The design of 3D museum environment was found to be the dominant factor that affects the participants' visiting styles. Their visiting styles varied depending on the design of 3D museum environments in terms of visitor pathways, the organisation of exhibit content and the layout of exhibit displays. The results revealed that effective design of the 3D environments affected visitor behaviour patterns in such a way as to lead to deeper engagement with the thematic content, supporting Chittaro and Ieronutti (2004) findings through tracking virtual visitors' movement in a 3D museum environment.

The relationship between the visitor styles and the design of the 3D environments indicated that the most appropriate ways of presenting exhibits are those which follow the pedagogic approaches which support engagement. Exhibits which are organised based on the constructivism approach without any specific exhibition route are more suitable for grasshopper and butterfly visitors to create their own individual and exploratory routes to learn about a subject such as in the London Science Museum. Exhibits which are arranged based on the traditional lecture and text approach with proposed visitor's pathway are more appropriate for ant visitors to move systematically from exhibit to exhibit for learning from beginning to end as in the Canadian Museum of Civilization for example.

Moreover, clear differences and similarities in the three visitor groups' preferences and interests and visiting styles were identified. It was found that the Canadian Museum of Civilization employing the traditional lecture and text approach was appropriate for all three visitor groups. Most visitors in each group were guided systematically to visit exhibits by following the proposed visitor’s path to learn thematic content from beginning to end (i.e. in a historical context), exhibiting ant visiting style. The London Science Museum using the constructivism approach was the most appropriate for researcher and professional visitors (i.e. most of them were butterfly visitors) to construct meanings of the exhibits through their prior knowledge and experience. This is because this visitor group is more knowledgeable about specific aspects of a collection of artefacts than the other two visitor groups. The results suggest that a museum website in choosing its intended pedagogic approach should be concerned about creating an effective 3D environment and exhibit content which encourages specific visitor styles for particular visitor groups in order to improve learning efficacy.

The participants’ performance throughout a series of the assigned tasks among the four museum websites was discussed in this observational research. The three measures, percentage of success, average time and range of completion times, were used to evaluate the participants’ performance of each task for analysis of the use of informational architecture and the layout of the exhibition in each museum website. The findings suggest that the layout of a 3D exhibition needs to be designed to ensure it is clear and simple in order to easily find information about exhibits. Information architecture should be consistent in the 3D environment for visitors to follow. The use of interactive metaphors (e.g. an exhibit icon with indication of the exhibit name when the cursor is moved over individual exhibit images) should be provided for visitors to select the specific exhibits. In addition, provision of a map is useful to represent the whole environment for visitors to acquire spatial knowledge for navigation.

The participants' subjective evaluation of the four museum websites through the post-observation questionnaire was analysed at the end of this chapter. It was found that the Canadian Museum of Civilization was the most effective in presenting its exhibit content and associated information in the 3D environment among the four museum websites.

Through the observation studies, the overall results indicated that the Canadian Museum of Civilization was the most effective among the four museum websites in presenting its exhibits in the 3D environment based on the intended pedagogy (i.e. the traditional lecture and text approach) in terms of the organisation of content, the layout of the exhibition and informational architecture, including the following key features:

- Organisation of exhibit content:

  The logical structure and organisation of exhibit content with the use of multiple media formats and 3D model artefacts attracted visitors' attention and held them for a long time for the development of learning. The exhibit content connecting relevant links was helpful to accommodate the different types of participants' personal interests and preference, and expectations.
- Layout of the exhibition rooms:

  Based on the traditional lecture and text approach, the virtual exhibits were designed to be displayed next to walls in the exhibition rooms in a sequential order with consideration of a visit path which encouraged a large number of the participants to follow ant behaviour patterns. Such an effective layout of the exhibition rooms matched the features of the ant visiting style.
- Information architecture:

  The effective use of the metaphors to clearly present information on the exhibits and environment allowed the participants to easily navigate the environment to find the exhibits through the map.

Having examined the levels of attraction and holding power of exhibits and the relationship between pedagogic approaches and visiting styles in the 3D environments of the four museum websites, six research hypotheses are proposed as follows:

1. If an exhibit features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) it will provide a **high level of attraction** and there will be a greater possibility to improve visitors' learning experience.

2. If the exhibit features rich multimedia formats (i.e. games or a video with high levels of interaction) it will provide a **high level of holding power** and there will be a greater possibility to improve visitors' learning experience.

3. If a web-based museum presents its information and learning resources for all **the three visitor groups** in a 3D environment, **the traditional lecture and text approach** will provide a greater potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject in ant visiting style.

4. If the design of the museum environment is based on **the traditional lecture and text approach** it will encourage visitors to follow 'ant' behaviour patterns and it will lead visitors to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject.

5. If a web-based museum needs to present its information and learning resources for **researcher and professional visitors** as a target audience using a 3D environment, **the constructivism approach** will provide the greatest potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) and encourage a butterfly visiting style.

6. If the design of the museum environment is based on **the constructivism approach** it will encourage the features of grasshopper and butterfly visitors and it will allow visitors to develop a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with selected aspects of the subject.

These six hypotheses concerning the relationship between attraction and holding power of exhibits, visiting styles and the design of a 3D museum environment based on pedagogic approaches for learning efficacy will be tested by interviews with museum project managers and multimedia developers who have experiences of designing their 3D virtual museum environments in the next chapter (Chapter Six). In addition, certain important aspects (e.g. the most effective ways of interacting with exhibits, the biggest problems in designing exhibits, pedagogic features in the 3D museum environments and so on) will be identified by the interview studies for the development of an effective 3D museum environment with an emphasis on information aspects and the learning content.

Chapter Six: Interviews

6.1 Introduction

This chapter focuses on the interviews with museum project managers and multimedia developers to test the research hypotheses formulated from the observation studies discussed in the last chapter (Chapter Five). The hypotheses are concerned with the relationship between the attraction and holding power of exhibits, visiting styles and the design of a 3D museum environment based on pedagogic approaches. These hypotheses were the basis of a set of questions to be asked in the interviews with museum and multimedia experts in order to address the main research question of this study: what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy. In addition, the interview studies aimed to identify a series of topics and issues regarding the biggest problems in designing virtual exhibits and the importance of pedagogic features in 3D virtual museum environments. These topics and issues are covered with each interviewee (i.e. museum project managers and multimedia developers) who plays a key role in creating his or her institutions' 3D virtual environments for the web.

As discussed in Chapter Three, the method of semi-structured interviews was used in this research in order to elicit the participants' point of view through a list of questions (i.e. each research hypothesis is stated in a question format) that is prepared in advance. Moreover, the main purpose of semi-structured interviews is to allow the participants to talk about their experiences and opinions on specific subjects (i.e. a series of topics and issues which are concerned with the most effective ways of interacting with virtual exhibits, the biggest problems in designing virtual exhibits, pedagogic features and so on).

For qualitative studies such as semi-structured interviews, Diamond (1999) stated that they are often conducted using a small size of samples that are chosen for specific reasons. Thus eight experts were recruited for the interviews on the basis of their expertise in areas relevant to the design of 3D museum environments.

At the end of this chapter, the findings from the interview research concerning the hypothesis will subsequently be used to develop a theoretical design reference model for creating an effective 3D museum environment as part of the overall research.

6.2 Aim of interviews

The aim of these interviews is to evaluate the six hypotheses generated from the observational studies with museum project managers and multimedia developers' involved in creating 3D online museum environments as both informational and learning resources.

6.3 Rationale

Interviews can be used to test research hypothesis through eliciting respondents' point of view and experience (Kvale, 1996). These interviews will both provide an in-depth understanding of the development of 3D environments for websites as well as either support or rejection of the research hypotheses. These results will form the basis for the development of a theoretical model for the effective design of a 3D museum environment based on the intended pedagogic approaches to encourage the related visiting style(s), leading to a deeper engagement with subject matters for learning efficacy. The hypotheses proposed from the observational studies are as follows:

1. If an exhibit features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) it will provide a **high level of attraction** and there will be a greater possibility to improve visitors' learning experience.

2. If the exhibit features rich multimedia formats (i.e. games or a video with high levels of interaction) it will provide a **high level of holding power** and there will be a greater possibility to improve visitors' learning experience.

3. If a web-based museum presents its information and learning resources for all **the three visitor groups** in a 3D environment, **the traditional lecture and text approach** will provide a greater potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject in ant visiting style.

4. If the design of the museum environment is based on **the traditional lecture and text approach** it will encourage visitors to follow 'ant' behaviour patterns and it will lead visitors to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject.

5. If a web-based museum needs to present its information and learning resources for **researcher and professional visitors** as a target audience using a 3D environment, **the constructivism approach** will provide the greatest potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) and encourage a

butterfly visiting style.

6. If the design of the museum environment is based on **the constructivism approach** it will encourage the features of grasshopper and butterfly visitors and it will allow visitors to develop a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with selected aspects of the subject.

These hypotheses are stated in a question format for the interviews with museum project managers and multimedia experts' involved in developing 3D online museum environments. For example, hypothesis 2 is stated in two questions as follows:

1. Do you think the exhibits which feature rich multimedia formats (i.e. games or a video with high levels of interaction) provide a **high level of holding power?**

2. Do you think that the exhibits with a **high level of holding power** improve visitors' learning experience?

A number of formalised questions for these hypotheses can be found in Appendix 6A.

In addition, certain important design aspects (e.g. the most effective ways of interacting with exhibits, the biggest problems in designing exhibits, pedagogic features in the 3D museum environments and so on) will also be discussed in the interviews with museum project managers and multimedia developers to aid the development of an effective 3D museum environment with an emphasis on information aspects and the leaning content.

6.4 Methodology

6.4.1 Validity and reliability

The validity of an interview is determined by whether it is an accurate reflection of the truth and correctness of interviewees’ statements. Kvale (1996) stated that the validity of interviews contains the logic of the derivations, unambiguous wordings of questions and the choice of linguistic styles for respondents’ transcripts.

Reliability with respect to an interview study relates to the consistency of the results. Hein (1998) discusses reliability of interviews, referring to Webb et al’s contention that the types of questions used affect the reliable data collection from respondents in Figure 6.1.

Questions about:	Present	Past	Future
Factual knowledge			
Opinion (Do you think?)			
Attitude (Do you believe?)			

Most reliable

Least reliable

Most reliable ⟷ Least reliable

Figure 6.1 Types of questions influence the reliable data collection from interviews

(Source: Hein 1998)

Figure 6.1 shows the interview questions about factual knowledge concerning present are the most reliable data collection; in contrast, the questions about and attitude toward future are the least reliable data collection from interviews. These research instruments are considered and used to interview museum project managers and multimedia experts for validity and reliability in order to test the research hypotheses through their current opinions and factual knowledge of the design of the 3D museum environments in these interview studies.

6.4.2 Methods

With regards to this research, the method of semi-structured interviews will be used to elicit museum project managers and multimedia developers' views and experiences of designing a 3D virtual museum environment and the research hypothesis. This is because the main objective of semi-structured interviews focuses on capturing 'the respondent's point of view (Livesey 2003).' In addition, this method can offer information through open-ended questions about aspects of a particular topic to be explored in detail and depth (UKMI 2006). Therefore, these interviews employ the method of semi-structured interviews in order to identify a series of topics using open-ended questions which are covered with each Museum project manager and multimedia developer who have created particular 3D environments on their own museum websites.

Diamond (1999) has proposed the following procedure for all types of interviews:

- 'Plan in advance how you will locate and choose your subjects.'
- 'Find a place and time for the interview that will be comfortable and convenient for your subjects.'
- 'When you arrange your questions, order them so the most personal questions come last.'
- 'Ask about only one item at time.'

This procedure has been implemented as follows:

- *'Plan in advance how you will locate and choose your subjects'*

  Two groups (i.e. museum project managers and multimedia developers) who created their institutions' 3D virtual environments on the websites will be selected as target subjects. The reason for a total number of subjects is given in Section 6.4.4.

- *'Find a place and time for the interview that will be comfortable and convenient for your subjects'*

  Locations and time for the interview will be discussed with subjects in order to arrange appropriate time and provide a comfortable place with privacy. Besides, those subjects who live in other countries will be interviewed by telephone. Thus the arrangement of time is important for the interview due to time differences.

- *'When you arrange your questions, order them so the most personal questions come last'*

  Personal questions (e.g. age, address and so on) will be placed at the end of the interview because the main purpose of this interview study is to elicit subjects' views and experiences as soon as possible rather than demographic questions (Patton 2002). The sequence of questions is discussed in Section 6.4.3.

- *'Ask about only one item at time.'*

  To ask one question at a time in order to make individual questions clear to the subject what is being asked.

6.4.3 The types and sequencing of questions

There are six different types of questions to ask people in interview research as follows (Patton 2002):

- Experience and behaviour questions: these focus on eliciting the respondent's behaviours, experiences, actions and activities.
- Opinion and values questions: these aim at investigating the respondent's cognitive and interpretive process related to their opinions, judgments and values.
- Feeling questions: these focus on understanding the respondent's emotion concerning their experiences and thoughts.
- Knowledge questions: these identify the respondent's factual information.
- Sensory questions: these gather the respondent's experiences of senses: seen, heard, touched, tasted and smelled.
- Background and demographic questions: these identify the respondent's characteristics.

The four categories of questions (i.e. experience and behaviour, opinion and values, knowledge, and background and demographic questions) are used to construct semi-structured interviews with consideration of reliable data collection based on the objectives of this research. However, feeling and sensory questions are not applicable to this interview research because the aim of the interviews is to determine interviewees' views, knowledge and experiences of developing museum websites rather than the impact on their senses and emotions.

As mentioned early, the validity of interviews includes the logic of the elicitations through sequential questions. Patton (2002) has suggested that 'standardized open-ended interviews must establish a fixed sequence of questions to fit their structured format.' In using open-ended questions format in this research, the sequence of questions suggested by Patton in the structure of this semi-structured interview with consideration of question types for reliability (discussed in Section 6.4.1) is explained as follows:

1. Experience and behaviour questions: these questions are presented at the beginning of the interview in order to ask interviewee's activities and experiences (e.g. current work) for straightforward descriptions. The aim of these questions is to elicit in depth information and greater details.
2. Opinion and values questions: once several experiences have been described, then opinions can be solicited, building on interpretations of the experiences (Patton 2002). The use of opinion and values questions is to identify interviewees' opinions in order to evaluate the research hypotheses.
3. Knowledge questions: the use of knowledge questions in interviews relies on the context because they may be threatening if asked too abruptly (Patton 2002). It can be useful to ask knowledge questions by following up experience questions which have a bearing on knowledge.
4. Background and demographic questions: these questions are listed at the end of the interview because 'the interviewee needs to become actively involved in providing descriptive information as soon as possible' rather than be asked routine demographic questions (Patton 2002). Besides, an interviewee may decline to participate in the interview when asked sensitive and personal questions (Diamond 1999). The aim of such questions is to identify interviewees' background information on age, education, occupation, etc.

The detailed questions used in the interviews with museum project managers and multimedia developers can be found in Appendix 6B.

6.4.4 Sample selection

Diamond (1999) contended that qualitative interviews are often conducted with a small size of samples that are chosen for specific reasons. Thus the two groups of specialists, museum project managers and multimedia experts, were chosen for interviews on the basis of their expertise in areas relevant to the design of 3D museum environments. In addition, valuable information gained from these participants' opinions and experiences was employed in order to test the hypotheses for developing a theoretical reference design model for creating an effective 3D museum environment.

A small sample size of four for each group was considered adequate, giving the total number of interviewees needed as eight. The list of particular for each interviewee group, their institutions and positions are presented in Table 6.1:

Group	**Institution**	**Position**
Museum project manager #1	National Museum of Natural Science (Taiwan)	Assistant Researcher
Museum project manager #2	National Museum of Marine Biology and Aquarium (Taiwan)	Research Assistant
Museum project manager #3*	Colchester Castle Museum (UK)	Documentation Officer
Museum project manager #4	Department of Biomedical Sciences at Cornell University (USA)	Research Associate
Multimedia expert #1	Narrative Rooms Inc. (USA)	Designer
Multimedia expert #2	Department of Informatics at University of Sussex (UK)	Reader
Multimedia expert #3	Virtual Gallerie, LLC (USA)	President

Multimedia expert #4	The Institute for Information Industry (Taiwan)	Associate Planning Engineer

Table 6.1 The list of each interviewee group and their institutions and positions

*There were two interviewees' respective responses to the questions completing the whole interview. Thus their answers were regarded as one Museum project manager's comments for analysis. In addition, only one interviewee provided his background information.

Marshall and Rossman (1999) pointed out that the problem with elite (e.g. specialists) interviewees is that 'it is often difficult to gain access to elites because they are usually somewhat elusive and busy people.' Due to limited access to several specialist participants, an alternative method was considered such as email for conducting in-depth interviewing in this qualitative research based on Meho's (2006) suggestion.

6.5 Result analysis

Concerning the purpose of qualitative interview analysis, Gorden (1980) asserts that it can be helpful to use an audiotape during the interview in order to reproduce a full text of interview content for detailed analysis of the results. During the process of the interviews, the contents of interviews were accurately recorded through an audio recorder in order to transcribe into text documents. Email-based interviews with specialist participants provided textual information through expressing their opinions and experiences in writing. The transcribed interview contents via telephone and the text-format contents through Email interviews were both used for in-depth analysis.

According to Diamond (1999), the method of content analysis is useful for dealing with qualitative data to organise them in terms of central themes, patterns and issues.

Besides, she points out that '[the] use of quotations is an important element in the analysis and presentation of qualitative research (Diamond 1999).' This is because quotations are regarded as the most effective way of conveying participants' experience and views. Therefore, these qualitative interview data were analysed using the method of content analysis to organise the data under the established themes and issues through the use of quotations from a series of semi-structured interviews with museum project managers and multimedia experts.

The analysis of the results consisted of two parts: their views and experiences of developing 3D museum environments and their opinions and support for the hypotheses.

6.5.1 Views and experiences of developing 3D museum environments

The data were analysed in narrative form to summarise the significant findings in order to identify what the two groups (museum project managers and multimedia experts) thought about two issues in the creation of 3D virtual environments, specifically the design of virtual exhibits and the development of 3D museum environments. The first issue related to the most effective ways of interacting with exhibits and the biggest problems in designing exhibits. The second issue covered specific topics regarding the biggest challenges, the pedagogic features and important criteria in the development of 3D web-based museum environments.

In terms of the most effective ways of interacting with exhibits, one multimedia expert noted that exhibit contents in different media must first attract visitor attention, then second provide opportunities, often through learning activities or games, for them to actively engage with learning experiences which stimulate curiosity and wonder (Multimedia expert #4, 2007). This view supports Yahya’s (1997) findings that attraction (visitors who stop in front of exhibits) is the most important for an effective exhibit because ‘important and interesting [as] an exhibit may be, no learning can occur unless the visitor stops in front of it.’

Multimedia expert #3 claimed that interaction with exhibits needed to allow manipulation of the virtual exhibits to see the details of 2D images and 3D model artefacts to be effective. ‘For 2D images such as paintings, there are very good technologies, such as Zoomify, that will allow you to examine a painting up close. For 3D objects, such as sculptures, artifacts, and installation art, you need a 3D model of the object [which allows you] to see all sides (Multimedia expert #3, 2007).’ Two museum projects described the most effective way of interacting with exhibits was also to provide associated information on exhibits through media (e.g. audios) or hyperlinks (Museum project manager #1 and #2, 2007).

Concerning the biggest problems in designing exhibits, the interviewees pointed out several issues concerning update and maintenance, dependence on external experts in 3D technology, size of information on exhibition content, difficulty in navigating the 3D environment, user interface, content creation and presentation methods for 3D models and photo-realistic exhibits as the following quotes show:

- ‘It is difficult for our people to pick up when we need to add many things, as the entire design tool is more difficult and more complicated in technology. The digital collection wanted us to add something and we were unable to. We needed to ask the company [external multimedia experts] to help us (Museum project manager #1, 2007).’
- ‘Having reviewed other 3D environments on the websites, we found that users

did not know how to use them. For instance, users find the environment like a labyrinth. Except for those who are good at playing computer games, users tend to get lost or dizzy (Museum project manager #2, 2007).'

- 'Size. One would like to have the most information possible in the nicest setting possible but in the smallest size possible as to make download time minimum (Museum project manager #3, 2007).'
- 'Thinking that the 3D real world is a model for 3D virtual spaces. You need to invent a space and a set of navigational and visual tools that match the computer 3D space which is nothing like a real world space (Multimedia expert #1, 2007).'
- 'The other problem in creating 3D environments is the difference between something that is created to look photo-realistic versus something that looks virtual. When you make everything look photo-real, it is easier to notice problems or things that don't look correct. Whereas, when you create something in 3D that looks virtual, the look is more consistent (Multimedia expert #3, 2007).'
- 'The accuracy of the content creation involved what we wanted to convey. For example, butterflies have 4 wings with a round body in general. In our making, we have to consider the pixels, as too many pixels will slow down the speed. The simple way we adopted is to use two plates as wings with pasted pictures and the middle is a rectangular pillar like a capsule (Multimedia expert #4, 2007).'

Museum project managers and multimedia experts talked about several challenges in the development of their 3D museum environments. The predominant challenges were as follows:

- Having difficulty in combining technical skills and curatorial knowledge to deliver accurate content that will effectively attract users (Museum project manager #1, 2007).
- Providing rich information about exhibits and whether they can meet the different needs of the visitors (Museum project manager #1 and #3, 2007).
- Considering users' hardware and the download speed when creating a virtual museum website on the Internet (Museum project manager #3 and #4, 2007).
- Creating a simple 3D model of the exhibits in a clear design of the 3D museum environment for visitors to easily navigate (Multimedia expert #1, 2007).
- Ensuring that fun is part of the educational games to motivate visitors to be involved in the development of learning (Multimedia expert #4, 2007).
- Building artefacts or a 3D museum environment such as roofs and ceilings and strange curved objects (Multimedia expert #3, 2007).

In terms of the pedagogic features in their 3D web-based museum environments, museum project managers and multimedia experts described a number of important pedagogic features as follows:

- Using games that are part of the learning activities for delivering knowledge to visitors (Museum project manager #1, 2007).
- Designing 3D model artefacts with animated movement to attract visitors and offer fresh experiences. The purpose of the environment is to stimulate them and add to their knowledge through interactive experience (Museum project manager #2, 2007).
- Enabling visitors to 'visualize specific parts of Roman Colchester and its most important objects (Museum project manager #3, 2007).'

- ‘Having 3D heart structures that can be observed in all directions and angles helps in learning all of its components (Museum project manager #4, 2007).’
- Providing exhibit images and texts that improve visitors’ knowledge of the artist and artworks by virtually walking through the 3D space and interacting with the art objects (Multimedia expert #1, 2007).
- Creating the 3D virtual space that enables visitors to click on exhibit images for further information about them using audios, videos and texts in the pop-up windows (Multimedia expert #3, 2007).

The results revealed that the integration of multiple media formats in a 3D museum environment is useful to explain knowledge and associated information about artefacts, supporting Paquet et al’s (2001) findings (see Section 2.8.2.3). In addition, Brown et al (2005) have proposed that Laurillard’s definition of different types of learning experiences are supported by the various categories of media forms (e.g. images, texts, videos, simulations: 3D models of artefacts, games, etc.) in virtual museum environments on websites (see Section 2.5.2). Such auxiliary media formats in the 3D museum space can enrich visitors’ different learning experiences.

In response to the question about important criteria in the development of their 3D online exhibitions, one Museum project manager felt that content needs to have richness, depth, accuracy and accessible knowledge categorization (Museum project manager #1, 2007). Another Museum project manager said that the users’ hardware, browsers and cross-platform such as PCs and Macs should be considered in order to offer smooth learning procedures (Museum project manager #2, 2007). Moreover, one multimedia expert described the aim of museum projects was needed to be clearly established for the type of the development of 3D museum environments. She stated that the aim of 3D museum projects should be clear in order to select appropriate design strategies for the development of 3D museum environments based on the intended learning approaches (Multimedia expert #4, 2007).

The other criteria were fun, navigation, interaction, and provision of 3D exhibits to encourage visitors to learn. Museum project manager #3 and #4 thought visitors should have fun in the museum. One multimedia expert observed that 'most importantly, they [3D museum environments] need to be easy to use in terms of navigation and interacting with art objects. These 3D exhibits need to provide the visitors with something that they were not able to experience at the museum. Last, it should encourage the users to educate themselves in their own time beyond the physical walls of the museum (Multimedia expert #3, 2007).'

6.5.2 Opinions and support for the hypotheses

Diamond (1999) pointed out that 'use of quotations is an important element in the analysis and presentation of qualitative research.' She proposed that direct quotations are the most effective way of conveying a participant's experience and sentiments on a series of topics from in-depth interviews. Thus, the data were transcribed in verbatim in order to test the research hypothesis.

Hypothesis 1:

If an exhibit features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) it will provide a **high level of attraction** and there will be a greater possibility to improve visitors' learning experience.

First, when they were asked "Do you think that the exhibits which feature rich multimedia formats (i.e. multiple media formats or 3D models combined with in-depth information) provide a **high level of attraction**?", all interviewees, except one multimedia expert, tended to agree that the exhibits with rich multimedia formats are useful to attract visitors' attention.

One Museum project manager argued that 'Yes. Our multimedia objects, in addition to video, pictures and films, also include 3D animation. For example, we have the most famous canoes display of Tao Tribe in Orchid Island (Lanyu) on the site. We present the making, assembly and painting of the canoes in animation, which cannot be shown in texts. This way should be attractive to visitors. Also, we make indigenous people tribes in navigation animation to make users experience and browse the tribes (Museum project manager #1, 2007).' Similarly, another Museum project manager observed: 'It does help. For me, we need to reduce the entry barriers to the minimum for users. When they see something, they believe it will make sounds or have actions after clicking on it. (Museum project manager #2, 2007).' Museum project manager #4 said that 'Yes, as long as they are fast to download and visually attractive.' In response to the question, the other Museum project manager and three of the multimedia experts simply replied, "Yes".

Second, when they were asked about the relationship between the exhibits with a **high level of attraction** and visitors' learning experience, all interviewees, except one multimedia expert, appeared to agree that the exhibits with a **high level of attraction** improve visitors' learning experience, as indicated by the following quotes:

> 'I think so. We use 3D display in anthropology, archaeology, ethnography, and virtual recovery. The effects are good. For users, it is a whole learning, as they are not seeing the flat media. They can know the details of the

process of animation, recovery or simulation. This helps their learning a lot (Museum project manager #1, 2007).'

'In web 3D [Waters of the World 3D], our timing is good and offers users different experiences from other websites. They are more curious to browse each page and want to know how creatures look (Museum project manager #2, 2007).'

'Yes (Museum project manager #3, 2007).'

'Definitively (Museum project manager #4, 2007).'

'Rather than placing interactive elements in the exhibit space, it is better to use the web to provide context and additional information on the physical exhibition. A visitor can visit the web site prior to the exhibit or after to gain additional perspective and understanding (Multimedia expert #1, 2007).'

'Could very well do, depends how well it is implemented (Multimedia expert #2, 2007).'

'They might be more excited about the exhibit, which could cause them to learn more, but this is up to the visitor (Multimedia expert #3, 2007).'

Hypothesis 2:

If the exhibit features rich multimedia formats (i.e. games or a video with high levels of interaction) it will provide a **high level of holding power** and there will be a greater possibility to improve visitors' learning experience.

In response to the question on the exhibit with rich multimedia formats (i.e. games or a video with high levels of interaction) and a high level of holding power, six out of the eight interviewees thought the visitors are held and engaged by such exhibits. One Museum project manager advocated that 'Definitely! Another advantage is users can see animation and feel surprised. They would like to try to visit each exhibit to see if animation is behind it. This is exciting to keep them learning (Museum project manager #1, 2007).' Although the other Museum project manager felt that videos do not provide a high level of holding power, he observed that 'games will be challenging to encourage users to continue visiting the website. Thus such well-designed games can provide a high level of holding power (Museum project manager #2, 2007).' The other two museum project managers agreed and simply said "Yes". Similarly, multimedia expert #2 repeated his comment in hypothesis one that it could very well but it also depends on how well it is carried out. Another multimedia expert said that 'Yes, but not for everyone. The younger generation loves these types of exhibits, but older people who are not as technically astute may not be attracted to these exhibits (Multimedia expert #3, 2007).'

When asked about their experiences and points of view about exhibits with regard to a high level of holding power improving visitors' learning experience, all eight interviewees agreed, as shown by the following quotes:

> 'The game for Austronesian people area is simple. Users can compare the current costume with the incorrect costume. Now, we have The Digital

> Museum for Children with a virtual island where children can have fun with games for half, one or two hours. Children can be more participative and have credits to get bonuses. They can have feedback in credits (Museum project manager #1, 2007).’
>
> ‘Definitely (Museum project manager #2, 2007)!’
>
> ‘Yes (Museum project manager #3, 2007).’
>
> ‘Yes (Museum project manager #4, 2007).’
>
> ‘Yes (Multimedia expert #1, 2007).’
>
> ‘Yes (Multimedia expert #2, 2007).’
>
> ‘If someone is spending more time with an exhibit, they will probably learn more, but this will depend on the learning aspects of the exhibit itself (Multimedia expert #3, 2007).’
>
> ‘The answer is, of course, yes (Multimedia expert #4, 2007).’

Hypothesis 3:

If a web-based museum presents its information and learning resources for all **the three visitor groups** in a 3D environment, **the traditional lecture and text approach** will provide a greater potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject in ant visiting style.

The result indicated that half of the eight interviewees seemed to support this statement of hypothesis. One Museum project manager stated that ‘if the display is traditional or texts, we may help people learning interactively. We do not have any special target audience. Everyone can choose what they like (Museum project manager #1).’ Another museum project stated that ‘if possible, we can do the same on the web. For example, we are now working on museum of virtual coral reef to show education and learning process (Museum project manager #2).’ Similarly, one Museum project manager and one multimedia expert tended to support, as shown by the following quotes:

> ‘Yes. The freedom of the user to move around a museum allows the user to focus on what is particular interesting to them and thus affects in a positive way its learning experience (Museum project manager #4, 2007).’

> ‘Perhaps. However, I believe that visitors like the freedom to interact with the exhibit on their own time and method (Multimedia expert #3, 2007).’

One Museum project manager made no response to the question. However, one multimedia expert felt that the way of viewing exhibit varies from person to person, depending on their understanding of the exhibited artefacts on display in the exhibition. She claimed that ‘well, for those who, say, want to know the classification or habits of dinosaurs, you give them step-by-step guide, they learn something. If their brain is full and you still use the traditional way, they will just walk away (Multimedia expert #4).’

Hypothesis 4:

If the design of the museum environment is based on **the traditional lecture and text approach** it will encourage visitors to follow 'ant' behaviour patterns and it will lead visitors to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject.

This hypothesis states that the museum environment based on **the traditional lecture and text approach** encourages visitors to follow 'ant' behaviour patterns, including the three key factors: a fixed **visitor's pathway**, **the organisation of exhibit content** in a sequential order and **exhibit displays** with hierarchical organisation of subject. Thus the hypothesis was stated as three questions in terms of the three key factors. The result showed that seven out of the eight interviewees appeared to support this hypothesis as evidenced by the following quotes:

1. *Do you think that a fixed **visitor's pathway** is suitable for ant visitors to follow the exhibition content step by step in a systematic manner?*

> 'Yes, this is also a learning model. In a systematic content, users take the fixed route. Well, the general public may not be so patient, unless they are students being required by teachers. The general public can only be attracted to go all over only with interesting design, rich content, special stuff or games (Museum project manager #1, 2007).'

> 'On the web 3D [Waters of the World 3D], there is a systematic structure. If required, users can view all the content one by one in accordance with the ages and regions. We did plan so. Users can be seen on the website

with the characteristics of the ant visiting style (Museum project manager #2, 2007).'

'Yes, I believe that this is best way to construct a course throughout the exhibits/museum (Museum project manager #3, 2007).'

'This is probably most appropriate in most cases. It reduces the level of skill needed for navigation. So for most audiences it is a good option. In test many web users have trouble with drop down menus. 3D navigation is quite a bit more difficult (Multimedia expert #1, 2007).'

'Maybe (Multimedia expert #2, 2007).'

'Ant style visitors usually prefer a fixed path, so, yes (Multimedia expert #3, 2007).'

'I think so. We did have conclusions at the beginning to have these visitor types. As you said, we then designed the routes accordingly (Multimedia expert #4, 2007).'

2. *Do you think that* ***the organisation of exhibit content*** *in a sequential order is suitable for ant visitors to learn thematic content for learning from beginning to end?*

'Of course! There are two possible conditions. The first one is to virtualise the actual exhibition site. This program is systematic for us to make a program. The virtual display continues the original display. The other is the purely virtual display in which we complete a virtual display on the Internet. If the display is systematic in organisation, it helps learning. That is good (Museum project manager #1, 2007)!'

'We think so and work hard towards it. There are some problems in our page layout in the actual operation but we did work towards it (Museum project manager #2, 2007).'

'Yes (Museum project manager #4, 2007).'

'In a 3D space it is an option to make navigation easier but there may be many other ways to accomplish the same thing (Multimedia expert #1, 2007).'

'Maybe (Multimedia expert #2, 2007).'

'Yes (Multimedia expert #3, 2007).'

'It should be so (Multimedia expert #4, 2007).'

3. *Do you think that* ***exhibit displays*** *with hierarchical organisation of subject encourage ant visitors to learn knowledge from the simple to the complex in a contextual orientation?*

'I think so. It is a way to convey knowledge from the simple to complicated, from the basic knowledge concept to the complicated or in categorization display. That is what the traditional display is about. The virtual display reflects the planning of the actual display in the same learning model (Museum project manager #1, 2007).'

'Yes. It will be nice if ant type viewers can watch step by step. Web 3D viewers tend to be attracted by new visual or 3D objects. With more detailed explanations, it seems the website is less likely to be viewed (Museum project manager #2, 2007).'

'Yes (Museum project manager #4, 2007).'

'It is important that visitors with wide ranges of interest and knowledge will be able to find something useful and informative. Editorial oversight and hierarchical organisation are important so that visitors can get at the level of information they desire quickly (Multimedia expert #1, 2007).'

'Maybe (Multimedia expert #2, 2007).'

'Perhaps. It will depend on the type of exhibit (Multimedia expert #3, 2007).'

'If your exhibit display has hierarchy and organisation, it can help them to select information they want (Multimedia expert #4, 2007).'

Hypothesis 5:

If a web-based museum needs to present its information and learning resources for **researcher and professional visitors** as a target audience using a 3D environment, **the constructivism approach** will provide the greatest potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) and encourage a butterfly visiting style.

Four out of the eight participants stated that a 3D museum environment based on **the constructivism approach** leads **researcher and professional visitors** to a deeper engagement and encourages a butterfly visiting style. One of the museum project managers advocated that ‘If you need a categorization, putting the constructivism approach with butterfly visiting style may be more appropriate. In the constructivism approach, users [research and professional visitors] have a certain background [they are knowledgeable about exhibits] and learn on their own. That is why the constructivism approach should match the butterfly visitors (Museum project manager #1, 2007).’ Another Museum project manager simply said “Yes” (Museum project manager #4, 2007).

It appears that one multimedia expert supported this statement according to her experience in developing a 3D virtual butterfly style museum. She observed that ‘those [researchers and professionals] who have background [they are knowledgeable about exhibit concept] look at what they want to see no matter what they are presented in 3D or multimedia. If you only use multimedia, it is only superficial. These people may spend one or two seconds and say “Wow, so beautiful!” and then go away (Multimedia expert #4, 2007)’ Although this multimedia expert did not mention that the researcher and professional visitors’ behaviours were butterfly visiting style, their behaviours can be categorised as butterfly visiting style based on Veron and Levasseur's (1983) classifications of typical visiting styles. One multimedia expert seemed to agree and simply replied "Perhaps" (Multimedia expert #2, 2007).

The other two (Museum project manager #2 and multimedia expert #3) said "not sure". However, one Museum project manager noted that 'most research and professional visitors would have almost certainly pre-planned their visit so layout almost becomes secondary (Museum project manager #3, 2007).'

Hypothesis 6:

If the design of the museum environment is based on **the constructivism approach** it will encourage the features of grasshopper and butterfly visitors and it will allow visitors to develop a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with selected aspects of the subject.

This hypothesis states that the museum environment based on **the constructivism approach** encourages grasshopper and butterfly visitors, including the three key factors: non-fixed **visitor's pathway**, **the organisation of exhibit content** with various levels of knowledge and interests, and **exhibit displays** with a constructivist layout with multiple entry points. The hypothesis was assessed using four questions on these three key factors. In responses to the four questions, the most interviewees' views tended to support this hypothesis.

1. Do you think that without any fixed ***visitor's pathway,*** *it will encourage grasshopper and butterfly visitors to create their own individual and exploratory* *routes to actively interact with exhibits for learning?*

After the first question, six out of the eight interviewees agreed that the omission of any fixed **visitor's pathway** encourages grasshopper and butterfly visitors to create their own individual and exploratory routes to actively interact with exhibits for learning, as evidenced by the following quotes:

> 'It works. Visit in non-fixed route is for grasshopper or butterfly visitors. Step-by-step visit is for ant visitors. Grasshopper or butterfly visitors want to see what they want. Being more flexible should give them better learning results (Museum project manager #1, 2007).'

> 'Again, this depends on content – I agree that without a fixed path this encourages self exploratory routes but could create confusion when introducing specific learning material (Museum project manager #3, 2007).'

> 'Yes, however I think it is a good idea to give options to the user as in some cases butterfly and grasshopper visitors may become ants or vice versa. Therefore the more options between free moving and predefined paths are important (Museum project manager #4, 2007).'

> 'Perhaps (Multimedia expert #2, 2007).'

> 'I think that grasshopper and butterfly visitors will always be happy with no fixed pathway. Yes, this style, as it fits with their methods of

> movement it would encourage education (Multimedia expert #3, 2007).’
>
> ‘There was a 3D virtual dinosaur museum in package software. You must start from the first door and follow its route from the beginning to the end. This is boring, as you cannot have exploration or surprises. What I expect is that a dinosaur suddenly runs out from a cave or there are other goals that I can learn from without a map. Therefore, I need to start from the first exhibition area to the later ones. Fixed routes may not be attractive to grasshopper or butterfly types of visitors (Multimedia expert #4, 2007).’

2. Do you think that ***the organisation of exhibit content*** *with various levels of knowledge and interests is suitable for grasshopper and butterfly visitors to choose exhibit content they desire?*

When asking the second question, one Museum project manager argued that ‘If the content includes different levels of knowledge, the visitor can jump [grasshopper and butterfly visiting styles] to see further information based on his/her professional background (Museum project manager #1, 2007).’ Museum project manager #3 stated that ‘I completely agree – grasshopper and butterfly visitors will be self selecting with exhibition content.’ Similarly, one Museum project manager and all four multimedia experts stated that **the organisation of exhibit content** with various levels of knowledge and interests is suitable for grasshopper and butterfly visitors to choose the exhibit content they desire, as the Museum project manager and three of the multimedia experts directly said “Yes” and the other multimedia expert replied “Perhaps”.

3. Do you think that the constructivist ***organisation of exhibit content*** *allow grasshopper and butterfly visitors to construct the meanings of artefacts through their prior experiences and knowledge?*

In response to the third question about the constructivist **organisation of exhibit content** and grasshopper and butterfly visitors, six out of the eight interviewees seemed to agree, as indicated by following quotes:

> ‘Yes, I agree with that. If the user is autonomous, he or she studies what is interesting. Active learning is better for grasshopper or butterfly visiting styles of visitors who like to have connective or constructivist learning model based on their background and know-how (Museum project manager #1, 2007).’

> ‘Yes, the majority of visitors will look for elements which they can relate to (Museum project manager #3, 2007).’

> ‘Yes (Museum project manager #4, 2007).’

> ‘Perhaps (Multimedia expert #2, 2007).’

> ‘Yes (Multimedia expert #3, 2007).’

> ‘Literally, it is O.K. In actual operation [of a 3D museum environment], you have to offer appropriate messages (Multimedia expert #4, 2007).’

The other answers from one Museum project manager and one multimedia expert to this question were “not sure”.

*4. Do you think that **exhibit displays** with a constructivist layout in multiple entry points are suitable for grasshopper and butterfly visitors to construct knowledge from which they can choose?*

According to response to the fourth question, six out of the eight interviewees advocated that **exhibit displays** with a constructivist layout in multiple entry points are suitable for grasshopper and butterfly visitors to construct knowledge from which they can choose, as evidenced by the following quotes:

> ‘Yes, I think so. This sounds quite natural. They want to be more flexible, diverse and free. It will be more appropriate for them (Museum project manager #1, 2007).’

> ‘If the exhibition content allows for this then it can work. However, it is important to establish which facts/information you want the visitor to leave with (Museum project manager #3, 2007).’

> ‘Yes (Museum project manager #4, 2007)’

> ‘Yes (Multimedia expert #2, 2007).’

> ‘Yes (Multimedia expert #3, 2007).’

> ‘I suppose so. I think grasshopper and butterfly types of visitors have their goals to learn; they are more open and they go to the places attracting them. Display design is related to the media performance and exhibit content/subjects they like to see (Multimedia expert #4, 2007).’

One multimedia expert did not respond to this question. However, one Museum project manager contended that if a 3D environment on the website is planned with too much freedom, virtual visitors will tend to ignore the information we want to give them (Museum project manager #2, 2007).

6.5.3 Overall conclusion

The results indicated that four of the six hypotheses appear to be supported by more than five of all the eight specialist interviewees based on their experiences and views. Moreover, although the two groups come from different backgrounds and diverse disciplines, they had similar points of view which seemed to support the statements of four hypotheses. Having identified the interviewees’ experience and views on the thematic topics, the analysis of the interview data revealed support of hypothesises as summarised in Table 6.2.

Legend: MPM = Museum project manager, ME = Multimedia expert, Q = Question

✓ = Agree ? = Neither/Not sure ╳ = Disagree/Not necessarily / = Non-response

Hypothesis 1:
If an exhibit features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) it will provide a **high level of attraction** and there will be a greater possibility to improve visitors’ learning experience.

	MPM #1	MPM #2	MPM #3	MPM #4	ME #1	ME #2	ME #3	ME #4	Results
Q1	✓	✓	✓	✓	╳	✓	✓	✓	Accept
Q2	✓	✓	✓	✓	✓	✓	✓	?	

Conclusion

This hypothesis proposing the relationship between rich multimedia formats and a high level of attraction was supported. Most of specialist participants claimed that exhibit content using media elements is effective in attracting visitors' attention which would then allow them to learn more.

Hypothesis 2:

If the exhibit features rich multimedia formats (i.e. games or a video with high levels of interaction) it will provide a **high level of holding power** and there will be a greater possibility to improve visitors' learning experience.

	MPM #1	MPM #2	MPM #3	MPM #4	ME #1	ME #2	ME #3	ME #4	Results
Q1	✓	✓	✓	✓	✗	✓	✓	?	Accept
Q2	✓	✓	✓	✓	✓	✓	✓	✓	

Conclusion

This hypothesis was supported but in order to improve visitors' learning experience it will also depend on the quality of the content and will not have equal holding power for all groups.

Hypothesis 3:

If a web-based museum presents its information and learning resources for all **the three visitor groups** in a 3D environment, **the traditional lecture and text approach** will provide a greater potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject in ant visiting style.

	MPM #1	MPM #2	MPM #3	MPM #4	ME #1	ME #2	ME #3	ME #4	Results
Q1	✓	✓	/	✓	?	✗	✓	?	Reject

Conclusion

This hypothesis was rejected because only half of the eight interviews were inclined to support it. This may be because visitors' interaction with exhibits on their own individual routes varies from person to person, depending on their understanding of the exhibited artefacts and what exhibition content is particular interesting to them.

Hypothesis 4:

If the design of the museum environment is based on **the traditional lecture and text approach** it will encourage visitors to follow 'ant' behaviour patterns and it will lead visitors to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject.

	MPM #1	MPM #2	MPM #3	MPM #4	ME #1	ME #2	ME #3	ME #4	Results
Q1	✓	✓	✓	✗	✓	✓	✓	✓	Accept
Q2	✓	✓	?	✓	✓	✓	✓	✓	
Q3	✓	✓	✗	✓	✓	✓	✓	✓	

Conclusion

This hypothesis was supported by seven out of the eight expert interviewees. Most of the expert participants stated that a 3D museum space based on the traditional lecture and text approach is able to attract ant visitors who go through all the exhibition content step by step in a systematic manner.

Hypothesis 5:

If a web-based museum needs to present its information and learning resources for **researcher and professional visitors** as a target audience using a 3D environment, **the constructivism approach** will provide the greatest potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) and encourage a butterfly visiting style.

	MPM #1	MPM #2	MPM #3	MPM #4	ME #1	ME #2	ME #3	ME #4	Results
Q1	✓	?	?	✓	/	✓	?	✓	Reject

Conclusion

Although four participants agreed with this hypothesis stating the relationship between the constructivism approach and research and professional visitors’ behaviours, this hypothesis was rejected due to lack of the majority of the interviewees’ support.

Hypothesis 6:

If the design of the museum environment is based on **the constructivism approach** it will encourage the features of grasshopper and butterfly visitors and it will allow visitors to develop a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with selected aspects of the subject.

	MPM #1	MPM #2	MPM #3	MPM #4	ME #1	ME #2	ME #3	ME #4	Results
Q1	✓	?	✓	✓	?	✓	✓	✓	Accept
Q2	✓	?	✓	✓	✓	✓	✓	✓	
Q3	✓	?	✓	✓	?	✓	✓	✓	
Q4	✓	✗	✓	✓	/	✓	✓	✓	

Conclusion

This hypothesis was supported. Most expert participants thought that the constructivism approach is appropriate for grasshopper and butterfly visiting styles allowing visitors to create their personal routes to select exhibition content at will.

Table 6.2 An overview of the participants’ views of the proposed hypotheses

6.6 Summary

The interviews with the two types of specialists, museum project managers and multimedia experts, were conducted to determine their expert views and experience of developing 3D virtual museum environments. Four interviewees in each group were recruited from eight different institutions for this qualitative interview research.

Two key issues, the design of virtual exhibits and the development of 3D museum environment, were identified from their views and experiences. In terms of ensuing effective interaction with an exhibit, attraction was considered to be a fundamentally important factor for a successful exhibit, supporting Yahya's (1997) findings. The other factors affecting the effectiveness of interacting with an exhibit included the level of manipulation of virtual exhibits and the range of media used in the presentation of information on exhibits.

Several important pedagogic features in the 3D web-based museum environments were also identified, including different categories of media forms that improve interactive experiences and enhance visitors' understanding of knowledge. The results revealed that exhibit content in the integration of multiple media formats in a 3D museum environment is useful to explain knowledge and associated information about artefacts, supporting Paquet al's (2001) findings. Brown et al (2005) suggested that Laurillard's model for different types of learning experiences underpinned by the various categories of media forms (e.g. images, texts, videos, simulations: 3D models of artefacts, games, etc.) in virtual environments on the museum websites enables the enrichment of visitors' different learning experiences. Furthermore, hypothesis 1 regarding the relationship between rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) and a high level of attraction and hypothesis 2 concerning the relationship between rich multimedia formats (i.e. games or a video with high levels of interaction) and a high level of holding power were both supported. Thus the design of the virtual exhibits with rich multimedia formats can enhance greater visitors' learning experiences through combining both high levels of attraction and holding power.

The biggest problems in designing exhibits were identified as update and maintenance, dependence on external experts in 3D technology, difficulty in navigating the 3D environment, user interface, content creation and presentation methods for 3D models and photo-realistic exhibits. Moreover, a number of challenges in the development of 3D museum environments was identified as accurate content, the different needs of the visitors, user hardware and the download speed, navigation, fun, and the creation of 3D model artefacts or a 3D architectural environment.

Important criteria established for the successful development of the 3D online exhibitions included:

- Content needs to be rich, in-depth, accurate, and demonstrate knowledge categorization.
- The aim of 3D exhibition projects should be clear in order to select appropriate design strategies appropriate to the intended learning approaches.
- 3D virtual exhibition environments should provide opportunities for enjoyment.
- Navigation and interaction are the most important criteria for a 3D exhibition environment. Moreover, 3D exhibits should encourage visitors to learn knowledge through interactive experiences rather than passive.
- Users' hardware, browsers and cross-platform such as PCs and Macs should

be considered in order to offer full compatibility for smooth learning procedures.

Hypothesis 4 and 6 concerning the relationship between the pedagogic approaches (i.e. traditional lecture and text, and constructivism) and visiting styles (i.e. ant and, grasshopper and butterfly visiting styles) were both supported. Therefore, the design of 3D museum environment based on these two pedagogic approaches in terms of visitor pathway, the organisation of exhibit content and the layout of exhibit displays it is proposed are the most effective in presenting exhibits and associated information to encourage these particular visitor styles, leading to a deeper engagement with the subject. However, hypothesis 3 and 5 proposing that the pedagogic approaches would encourage specific visitor styles for particular visitor groups failed to be supported, presumably because visitors interacting with exhibit vary from person to person depending on their individual preferences and understanding of exhibition content, subjects, particular interests, learning aspects and so on.

The four supported hypotheses concerning exhibits with rich multimedia media for both high levels of attraction and holding power and the pedagogic approaches regarding three key design factors (i.e. visitor pathway, the organisation of exhibit content and the layout of exhibit displays) influencing the related visiting styles will be used to develop a theoretical design reference model for the effective design of a 3D museum environment. The next chapter (Chapter Seven) therefore proposes a theoretical design reference model with emphasis on facilitating the relationship between attraction and holding power of exhibits, visiting styles and the design of the 3D museum environment based on pedagogic approaches for learning efficacy.

Chapter Seven: Development and Evaluation of Theoretical Design Reference Model

7.1 Introduction

This chapter describes the development of the theoretical design reference model and the creation and testing of a prototype 3D museum exhibition to validate the theoretical model. From the results of the interview studies in the last chapter, the four supported research hypotheses include:

Hypothesis 1: If an exhibit features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) it will provide a **high level of attraction** and there will be a greater possibility to improve visitors' learning experience.

Hypothesis 2: If the exhibit features rich multimedia formats (i.e. games or a video with high levels of interaction) it will provide a **high level of holding power** and there will be a greater possibility to improve visitors' learning experience.

Hypothesis 4: If the design of the museum environment is based on **the traditional lecture and text approach** it will encourage visitors to follow 'ant' behaviour patterns and it will lead visitors to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject.

Hypothesis 6: If the design of the museum environment is based on **the constructivism approach** it will encourage the features of grasshopper and butterfly visitors and it will allow visitors to develop a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with selected aspects of the subject.

These four supported hypotheses and the key findings from the previous studies were used to propose a theoretical design reference model with emphasis on facilitating the attraction and holding power of exhibits, visiting styles and the design of 3D museum environments based on pedagogic approaches for learning efficacy. The Reeves model was chosen and modified to include three phases (i.e. analysis, design and assessment phases) as the basis for the development of a theoretical design reference model for creating a 3D museum environment. This theoretical design reference model could be employed as a tool for virtual museum designers to consider when building their 3D exhibition environments as both an informational and learning resource.

First the derivation of the proposed theoretical design reference model from the previous research findings is illustrated. The detailed framework of the theoretical model is then introduced and its three phases are presented accordingly.

The prototype of a 3D exhibition environment, “The Meanings behind the Patterns on Plates”, was created based on the analysis and design phase parts of the theoretical design reference model. The validation of the proposed theoretical design reference model was achieved through prototype evaluation using user testing and expert evaluation according to the assessment phase of the theoretical model at the end of this chapter. The findings from the results of the prototype evaluation will indicate whether the theoretical design reference model can be considered a valid design method for creating effective 3D museum environments to accommodate the associated visiting styles and ultimately improve learning efficiency.

7.2 Theoretical design reference model

As discussed in Chapter Three (Section 3.2.6), an instructional design model is a design method that enables designers to organise the learning materials and content based on appropriate pedagogic approaches in order to achieve the desired goals. As there are no current instructional design models specifically for 3D virtual museum environments for learning purposes, it is proposed that existing generic instructional design models can be employed to develop a theoretical design reference model for the design of a 3D museum environment as both informational and learning resources. There are several different types of instructional design models such as the ADDIE model, the Reeves multimedia design model and the Dick and Carey Systems Approach Model. An overview of these models for instructional design is as follows:

- ADDIE Model

This model is a systematic instructional design model consisting of five principle phases: Analysis, Design, Development, Implementation, and Evaluation (Learning Theories Knowledgebase 2008).

1. *Analysis* deals with the characteristics of learners in terms of their existing knowledge, needs and skills and intended objectives to be achieved.
2. *Design* documents specific learning objectives, assessment instruments and content.
3. *Development* focuses on completing the actual creation of the content and learning materials.
4. *Implementation* delivers or distributes these learning materials to the learner group.
5. *Evaluation* aims to assess the effectiveness of the learning materials.

- Reeves multimedia design model

In 1994, Reeves proposed a multimedia design model as a design method for the process of developing media products for educational purposes, and included four principal phases: 1) analysis, 2) design, 3) production, and 4) evaluation (Reeves 1994):

1. *Analysis* aims to plan project objectives and identify audience needs and finally specify product content.
2. *Design* is to create treatment specifications and specify pedagogic interactions.
3. *Production* focuses on the process of making media products such as audio recordings, films/movies, videos and so on, including pre-production, production and post-production.
4. *Evaluation* emphasizes the product assessment to ensure the functional effectiveness and instructional validity.

- Dick and Carey Systems Approach Model (the Dick and Carey Model)

This model describes a systematic method for designing instruction that starts by identifying instructional goals and ends with summative evaluation. This model includes the following stages (Dick and Cary 1978):

1. *Identifying an instructional goal* aims at the identification of instructional goals derived from a particular curriculum or students’ learning difficulties.
2. *Conducting an instructional analysis* is to analyze the subordinate skills to be learnt in order to achieve the desired goals.
3. *Identifying entry behaviours and characteristics* deals with the identification of specific knowledge, skills and the general characteristics of learners.
4. *Writing performance objectives* is to specify statements of instruction related to its goals and the criteria for successful performance.

5. *Developing criterion-referenced tests* focuses on the development of assessment instruments to evaluate students' ability.
6. *Developing an instructional strategy* outlines a strategy in terms of sections on pre-instructional activities, the presentation of content information, practice and feedback.
7. *Developing and selecting instruction* is to produce the instructional module, including a student manual, learning materials, tests and a teacher guide.
8. *Designing and conducting the formative evaluation* is to determine the effectiveness of the module works and to collect data for improving the modules based on the formative evaluation.
9. *Revising instruction* emphasizes a revision of instruction based on various formative evaluations.
10. *Conducting summative evaluation* 'occurs only after the instruction has been formatively evaluated and sufficiently revised to meet the standards of the designer (Dick and Cary 1978).'

According to Siemens (2002), the ADDIE model is often used in formal education (i.e. schools and colleges), academic circles or e-Learning programmes. It can be argued that this model may be not effective for designing activities or programmes for museums in the educational setting because museums are regarded as environments for informal education. Clark (2004) argues that the Dick and Carey Systems Approach Model 'details a comprehensive and detailed process, however, it has been criticized for at the same time being too rigid and cumbersome for the average design process.' The features of the Reeves multimedia design model aim to deal with developing media products for educational purposes. Therefore, this model was considered as the most appropriate model to be adopted for the development of a theoretical design reference model for creating a 3D museum learning environment on the web. This is because museum websites can be also regarded as one of the forms of mass media for communication between virtual visitors and the range of museum objects for educational purposes. However, the production phase of the Reeves model is not directly applicable to this research study which is focused on the design of a museum website rather than the production phase. As a result, the Reeves model was modified to include only three phases (i.e. analysis, design and assessment phases) as a basis for developing a theoretical design reference model for the design of a 3D virtual museum environment.

A new theoretical design reference model is proposed which consists of three phases (analysis, design and assessment phases) and each of these phases is divided into a set of specific tasks or activities:

- Phase 1: Analysis (6 tasks)

  Task 1: The aim of the 3D environment

  Task 2: Target audience

  Task 3: Selection from two pedagogic approaches

  Task 4: Selection of exhibits

  Task 5: Selection from three representational schemes

  Task 6: Selection from three dimensions of simulation

- Phase 2: Design (2 tasks)

  Task 1: Choice of rich multimedia formats

  Task 2: Three key design factors (visitor pathways, the organisation of exhibit content and the layout of exhibit displays)

- Phase 3: Assessment (2 evaluation activities)

  Activity 1: User testing (4 parts)

Part 1: Testing for the occurrence of the necessary behaviours for learning

Part 2: Testing for visiting styles and pedagogic approaches match those predicted

Part 3: Testing performance of tasks

Part 4: Post-visit questionnaire

Activity 2: Expert evaluation

Each phase in the proposed theoretical design reference model and its specific tasks or activities are derived from the findings of this PhD research and are shown in Table 7.1.

Research Findings		**Analysis Phase**	**Design Phase**	**Assessment Phase**
Literature Review	Web-based virtual museum	Task 1: The aim of the 3D environment	Task 2: Three key design factors (organisation of exhibit content)	Activity 1: User testing Part 4: Post-visit questionnaire (Informational aspects) Activity 2: Expert evaluation
	Museum theory	Task 1: The aim of the 3D environment Task 4: Selection of exhibits Task 5: Selection from three representational schemes	Task 2: Three key design factors (organisation of exhibit content and layout of exhibit displays)	Activity 1: User testing Part 4: Post-visit questionnaire (Informational aspects) Activity 2: Expert evaluation
	Informational and learning resource	Task 1: The aim of the 3D environment Task 4: Selection of exhibits	Task 2: Three key design factors (organisation of exhibit content)	Activity 1: User testing Part 4: Post-visit questionnaire (Informational and learning aspects) Activity 2: Expert evaluation
	Visitor study	Task 1: The aim of the 3D environment Task 2: Target audience	Both tasks	Activity 1: User testing Part 2: Testing for visiting styles and pedagogic approaches match those predicted (Visiting styles) Activity 2: Expert evaluation
	Educational theories	Task 1: The aim of the 3D environment Task 3: Selection from two pedagogic approaches	Task 2: Three key design factors (organisation of exhibit content and layout of exhibit displays)	Activity 1: User testing Part 2: Testing for visiting styles and pedagogic approaches match those predicted (Pedagogic approaches) Part 4: Post-visit questionnaire (Learning aspects) Activity 2: Expert evaluation

	Virtuality and simulation theory	Task 1: The aim of the 3D environment Task 6: Selection from three dimensions of simulation	Task 2: Three key design factors (organisation of exhibit content)	Activity 1: User testing Part 4: Post-visit questionnaire (Informational aspects) Activity 2: Expert evaluation
	3D web technologies	/	Both tasks	Activity 1: User testing Part 3: Testing performance of tasks Part 4: Post-visit questionnaire Activity 2: Expert evaluation
Critical Review		Task 1, 2, 3, 5 and 6	Task 1: Choice of rich multimedia formats Task 2: Three key design factors (organisation of exhibit content)	/
Observation Studies		Task 2: Target audience Task 3: Selection from two pedagogic approaches	Both tasks	Activity 1: User testing (all four parts)
Interviews		Task 1: The aim of the 3D environment Task 3: Selection from two pedagogic approaches	Both tasks	Activity 2: Expert evaluation

Table 7.1 An outline of the theoretical model derived from the research findings

The analysis phase was mainly derived from the literature review and the critical review. The analysis phase systematically addresses all six tasks in the analysis needed for the development process of a 3D virtual museum. In task 3, from the results of the observation and interview studies, two pedagogic approaches (i.e. traditional lecture and text, and constructivism) are selected because they were shown to effectively encourage the related visiting style(s), leading to a deeper engagement with the thematic content. In task 5, three representational schemes based on a semiotic perspective are effective to interpret meanings of physical artefacts in virtual museums on the websites. In task 6, each of three dimensions of simulation is related to a degree of virtuality according to the types of museums for communicating their contextual information and historical and cultural significance.

The design phase was derived from the observation studies showing a range of design factors that contribute to the effective design of a 3D virtual museum environment, together with the four supported hypotheses from the results of the interview studies. Hypothesis 1 and 2 concerning exhibits with rich multimedia formats to enhance visitors’ learning experiences through high levels of attraction and holding power are embedded in task 1. Hypothesis 4 and 6 concerning the two pedagogic approaches in terms of three key design factors (i.e. visitor pathway, the organisation of exhibit content and the layout of exhibit displays) to encourage the related visiting style(s), leading to a deeper engagement with the subject are embedded in task 2.

The assessment phase contains two evaluation activities: user testing and expert evaluation. As mentioned in Chapter Three, Karoulis et al (2006) stated that ‘the most applied methodologies are the expert-based and the empirical (user-based) evaluation.’ Both evaluation methodologies can be employed to analyse the usability and effectiveness of museum websites, such as Harms and Schweibenz’s (2001) work. A combination of both evaluation methodologies was therefore adopted to validate the theoretical model through evaluation of a prototype 3D exhibition. The derivation of the assessment phase through user testing was mainly from the observation studies and partly from the literature review and includes all four parts. These four parts include important elements (e.g. pedagogic approaches, visiting styles, interaction metaphors, information architecture and so on) or measures (e.g. attraction and holding power) for evaluating effectiveness of a 3D virtual museum exhibition in educational settings. The expert evaluation in the assessment phase was derived from the literature review and interviews. The assessment phase shows the detailed practices and techniques for the two evaluation activities in the evaluation of the 3D virtual museum environment on the web.

Based on the Reeves model, the proposed theoretical model consists of three phases for developing a 3D museum environment, namely, an analysis phase, a design phase and an assessment phase. The three phases were considered as essential elements of the design method for the development of a 3D museum environment during the design process. An overview of the theoretical design reference model is shown in Figure 7.1.

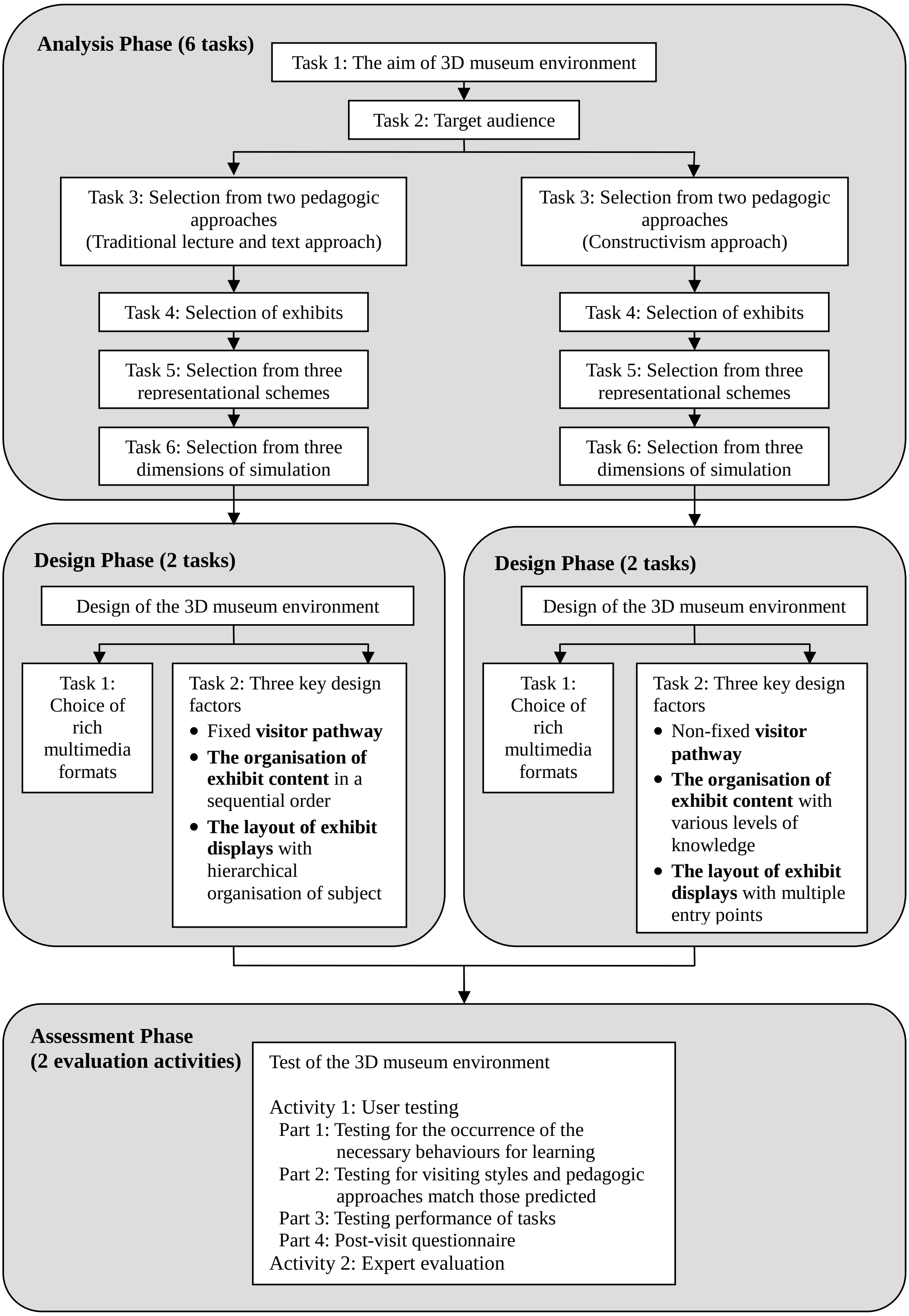


Figure 7.1 An overview of the theoretical design reference model

The analysis phase includes six tasks, notably the aim of 3D museum environment, target audience, selection from two pedagogic approaches, selection of exhibits, selection from three representational schemes and three dimensions of simulation. The design phase addresses two tasks in terms of choice of rich multimedia formats and the three key design factors influencing the visitor's behaviours in 3D virtual museum environments identified in the two earlier primary research works (observations and interviews). The assessment phase presents two evaluation activities which are user testing and expert evaluation. User testing includes four parts: testing for the occurrence of the necessary behaviours for learning during free navigation, testing whether the visiting styles and pedagogic approaches match prediction, testing performance through a range of tasks and post-visit questionnaires. Expert evaluation is to assess the prototype 3D exhibition by experts who have experience of developing 3D museum environments or are knowledgeable in the field of museums. It is proposed that this theoretical design reference model could be employed as a tool for virtual museum designers to create an effective 3D web-based museum environment based on the intended pedagogic approach which encourages specific visitor styles for learning efficacy.

7.2.1 Analysis phase

In this phase there are six tasks. The first task is to establish the aim of 3D museum environment, followed by the determination of the target audience. The following tasks based on the nature of the target audience are the choice of appropriate pedagogic approach, selection of exhibits and selection from three representational schemes. Choosing from the three dimensions of simulation is the final task.

Task 1: The aim of 3D museum environment

At this stage, virtual museum designers need to define the aim of the 3D museum environment i.e. the way in which knowledge and information on museum collections are presented, taking into account ideas for an exhibition, scope of collections, educational goals and so on.

Task 2: Target audience

Once the aim of the 3D museum environment has been established, an agreement and clear definition of the target audience(s) is of fundamental importance in order to organise appropriate exhibit content and learning activities for their needs. Virtual museum designers need to make these decisions in consultation with the museum curator.

Task 3: Selection from two pedagogic approaches

In order to effectively communicate the different meanings of artefacts which can be learnt, it is important to select appropriate pedagogic approaches to construct the exhibition content in the 3D museum development in order to ensure effective museum education.

- Traditional lecture and text approach

The key features of this approach are to arrange a hierarchy of exhibition content in an orderly manner using a direct visitor route with a clear beginning and a specific end. The exhibit content needs to be arranged to reflect the true structure of the subject matter in a didactic context (Hein 1995). This approach is employed to arrange exhibit content when the subject matter is about facts, stories or chronological context. The information content is divided into small digestible pieces in a logical order and visitors learn these in the systematic manner intended (Black 2005).

- Constructivism approach

The key features of this approach are to provide multiple points of entry for visitors with prior understanding and/or experience by which they can construct their own understanding through active learning modes (Hein 1995). This approach is used to organise exhibit content when the subject matter is about concepts rather than facts – ‘in order to build on existing experience to construct new meanings, visitors will require an understanding of the “whole” as well as parts, and parts must understood in the context of the whole (Black 2005).’

Task 4: Selection of exhibits

Museum artefacts can contain various themes and meanings ‘when they are presented or grouped with a different collection of companions’ on display in the same museum exhibition (Hooper-Greenhill 1991). Thus virtual museum designers should consider that exhibits with a number of accompanying museum artefacts need to be appropriately chosen with reference to the exhibit significance, meanings and messages which a virtual museum is intended to present or communicate. Moreover, selection of exhibits needs to relate to the aim of 3D exhibition environment.

Task 5: Selection from three representational schemes

In this stage, selection from three modes of representational schemes is based on a semiotic approach to interpret meanings of physical artefacts in virtual museums (see Section 2.3.1). These three representational schemes are necessary for virtual museum designers to organise exhibit contents and the subject matter through the interpretation of physical artefacts depending on the meaningful significances and contexts afforded by them. The three representational schemes proposed by Tang

(2005) include:

- Narrative-centered

The objects are arranged by a narrative which is a text structured through the time sequence of the events, conveying a message by invoking historical significance. This scheme seems to be appropriate for the traditional lecture and text approach as the subject matter is in a chronological order using (hi)story-telling method allows visitors to follow exhibit content from a clear beginning to a special end.

- Object-centered

The objects are organised to emphasize inherent value of artefacts in the traditional sense of museums, interpreting aesthetic values and cultural context and meaning. This scheme appears to be suitable for the constructivism approach as artefacts are arranged in a subject-based way to present concepts of values of beauty and cultural significance that allow visitors to connect the concepts based on their past and current knowledge.

- Information-centered

The objects are structured to illustrate the images with accompanying interpretation text suited to the information transmission model of a museum. This can be applied most widely in explaining the visual documentation of the natural specimens of animals and insects and the demonstration of scientific process and natural phenomena. This scheme may be suitable for the constructivism approach because the constructivist layout of displays provides a range of thematic subjects with multiple entry points in a more active way for self-directed exploration through various levels of knowledge and a large amount of associated information related to the interpretation of the underlying information of exhibits and the different layers of content.

Task 6: Selection from three dimensions of simulation

Once the mode of representational scheme has been selected, virtual museum designers can choose one of the three dimensions of simulation for the presentation of virtual exhibits. This is because the simulation of an exhibit should highlight the messages signified which needs to be conveyed through the representational schemes. These depend on what historical and cultural meanings and contextual information need to be interpreted (see Section 2.7.1). The three dimensions of simulation are as follows:

- Reconstruction

The reconstructed cultural materials (e.g. historic sites, artefacts and archaeological structures etc.) are presented within a virtual museum environment for virtual visitors to visually appreciate the original appearance of archaeological buildings and places through accurate simulation using computer-generated models.

- Reproduction

Reproduction of original artefacts in a virtual museum, especially for an art museum website, is always regarded as an iconic signifier which should be as close to the original as possible.

- Representation

Representation of an artefact in a museum website such as a science museum is often considered as a symbolic signifier in order to focus on the underlying scientific principle(s) through the digital representation of the original.

7.2.2 Design phase

Based on the findings of the observations and interviews, the design phase involves the arrangement of exhibits with rich multimedia formats in a 3D online museum environment based on the chosen pedagogic approach and visitor pathways, the organisation of exhibit content and the layout of exhibit displays for learning efficacy. This design phase includes two tasks as follows:

Task 1: Choice of rich multimedia formats

As mentioned earlier (Section 5.5.3.1), regarding the learning process in museums, exhibits' attraction and holding power are identified as necessary steps to learning: attraction (visitors who stop at the exhibit) and holding power (time spent by visitors at the exhibit) (Wolf 1985 and Yahya 1997). Earlier research (the observation studies and interviews) indicated that the design of effective exhibits in a web-based 3D museum environment needs to both attract and engage visitors through the use of rich multimedia formats. It was found that attraction levels were highest for the exhibits which employed multiple media formats or 3D model artefacts combined with in-depth interpretive content and information; holding power was highest for the exhibits which used games or videos with high interaction.

As discussed in the literature review (see Section 2.5.2), the diverse types of learning experiences underpinned by the various categories of media forms corresponding to specific methods (e.g. images, texts, videos, simulation of 3D artefacts, games, etc.) in web-based virtual museum environments can enable the enrichment of visitors' different learning experience as shown in Table 7.2 (Brown et al 2005).

Learning experience	**The use of methods**	**Media forms**
Attending, apprehending	Texts, graphics, audios, videos, animations, etc.	Narrative
Investigating, exploring	Online museum library, catalogues, databases, search engines, hypermedia (e.g. hypertext), etc.	Interactive
Discussing, debating	Emails, online conferencing, online discussion boards, chat rooms, etc.	Communicative
Experimenting, practising	Simulations, virtual environments, educational games, etc	Adaptive
Articulating, expressing	Production, modelling, etc.	Productive

Table 7.2 The use of media and methods and the types of learning experience

(Source: adapted from Laurillard's (2002) model)

In addition, the final choice of methods and media would also be influenced by time, cost, resources and multimedia skills available.

Task 2: The three key design factors: visitor pathways, the organisation of exhibit content and the layout of exhibit displays

Within this stage, a 3D museum environment is developed based on the intended pedagogic approach which encourages specific visitor style(s), leading visitors to a deeper engagement with the subject. This can be achieved by employing suitable visitor pathways, organisation of exhibit content and layout of exhibit displays in a 3D virtual space depending on the pedagogic approach. The detailed suggestions are provided to guide virtual museum designers to create an effective 3D museum environment based on its intended pedagogic approach for the improvement of learning efficiency as follows:

The design of the 3D environment based on the traditional lecture and text approach

- A fixed **visitor pathway** should be provided so that ant visitors can follow the exhibition content step by step in a systematic manner.
- **The organisation of exhibit content** should be arranged in a sequential order so that ant visitors can learn thematic content from beginning to end.
- **The layout of exhibit displays** should provide a hierarchical organisation of the subject in order to encourage ant visitors to learn knowledge from the simple to the complex in a particular context.

The design of the 3D environment based on the constructivism approach

- A non fixed **visitor pathway** should be provided so that grasshopper and butterfly visitors can create their own individual and exploratory routes to actively interact with exhibits for learning.
- **The organisation of exhibit content** should provide various levels of knowledge in order to encourage grasshopper and butterfly visitors to choose the exhibit content they desire, constructing the meanings of artefacts through their prior experiences and knowledge.
- **The layout of exhibit displays** must provide multiple entry points for grasshopper and butterfly visitors to construct knowledge in the way they choose.

7.2.3 Assessment phase

The final phase is to assess the success and effectiveness of a prototype 3D museum environment in terms of its intended pedagogic approaches through two evaluation activities: user testing (observations combined with performance tasks and questionnaires) and expert evaluation (semi-structured interviews). The purpose of these evaluation activities in this particular study is also to test the theoretical model in order to make changes that improve the proposed theoretical model if necessary.

Activity 1: User testing

The user testing is conducted with visitors interacting with exhibits in a museum exhibition after they have been presented in order to understand how effective and successful the exhibition is in presenting the exhibit contents and activities. The observational techniques and practices used in the previous observation studies (Chapter Five) were useful to identify visitors' interactions with exhibits (i.e. the occurrence of the necessary behaviour for learning) and their visiting styles within the 3D exhibition. Thus the evaluation of the new 3D museum environment through user testing will employ the same approach to that taken in the observation studies. The target audience in this evaluation will include three typical types of visitors (i.e. general public, researchers and professionals, and schools) as proposed by Bowen et al's (2001) classification. The same number of subjects (i.e. ten subjects in each visitor group will be recruited based on non-proportional stratified random sampling method, giving a total number required as thirty) is based on Diamond's (1999) recommendation. User testing contains four parts in the assessment phase as follows:

Part 1: Testing for the occurrence of the necessary behaviours for learning during free navigation

Within this stage, the effectiveness of a virtual exhibit and its content is accessed through user testing by measuring the prerequisite behaviour for learning to occur according to the two observational measures (see Observations Chapter Five, Section 5.5.3.1):

- Attraction: visitors who stop at exhibit images or click on exhibit images for additional information about them for at least 5 seconds.

- Holding power: amount of time spent by visitors interacting with exhibits.

Part 2: Testing whether visiting styles and pedagogic approaches match those predicted

Within this stage, the occurrence of specific visiting styles in the 3D museum environment will indicate whether the environment based on a particular pedagogic approach encourages visitors to follow the related visiting style(s), leading to a deeper engagement with exhibits and the subject matters. For example, the design of a museum environment is based on **the traditional lecture and text approach** to encourage visitors to follow ant visiting style (hypothesis 4); the design of the museum environment is based on **the constructivism approach** to encourage visitors to follow grasshopper and butterfly visiting styles (hypothesis 6).

Part 3: Testing performance through a range of tasks

During this stage, visitors are asked to perform a series of tasks in the 3D museum environment in order to evaluate how effective the information architecture and navigation paths are presented to visitors (see Section 5.5.3.2). The rational of establishing a series of tasks is based on two parts:

1. Interaction metaphors (e.g. an exhibit icon with indication of the exhibit name when the cursor is moved over individual exhibit images) used in navigation paths.
2. Information architecture and different media presentation formats (e.g. combinations of texts, images, photographs, videos, audios, 3D models, games and so on) used in exhibit content.

In the first part of testing performance, the participants are asked to find the specified exhibits in the 3D museum environments in order to measure the effectiveness of interaction metaphors used in navigation paths. In the second part of testing performance, the participants interact with individual exhibits and additional information using different media presentation formats during learning experience in order to evaluate the effectiveness of information architecture.

Three measures (refer to Chapter Five Section 5.6.2.2), percentage of success, average time and range of completion times, are used to judge each task in the 3D exhibition.

Part 4: Post-visit questionnaires

The purpose of the post-visit questionnaire is to collect data regarding visitors' subjective evaluation of a 3D museum environment. The questionnaire covers a number of issues, including immersion, presence, usability (i.e. metaphors, orientation, navigation and integration of multiple media formats) and informational and learning aspects.

Activity 2: Expert evaluation

Expert evaluation in the assessment phase is conducted by semi-structured interview with a museum project manager and a multimedia expert. This expert evaluation is the same approach to that taken in the interview studies (Chapter Six). This is because the method of semi-structured interviews can qualitatively determine the specialist respondents' point of view and perspectives on a prototype 3D exhibition in order to assess the theoretical design reference model. A series of issues for assessment include immersion, presence, usability (i.e. metaphors, orientation and navigation), attraction, holding power and pedagogic approaches. These issues are examined using open-ended questions which are covered with each expert who is knowledgeable about the design of the 3D online museum environment. It is also intended that the 3D exhibition prototype design's assessment by the experts could also include suggestions for improvements if necessary.

In using an open-ended question format in this expert evaluation, the four categories of questions (i.e. experience and behaviour, opinion and values, knowledge, and background and demographic questions) is employed to construct semi-structured interviews with the sequence of questions (refer to Chapter Six Section 6.4.3). The use of the question types and the sequence of questions in the expert interviews are as follows:

1. Experience and behaviour questions: these questions at the beginning of the interview are to ask experts about relevant experiences in their work in the form of direct descriptions.
2. Opinion and values questions: the opinion and values questions used were to identify experts' opinions, values and judgments on the designed prototype based on the proposed theoretical model.
3. Knowledge questions: the knowledge questions in interviews depend on the context (Patton 2002). It can be useful to ask knowledge questions by following up experience questions which have a bearing on knowledge.
4. Background and demographic questions: such questions are presented at the end of the interviews in order to identify experts' personal information on age, education, occupation, role etc.

7.3 Design of the prototype 3D museum environment

7.3.1 Project brief

The purpose of producing a prototype 3D virtual exhibition is experimentally to validate the theoretical design reference model through two evaluation activities: user testing and expert evaluation. The project is in collaboration with the Taipei County Yingge Ceramics Museum in Taiwan. This museum was selected for collaboration because it is the first major museum entirely devoted to ceramic art in Taiwan and has strong learning goals and provides educational activities through its virtual museum learning environments on the website. In addition, this museum plays a significant role in shaping national identity through its ceramic collections due to its “very strong Chinese folk culture connections” between Taiwan and Mainland China.

The museum houses a large number of collections of ceramic artefacts including earthenware, stoneware and porcelain. The museum’s vast collections can be classified into five categories of ceramics: ‘for daily use, for architecture, for sanitation, of art, and for industry (Taipei County Yingge Ceramics Museum, 2004).’ In addition, the history of the Yingge ceramics is regarded as the best representative of the development of modern ceramics and the modern ceramics industry in Taiwan.

As the Yingge collection of various patterns on pottery such as eating utensils for daily use is so well-known, the aim of this project is to design a working prototype 3D virtual web-based exhibition (Figure 7.2) (refer to Appendix 7A for index.html), “The Meanings behind the Patterns on Plates”, with emphasis on symbolic meanings of the different patterns on ceramic plates in Taiwanese and Chinese folk culture.

These decisions were made by the researcher in consultation with a chief of Collection & Exhibition Department in the Taipei County Yingge Ceramics Museum.

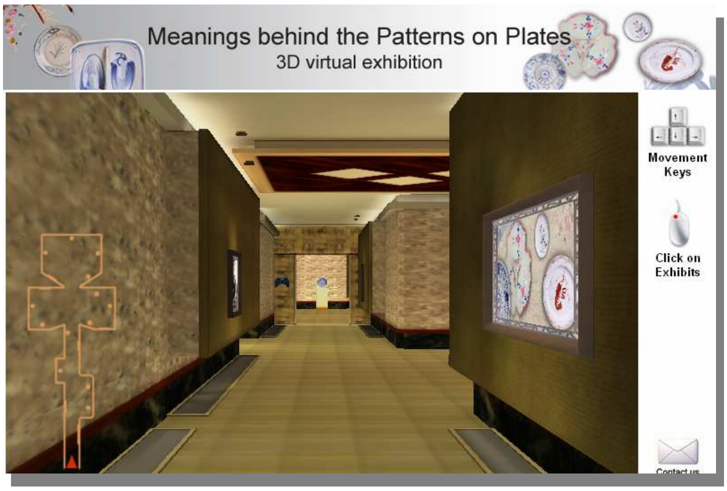


Figure 7.2 the prototype 3D virtual exhibition

The following two subsections illustrate how the theoretical model was applied as part of the analysis and design phases of the prototype.

7.3.2 Application of the theoretical model

The prototype 3D virtual exhibition was developed based on the analysis and design phases of the theoretical design reference model. This section presents the application of the analysis and design phases.

7.3.2.1 Analysis phase

This subsection describes the six tasks of the analysis process of the prototype:

Task 1: The aim of 3D museum environment

The main purpose of the prototype 3D virtual exhibition is to communicate the significance and metaphorical meanings behind the different patterns on ceramic plates in Taiwanese customs and Chinese folk culture. Moreover, the exhibition is devoted to revealing technological possibilities and cultural values through their material, form, decoration and production from the Ching Dynasty to the modern Taiwan. The aim was determined with the chief at Collection & Exhibition Department in order to incorporate the framework of the museum mission, scope of collections, audience needs and so on. Virtual visitors can be stimulated by a number of learning programmes such as games, a video and rich multimedia formats to perceive the cultural meanings and value of aesthetic of diverse patterns on plates in the 3D virtual exhibition as an informational and learning resource.

Task 2: Target audience

After discussing with the chief at Collection & Exhibition Department, the aim of the prototype 3D virtual exhibition attempts to present exhibit content to a wide audience. Thus the exhibition was developed for three typical groups of visitors (i.e. the general public, researchers and professionals and schools) who vary in background, ability, level of skills, interests and knowledge. The general public may have general interests in ceramic plates in the historical and industrial contexts. Expert visitors may be interested in specific ceramic plates in terms of cultural significance related to their professional needs or studies. School students in the age range of 11-18 can search basic information for their homework or assignments. Teachers might prepare a visit plan or use the exhibit content as teaching materials in their educational activities.

Task 3: Selection from two pedagogic approaches

Based on the aim of the 3D exhibition, two pedagogic approaches were used in the prototype 3D exhibition because they were shown to be effective in 3D virtual environments to encourage a diverse range of visitor style(s), leading to a deeper engagement with the subject matter. The traditional lecture and text approach is used to explain historical perspectives and chronological events based on hierarchical layout of exhibit displays in a linear visitor route that helps visitors to acquire knowledge of exhibit content step by step. The constructivism approach is employed to interpret cultural meanings and various patterns' aesthetic values through a range of points of view and numbers of entry levels that allow visitors to select exhibition content as they desire, constructing their own learning.

Task 4: Selection of exhibits

In order to achieve the aim of the 3D exhibition, appropriate exhibits were considered in terms of their significance when they are grouped. There are three common themes in the painting of ceramic plates, namely fish, flowers, and crabs and prawns (Jian 2001). Ceramic plates decorated with these three common themes were selected as groups of artefacts for cultural interpretation of concepts of symbolic patterns using the constructivism approach. In addition, a number of artefacts was chosen to interpret the historical context section of the exhibition such as the time and place of their production and the introduction of new ceramic techniques in the different stages using the traditional lecture and text approach.

Due to limited photographic access to several well-known plates on display in the current exhibitions, a number of artefact images was obtained from books or the museum websites. In addition, several artefacts from a collection of pottery in the museum storage were selected for modelling 3D artefacts. Figure 7.3 shows the process of taking photographs of the selected artefacts in the repository of the museum.

Figure 7.3 Taking photographs of the selected artefact

Task 5: Selection from three representational schemes

Two representational schemes, narrative-centered and information-centered, were selected to place exhibits in appropriate locations within the 3D exhibition space based on the selected artefacts relation to the aim of the exhibition. For the traditional lecture and text approach, exhibits were arranged in a linear exhibition space (Figure 7.4 marked by a red line) using a narrative-centered scheme in order to interpret the history of Taiwanese plates, including tableware production in early times, the application of pigments in chronological order, the obtaining of clay sources, trade in household ceramics and so on.

For the constructivism approach, exhibits were organised in three exhibition rooms (Figure 7.4 marked by a blue line) employing an information-centered scheme to explain cultural values and the semiotics of the pattern designs (i.e. fish, flowers, and crabs and prawns) in terms of Taiwanese folk culture and

Chinese customs with discussion of motifs and aesthetic concepts, and provision of associated information about plate sizes, forms, painting skills, manufacturing techniques and so on.

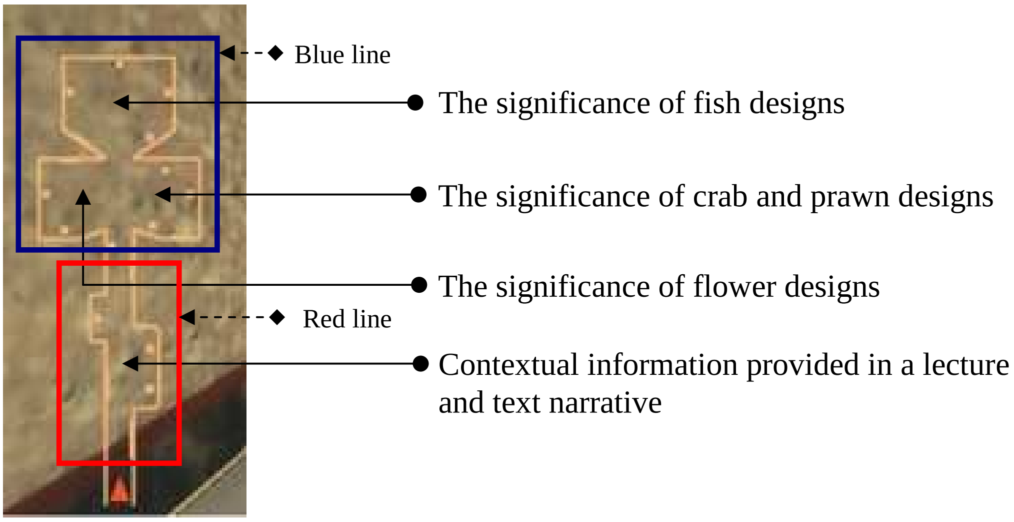


Figure 7.4 The 3D exhibition space

Red: a linear exhibition space based on the traditional lecture and text approach
Blue: three exhibition rooms based on the constructivism approach

Task 6: Three dimensions of simulation

The physical artefacts and the prototype exhibition were presented based on the different dimensions of simulation relate to levels of realism as follows (Table 7.3):

	Exhibition	**Artefacts**
Simulation dimensions	Representation	Reproduction
Realism levels	Abstraction	Hyper realities

Table 7.3 The 3D model artefacts and the 3D exhibition based on the dimensions of simulation relate to levels of realism

- **Exhibition**

Based on the two pedagogic approaches chosen, the prototype 3D exhibition (Figure 7.5) was designed as an imaginary exhibition which is not intended to create a replica of the existing physical exhibition in its architectural environment. This is because the designed prototype needs to construct its visitor pathways, the organisation of exhibit content and the layout of exhibit displays more flexibly and effectively without physical constraints and geographic limitations. Moreover, the creation of the 3D exhibition is a realistic 3D exhibition representation with a high quality of visual information that contributes to an immersive environment in order to give visitors a sense of presence with a feeling of truly being in an actual museum.

Figure 7.5 The imaginary 3D exhibition

- Artefacts

The patterns on the selected artefacts not only contain significant meanings but also contain values of beauty. Thus the reproduction of the chosen artefacts (Figure 7.6) was used in the prototype exhibition in order to present aesthetic values of the patterns through their visual expression as an iconic signifier as close to the original as possible. This 3D model artefact was produced by 3D

Studio Max for modelling and mapping texture from photographs of the authentic artefact. Besides, the reproduction of the authentic artefacts was accurately created by high-resolution and vivid visual information which give a realistic feeling of viewing the physical patterns themselves.

Figure 7.6 The realistic reproduction of a 3D model artefact

7.3.2.2 Design phase

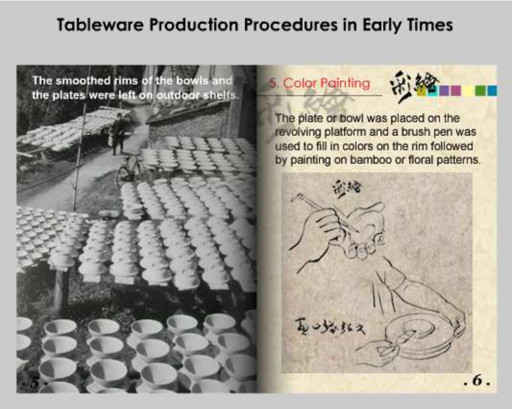
For each exhibit, different presentation methods were chosen, including combinations of photographs, images, 3D models, textual descriptions, videos and games in order to both attract and engage visitors within the 3D exhibition. The prototype exhibition space was created based on the two pedagogic approaches (i.e. traditional lecture and text, and constructivism).

Task 1: Choice of rich multimedia formats

Rich multimedia presentation formats were used in exhibits in order to provide high levels of attraction and holding power. The previous research findings (i.e. the observation studies and interviews) indicated that exhibits using multiple media formats (e.g. photographs, images and texts) or 3D models combined with in-depth interpretive content and associated information provide high levels of attraction; exhibits employing games or videos with high interaction provide a high level of holding power. Moreover, the different types of visitors' learning experiences can be underpinned by the distinct categories of media forms in virtual museum environments (Brown et al 2005) (see Section 7.2.2).

- Attraction

Exhibits using multiple media formats, "Tableware Production" (Figure 7.7), or 3D models such as **"**Small Blue and White Plate with Crab Patterns**"** (Figure 7.8) combined in-depth interpretive content and information to provide a high level of attraction in order to raise visitors' attention on the topics.



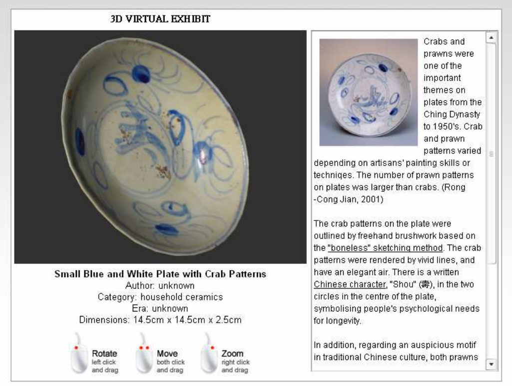
Tableware Production Procedures in Early Times

The smoothed rims of the bowls and the plates were left on outdoor shelfs.

5. Color Painting

The plate or bowl was placed on the revolving platform and a brush pen was used to fill in colors on the rim followed by painting on bamboo or floral patterns.

Figure 7.7 Tableware Production using multiple media formats



3D VIRTUAL EXHIBIT

Small Blue and White Plate with Crab Patterns
Author: unknown
Category: household ceramics
Era: unknown
Dimensions: 14.5cm x 14.5cm x 2.5cm

Crabs and prawns were one of the important themes on plates from the Ching Dynasty to 1950's. Crab and prawn patterns varied depending on artisans' painting skills or techniqes. The number of prawn patterns on plates was larger than crabs. (Rong -Cong Jian, 2001)

The crab patterns on the plate were outlined by freehand brushwork based on the "boneless" sketching method. The crab patterns were rendered by vivid lines, and have an elegant air. There is a written Chinese character, "Shou" (壽), in the two circles in the centre of the plate, symbolising people's psychological needs for longevity.

In addition, regarding an auspicious motif in traditional Chinese culture, both prawns

Figure 7.8 Small Blue and White Plate with Crab Patterns using

a 3D model combined with in-depth interpretive content

Tableware Production (Figure 7.7) describes the procedures for producing household ceramics with emphasis on plates in early times through the integration of multiple media formats (i.e. texts, images and photographs). The integration of multiple media formats used in this exhibit is very helpful in interpreting additional information about the exhibit like the obtaining of clay sources, ceramic plats of industrial techniques, pattern designs on plates and package delivery. Moreover, this exhibit was designed as an illustrated book using Adobe Flash. Visitors are allowed to virtually flip the book to *apprehend* and *comprehend* knowledge in a narrative using linear media formats (i.e. texts, images and photographs).

Small Blue and White Plate with Crab Patterns is a 3D model artefact which combines in-depth cultural and contextual interpretation by offering relevant links to associated information for the specification of the exhibit. For example, associated information about Chinese characters as patterns on plates (Figure 7.9) and boneless sketching method (Figure 7.10) used in the original artefact is provided by hypertext and pop windows. Moreover, the simulation of the 3D model plate with crab patterns provides the visitor with a *practical* experience of aesthetic appreciation in terms of shape, pattern design and style. Relevant links to associated information about the exhibit using hypertext allows virtual visitors to discover content in an interactive way for *investigating and exploring* learning experience.

Chinese characters as patterns on plates

Chinese characters used as patterns on plates were also one of the popular subjects. "Fu" (福) (good wishes) (Figure 1), "Shou" (壽) (longevity) (Figure 2), "Lu"(祿) (prosperity) and "Xi" (囍) (happiness) (Figure 3) were commonly used in plates or dishes in the early Taiwan era, representing people's collective psychological needs in a society. On the whole, these written or printed Chinese characters are based on the various styles of calligraphy such as running script, grass script, regular script and so on.

Figure 1 Painted Fu Character Plate

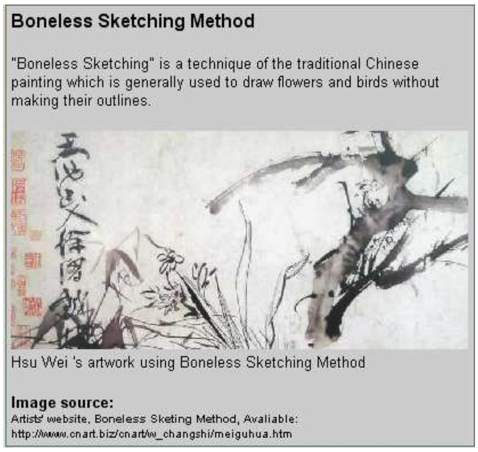
Figure 2 Painted Shou Character Plate

Figure 3 Big Plate with Phenix Patterns and Xi Character

Image Source:
Yingge Ceramics Museum, Collection search, Available: http://digital.ceramics.tpc.gov.tw/Web/collection/Search.aspx

Taipei County Yingge Ceramics Museum (2002), Beauty of daily life-Yingge Tableware: Blessings and Wishes of People, Available: http://www.ceramics.tpc.gov.tw/Mweb/download/taubo/main_e.htm

Figure 7.9 Chinese characters as patterns on plates



Boneless Sketching Method

"Boneless Sketching" is a technique of the traditional Chinese painting which is generally used to draw flowers and birds without making their outlines.

Hsu Wei 's artwork using Boneless Sketching Method

Image source:
Artists' website, Boneless Sketing Method, Avaliable:
http://www.cnart.biz/cnart/w_changshi/meiguhua.htm

Figure 7.10 Boneless sketching method

- Holding power

Exhibits employing games, “Recognising 5 Patterns” (Figure 7.11) and “Jigsaw Puzzle” (Figure 7.12) or the video, “Blue and White Drawing”, (Figure 7.13), are media rich with high interaction and provide a high level of holding power in order to engage visitors to interact with exhibit content for a long period of time. Recognising 5 Patterns was created to help visitors recognise the five common patterns on the plates. Visitors can be helped to memorise the five patterns by playing the game or looking at a list of the five plates provided within the game. The Jigsaw Puzzle game provides two parts, namely, jigsaw puzzle with the photograph of the ceramic plate and Question & Answering (Q&A). Visitors are required to finish the first part, jigsaw puzzle, within 50 seconds and then carry on to the second part: Q&A. The purpose of the Q&A is to ask visitors questions about decorative style and cultural meanings behind the plate. They can obtain knowledge of the plate in the gaming environment through this evaluative reinforcement. To aid this process, feedback is provided by clues when visitors provide the wrong answers. Both educational games provide the potential for visitors to gain knowledge during *practising* experience based on "direct intrinsic feedback" on visitors' action in the learning process.

Can you recognise patterns on the plates?

How to Play Game

Click on the right plate 10 times during the game, you'll win!
If you click on the wrong plate 3 times during the game, you'll lose!

I want to know the plates first!

Please choose a tool to play game!

Figure 7.11 Recognising 5 Patterns

Jigsaw Puzzle

Time Remaining: 46

Please drag 9 pieces to their correct position in this frame !

Source: Taipei County Yingge Ceramics Museum

Figure 7.12 Jigsaw Puzzle

Figure 7.13 Blue and White Drawing

The video content (Figure 7.13) presents an introduction to the blue and white drawing skills through the artist's performance, and was originally produced by the Yingge Ceramics Museum. This video clip was designed with English subtitles and interaction through a control bar. This allows visitors to manipulate the bar to look at specific information based on their personal preferences. Blue and White Drawing using the video provides an opportunity to support visitors' *attending and apprehending* experience.

Task 2: The three key design factors: visitor pathways, the organisation of exhibit content and the layout of exhibit displays

The prototype 3D exhibition was designed based on two pedagogic approaches: traditional lecture and text, and constructivism. This was achieved by designing suitable visitor pathways, organisation of exhibit content and layout of exhibit displays in the 3D exhibition space depending on the pedagogic approach which would encourage specific visitor styles, leading visitors to a deeper engagement with the subject matter. For each pedagogic approach, the three key design factors can be further explained as follows:

The traditional lecture and text approach

- A fixed **visitor pathway** (Figure 7.14 marked by a red line) was provided by creating a linear exhibition space. Thus ant visitors can follow the exhibition content step by step in a systematic manner.

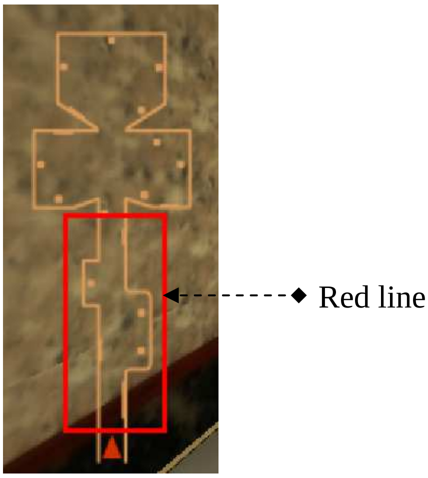
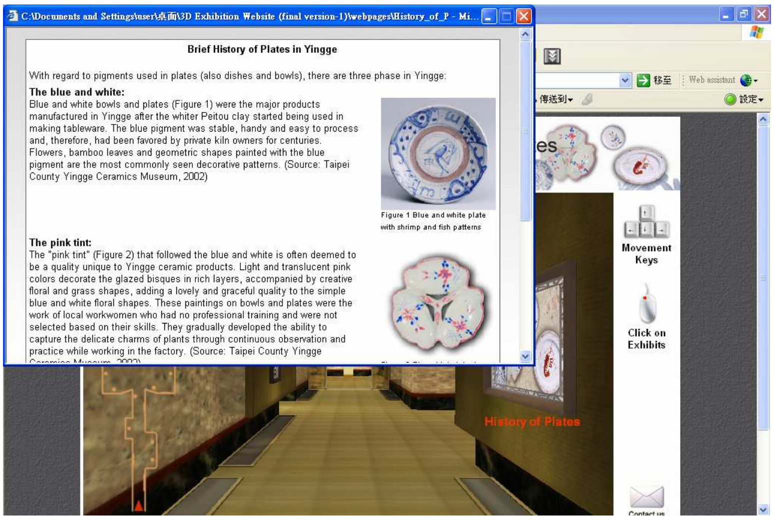


Figure 7.14 A fixed visitor pathway in the liner exhibition space

- **The organisation of exhibit content** was arranged in a sequential order, including three stages: 1) a brief history of ceramic plates, 2) the procedure for producing plates in early times and 3) the three phases of the application of the ceramic pigments in plates with pattern designs. In the first stage, a brief history of ceramic plates in terms of the application of pigments in chronological events is included. The second stage provides sequential information about the Yingge ceramics industry through “Tableware Production” (Figure 7.15). This exhibit content was organised as an illustrated book which systematically explains the procedures for producing household ceramics in early times. The final stage provides detailed information about the three phases of the application of the ceramic pigments in the specific plates with different pattern designs. In addition, the video in this stage presents sequential information on how to apply blue and white decoration to a plate with the different painting skills through the artist’s performance. This thematic content allows ant visitors to learn from each topic from beginning to end.

Figure 7.15 Tableware Production designed as an illustrated book

- **The layout of exhibit displays** with hierarchical organisation of subject through the groups of artefacts was provided in the linear exhibition space. The exhibits were arranged to encourage ant visitors to obtain a basic understanding of ceramic plates and then carry on obtaining a high level of knowledge of specified exhibits from the simple to the complex in a particular context. For example, "The History of Plates" (Figure 7.16) in the first position in the space gives visitors a basic understanding of the brief plate history. This is followed by "Tableware Production" which allows visitors to learn the procedure for producing plates in early times in an orderly manner. Later, the application of the ceramic pigments in plates with pattern designs through specific exhibits enables visitors to learning more in-depth information about the patterns.



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Brief History of Plates in Yingge

With regard to pigments used in plates (also dishes and bowls), there are three phase in Yingge:

The blue and white:
Blue and white bowls and plates (Figure 1) were the major products manufactured in Yingge after the whiter Peitou clay started being used in making tableware. The blue pigment was stable, handy and easy to process and, therefore, had been favored by private kiln owners for centuries. Flowers, bamboo leaves and geometric shapes painted with the blue pigment are the most commonly seen decorative patterns. (Source: Taipei County Yingge Ceramics Museum, 2002)

Figure 1 Blue and white plate with shrimp and fish patterns

The pink tint:
The "pink tint" (Figure 2) that followed the blue and white is often deemed to be a quality unique to Yingge ceramic products. Light and translucent pink colors decorate the glazed bisques in rich layers, accompanied by creative floral and grass shapes, adding a lovely and graceful quality to the simple blue and white floral shapes. These paintings on bowls and plates were the work of local workwomen who had no professional training and were not selected based on their skills. They gradually developed the ability to capture the delicate charms of plants through continuous observation and practice while working in the factory. (Source: Taipei County Yingge

Figure 7.16 The History of Plates

The constructivism approach

- A non fixed **visitor pathway** was provided to allow grasshopper and butterfly visitors to create their own exploratory routes to actively interact with exhibits on display in the three exhibition rooms (Figure 7.17 marked by a blue line) for learning.

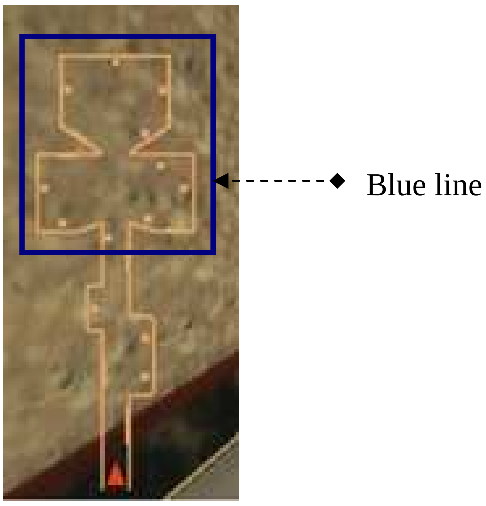
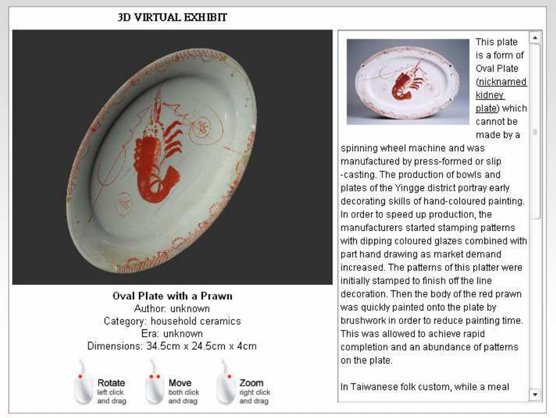


Figure 7.17 The three exhibition rooms

- **The organisation of exhibit content** provided various levels of knowledge through relevant links that encourage grasshopper and butterfly visitors to choose the exhibit content they desire, constructing the meanings of the artefacts through their prior experiences and knowledge. For example, “Oval Plate with a Prawn” (Figure 7.18) presents cultural information content and its pattern designs through a 3D model combined with texts and an image. Various levels of knowledge (e.g. painting skills, the shape and so on) were provided by offering relevant links (Figure 7.19) to associated information for interpretations.



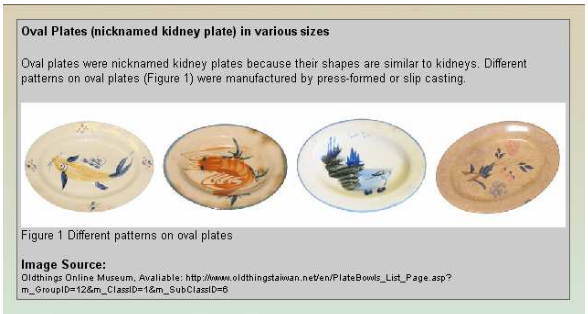
3D VIRTUAL EXHIBIT

Oval Plate with a Prawn
Author: unknown
Category: household ceramics
Era: unknown
Dimensions: 34.5cm x 24.5cm x 4cm

This plate is a form of Oval Plate (nicknamed kidney plate) which cannot be made by a spinning wheel machine and was manufactured by press-formed or slip -casting. The production of bowls and plates of the Yingge district portray early decorating skills of hand-coloured painting. In order to speed up production, the manufacturers started stamping patterns with dipping coloured glazes combined with part hand drawing as market demand increased. The patterns of this platter were initially stamped to finish off the line decoration. Then the body of the red prawn was quickly painted onto the plate by brushwork in order to reduce painting time. This was allowed to achieve rapid completion and an abundance of patterns on the plate.

In Taiwanese folk custom, while a meal

Figure 7.18 Oval Plate with a Prawn



Oval Plates (nicknamed kidney plate) in various sizes

Oval plates were nicknamed kidney plates because their shapes are similar to kidneys. Different patterns on oval plates (Figure 1) were manufactured by press-formed or slip casting.

Figure 1 Different patterns on oval plates

Image Source:
Oldthings Online Museum, Avaliable: http://www.oldthingstaiwan.net/en/PlateBowls_List_Page.asp?m_GroupID=12&m_ClassID=1&m_SubClassID=6

Figure 7.19 Various levels of knowledge through a relevant link

- **The layout of exhibit displays** was provided using multiple entry points in the three exhibition rooms that allow grasshopper and butterfly visitors to construct knowledge from which they can choose. Each exhibit was placed in one of three themed areas (i.e. fish, flowers, and crabs and prawns) in its intended exhibition room according to its pattern designs. For example, plates with crab or prawn patterns in their own themed exhibition room (Figure 7.20).

Figure 7.20 Crab or prawn patterns on plates

7.4 Evaluation of the theoretical model and results analysis

The evaluation of the proposed theoretical model includes two evaluation activities: user testing (observations combined with performance tasks and questionnaires) and expert evaluation (semi-structured interview). Information content in the prototype 3D exhibition was checked by a member of the museum staff at the Archival Department in the Taipei County Yingge Ceramics Museum before the prototype evaluation to confirm that no error had been made in interpreting contextual and cultural information about exhibits.

The procedure for the user testing is the same approach to that taken in the observation studies (refer to Section 5.4.2.1). The results of the user testing includes five parts: participant profile, the occurrence of the necessary behaviours for learning during free navigation, testing whether visiting styles and pedagogic approaches match those predicted, testing performance through a range of tasks and post-visit questionnaires.

7.4.1 The analysis of results of the user testing

7.4.1.1 Participant profile

As mentioned earlier, three typical types of visitors (i.e. the general public, researchers and professionals, and schools) were selected as targeted subjects for this user testing. Ten subjects in each group were recruited based on non-proportional stratified random sampling method, giving the total number of subjects as thirty in line with Diamond’s (1999) recommendation. The user testing includes thirty participants who freely visited and performed the tasks on the prototype 3D exhibition during February 2008. The numbers and percentage of the participants are shown in Table 7.4. The original data of the user testing can be found in Appendix 7B.

Category	**Item**	**Number / Percentage (%)**
Gender	Male	16 (53%)
	Female	14 (47%)
Age	11-18	4 (13%)
	19-30	16 (53%)
	31-40	6 (20%)
	41-50	3 (10%)
	51+	1 (3%)
Education	GCSE	4 (13%)
	A level	4 (13%)
	First degree	9 (30%)
	Master’s degree	11 (37%)
	Doctoral degree	0 (0%)
	Other	2 (7%)
Internet experience	Yes	30 (100%)
	No	0 (0%)
	Every day	29 (97%)
	3-6 times per week	1 (3%)
	Once or twice per week	0 (0%)

	Once or twice per month	0 (0%)
	Once or twice per year	0 (0%)
Museum website experience	Yes	22 (73%)
	No	8 (27%)
	Every day	0 (0%)
	Once or more per week	0 (0%)
	Once or twice per month	9 (41%)
	Once or twice per year	6 (27%)
	Less than once per year	7 (32%)
3D web-based environment experience	Yes	20 (67%)
	No	7 (23%)
	Unsure	3 (10%)
	Every day	3 (15%)
	Once or more per week	2 (10%)
	Once or twice per month	9 (45%)
	Once or twice per year	5 (25%)
	Less than once per year	1 (5%)
Category	**Item** ***multiple selection possible**	**Mentioned (frequency)**
Opinions of the 3D environments on the Internet	Easy to use	8
	Fun	15
	Useful	11
	Attractive	11

Table 7.4 The numbers, profiles and percentages of the participants

All thirty participants have experience in using the Internet and usually use the Internet every day, except for one participant. Most participants (73%) have visited museum websites before. In addition, 41% of them visit museum websites once or twice per month. 67% of the participants have online 3D environment experience such as E-Commerce, museum, game and E-Learning websites. When asked about their opinions of 3D web environments, those participants who had 3D environment experience regarded 3D environments as easy to use (8), fun (15), useful (11) and attractive (11).

The numbers, profiles and percentages of the participants in each group are shown in Table 7.5.

Category	**Item (Number / Percentage (%))**	**General public**	**Researcher and professional**	**Schools**
Gender	Male	5(17%)	7(23%)	4(13%)
	Female	5(17%)	3(10%)	6(20%)
Age	11-18	0(0%)	0(0%)	4(13%)
	19-30	9(30%)	6(20%)	1(3%)
	31-40	1(3%)	3(10%)	2(7%)
	41-50	0(0%)	1(3%)	2(7%)
	51+	0(0%)	0(0%)	1(3%)
Education	GCSE	0(0%)	0(0%)	4(13%)
	A level	3(10%)	0(0%)	1(3%)
	First degree	6(20%)	2(7%)	1(3%)
	Master’s degree	0(0%)	8(27%)	3(10%)
	Doctoral degree	0(0%)	0(0%)	0(0%)
	Other	1(3%)	0(0%)	1(3%)
Internet experience	Yes	10(33%)	10(33%)	10(33%)
	No	0(0%)	0(0%)	0(0%)
	Every day	10(33%)	9(30%)	10(33%)
	3-6 times per week	0(0%)	1(3%)	0(0%)
	Once or twice per week	0(0%)	0(0%)	0(0%)
	Once or twice per month	0(0%)	0(0%)	0(0%)
	Once or twice per year	0(0%)	0(0%)	0(0%)
Museum website experience	Yes	6(27%)	7(32%)	9(41%)
	No	4(18%)	3(14%)	1(5%)
	Every day	0(0%)	0(0%)	0(0%)
	Once or more per week	0(0%)	0(0%)	0(0%)
	Once or twice per month	1(5%)	4(18%)	4(18%)
	Once or twice per year	3(14%)	2(9%)	1(5%)
	Less than once per year	2(9%)	1(5%)	4(18%)
3D web-based environment experience	Yes	7(35%)	8(40%)	5(25%)
	No	3(15%)	1(5%)	3(15%)
	Unsure	0(0%)	1(5%)	2(10%)
	Every day	1(5%)	2(10%)	0(0%)
	Once or more per week	0(0%)	1(5%)	1(5%)
	Once or twice per month	6(30%)	3(15%)	0(0%)
	Once or twice per year	0(0%)	2(10%)	3(15%)
	Less than once per year	0(0%)	0(0%)	1(5%)
Category	**Item Mentioned *multiple selection possible**	**General public**	**Researcher and professional**	**Schools**
Opinions of the 3D environments on the Internet	Easy to use	2	3	3
	Fun	7	5	3
	Useful	4	5	2
	Attractive	5	5	1

Table 7.5 The numbers, profiles and percentages of the participants in each group

Almost all school participants (9 out of 10 participants) have visited virtual museums on websites before. 4 of them visit museum websites once or twice per month. However, the biggest number of the school participants (4 participants) visit museum websites less than once per year compared to the other two groups. Most researcher and professional participants (8 participants) have online 3D environment experience, followed by the general public (7 participants) and school participants (5 participants). In terms of each group' opinions of 3D web environments, the most frequently mentioned by general public was fun (7), by researchers and professionals was fun (5), useful (5) and attractive (5) and by school participants was easy to use (3) and fun (3).

7.4.1.2 Testing for the occurrence of the necessary behaviours for learning during free navigation

Visitor behaviour measurement within an exhibit includes attraction and holding power (refer to Chapter Five Section 5.6.2.1.1) to assess the necessary behaviours for learning to occur. In these observations, attraction is calculated by the number of participants who stopped to look at the exhibit image or clicked on the exhibit image for further information about it for at least five seconds; holding power is calculated by dividing the total time spent by those participants who stopped at the exhibit or clicked on the exhibit image for viewing information about it by the number of the participants who stopped at the exhibit. The thirty participants learning-associated behaviours associated with exhibits in the prototype 3D exhibition based on attraction and holding power are shown in Table 7.6.

Exhibits	**Attraction** **(no people)** **(stopped at exhibits < 5 seconds excluded)**	**Holding power** **(in seconds)**
History of Plates	17	22.1
Tableware Production	13	42.1
Stoneware Blue and White Lines Plate	16	24.2
Blue and White Drawing (video)	24	59.9
Imari Japan Bowl (3D model artefact)	23	27.8
Plate Decorated with Floral Pattern	19	20.4
Colour Painted Plate with a Rooster	23	17.1
Recognising 5 Patterns (game)	27	49.4
Small Blue and White Plate with Crab Patterns (3D model artefact)	13	21.4
Colour Painted Plate with a Shrimp and Waterweeds	15	16.1
Oval Plate with a Prawn (3D model artefact)	16	24.4
Jigsaw Puzzle (game)	19	27.3
Blue and White Plate with Floral Patterns (3D model artefact)	15	19.4
Three triple-lobed Plates with Grassy and Floral Patterns (3D model artefact)	19	20.5
Colour Painted Plate with Peony	13	12.2
Blue and White Dish with a Small Fish (3D model artefact)	18	19.8
Blue and White Plate with Fishes (A) (3D model artefact)	12	15.2
Blue and White Plate with Fishes (B) (3D model artefact)	12	18.3
Colour Painted Plate with a Fish (3D model artefact)	19	22.6
Colour Painted Dish with a Small Fish	12	14.4

Table 7.6 Attraction and holding power of each exhibit in the 3D exhibition

With regard to attraction, all exhibits attracted at least 12 participants' attention. "Recognising 5 Patterns" using a game attracted the highest number of participants' attention (27 participants), followed by "Blue and White Drawing" (video) (24 participants). “Imari Japan Bowl” (3D model artefact) and “Colour Painted Plate with a Rooster” both were ranked in third place in attraction (23 participants). According to the participants’ comments, this was because the well-designed video content attracted them to see information and the game included playable and challenging content to further attract or engage them (refer to Section 7.4.1.5).

In terms of holding power, all exhibits held the participants for 14 seconds, except “Colour Painted Plate with Peony”. The “Blue and White Drawing” (video) held the participants for the longest periods of time (59.9 seconds) followed by “Recognising 5 Patterns” (game) (49.4 seconds) and “Tableware Production” using multiple media formats (i.e. texts, images and photographs) (42.1 seconds). However, although “Jigsaw Puzzle” used a game, this exhibit did not hold the participants for a long period of time (27.3 seconds) compared with “Recognising 5 Patterns”. This was perhaps due to lack of originality of the features of the game format and less challenging content. This view was supported by several participants. Though “Tableware Production” did not use a game or a video, it held the participants for a long period of time (42.1 seconds). This was probably because this exhibit was designed in an interactive book format with a large amount of detailed information.

Following identification of the relationship between attraction and holding power of the exhibits, the top three exhibits for attraction and the top three exhibits for holding power are presented in Table 7.7-7.8 and Figure 7.21:

Exhibits	**Attraction (no people)** (stopped at exhibits < 5 seconds excluded)	**Holding power (in seconds)**
Recognising 5 Patterns (game)	27 (90%)	49.4
Blue and White Drawing (video)	24 (80%)	59.9
Imari Japan Bowl (3D model artefact)*	23 (77%)	27.8
Colour Painted Plate with a Rooster*	23 (77%)	17.1

Table 7.7 The top three exhibits for attraction

* Both "Imari Japan Bowl" and "Colour Painted Plate with a Rooster" which attracted the same number of the participants' attention were ranked in third place

Exhibits	**Attraction (no people)** (stopped at exhibits < 5 seconds excluded)	**Holding power (in seconds)**
Blue and White Drawing (video)	24 (80%)	59.9
Recognising 5 Patterns (game)	27 (90%)	49.4
Tableware Production (multiple media formats)	13 (43%)	42.1

Table 7.8 The top three exhibits for holding power

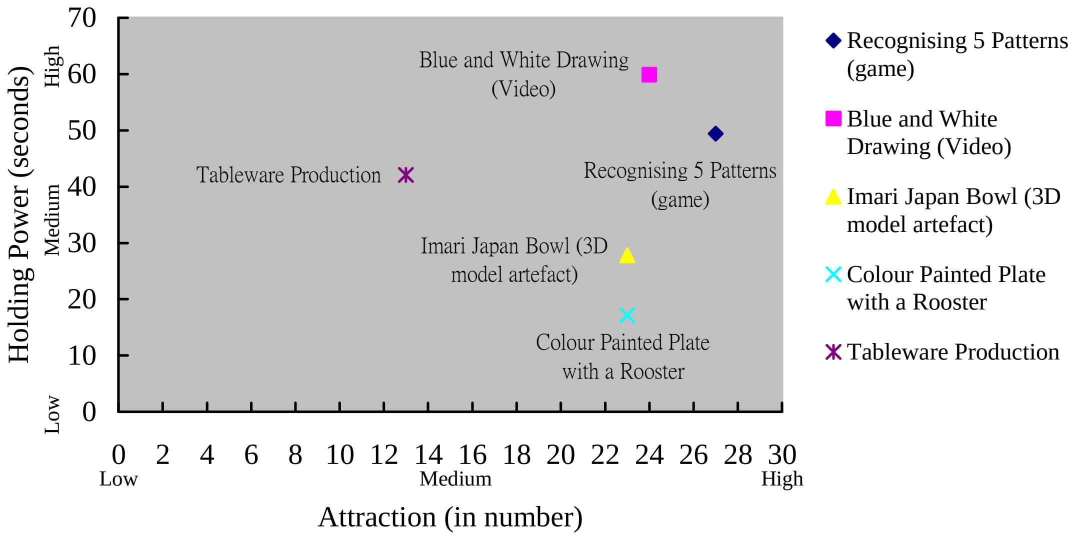


Figure 7.21 A scatter plot indicating the rating of the five exhibits through attraction and holding power

These results show in Figure 7.21 that “Recognising 5 Patterns” using a game and “Blue and White Drawing” using a video not only had a higher level of attraction but also had a higher level of holding power. The participants were attracted by the video and the game due to their high level of visibility. The large TV icon was used to represent “Blue and White Drawing” (video) (Figure 7.22) and the game icon was placed in a visible location to represent “Recognising 5 Patterns” (Figure 7.23). In addition, the video content (Blue and White Drawing) based on the ceramic artists’ performance engaged them for the full length of viewing time (59.9 seconds). The game (Recognising 5 Patterns) provided a high level of interaction with playable content to engage them for a relatively long time (49.4 seconds). These findings indicate that most participants were attracted, and then they were held for a long time interacting with these two exhibits and therefore support the two necessary behaviours for learning to occur. Moreover, it is noteworthy that the two exhibits combined high values for both high levels of attraction and holding power and therefore have great potential for learning. Thus compares well with the six most effective and successful exhibits in the four museum websites examined during the observation studies (Chapter Five Section 5.6.2.1.1). None of these exhibits was able to combine both high levels of attraction and holding power.

Figure 7.22 the video using a large TV icon

Figure 7.23 the game in visible location

The “Imari Japan Bowl” and “Colour Painted Plate with a Rooster” attracted the same numbers of the participants (23). The “Imari Japan Bowl” attracted most participants to interact with the 3D model artefact combined with in-depth interpretive content. Although “Colour Painted Plate with a Rooster” did not use multiple media formats or 3D models combined with in-depth information, it was attractive to most participants. This may be due to the large exhibit icon used (Figure 7.24).

Figure 7.24 Colour Painted Plate with a Rooster using a large icon

“Tableware Production” held the participants for a long period of time (42.1 seconds) due to the amount of detailed information using multiple media formats (i.e. texts, images and photographs). The participants explained that they were engaged to the exhibit by the facility to virtually flip the page of the book once they found information useful according to participant subjective response in the post-visit questionnaire (Question 22) (refer to Section 7.4.1.5). However, several participants stated that the dull exhibit icon was used to represent “Tableware Production” which caused them to ignore the exhibit as evidenced by the following quotes:

> ‘I did not see “Tableware Production” because its exhibit image colour is dull and looks like the [exhibit] wall’s colour (Research and professional participant #9).’

> ‘I saw it [Tableware Production] but I was attracted by the TV screen [Blue and White Drawing] because it is big and clear (School participant # 1).’

The results indicated that the levels of visibility in terms of vivid and big exhibit icons used and the spatial arrangement of exhibits displayed in visible positions partly influenced the level of attraction of the exhibits. These factors affect on the attraction of the exhibits will be discussed in the recommendations for further research in the next chapter.

Although these factors influenced attraction levels of the exhibits in some cases, the results of user testing tended to support hypothesis 1 “the exhibit which features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) provides a **high level of attraction** and there is a greater possibility to improve visitors’ learning experience” as shown by “Imari Japan Bowl” (3D model artefact) exhibit. Hypothesis 2 “the exhibit which features rich multimedia formats (i.e. games or a video with high levels of interaction) provides a **high level of holding power** and there is a greater possibility to improve visitors’ learning experience” is also further supported by the success of the “Recognising 5 Patterns” (game) and “Blue and White Drawing” (video) exhibits.

7.4.1.3 Testing whether visiting styles and pedagogic approaches match those predicted

At this stage, the user testing is to evaluate whether the participants’ visiting styles and pedagogic approaches match those predicted (i.e. hypothesis 4 and 6) (refer to Section 7.2.3) in the prototype 3D exhibition. The participants’ visiting styles in the prototype 3D exhibition were classified into the four categories (i.e. ant, fish, grasshopper and butterfly visiting styles) based on their visit pathways, movements, time spent in front of each exhibit and the number of stops (Veron and Levasseur 1983; Marti 2001; Chittaro and Ieronutti 2004). After 30 participants behaviours were observed, it was noted that most participants had more than one visiting style when visiting the prototype 3D exhibition. The proportion of the participants' visiting styles in the 3D exhibition was classified into the four categories shown in Table 7.9 and graphically presented in Figure 7.25.

Visiting style / **Pedagogic approach**	**Ant**	**Fish**	**Grasshopper**	**Butterfly**	**Not classified**	**Total**
Traditional lecture and text	17 (57%)	1 (3%)	7 (23%)	5 (17%)	0 (0%)	30
Constructivism	4 (13%)	3 (10%)	12 (40%)	9 (30%)	2 (7%)	30

Table 7.9 The frequencies of visiting styles which occurred in the 3D exhibition

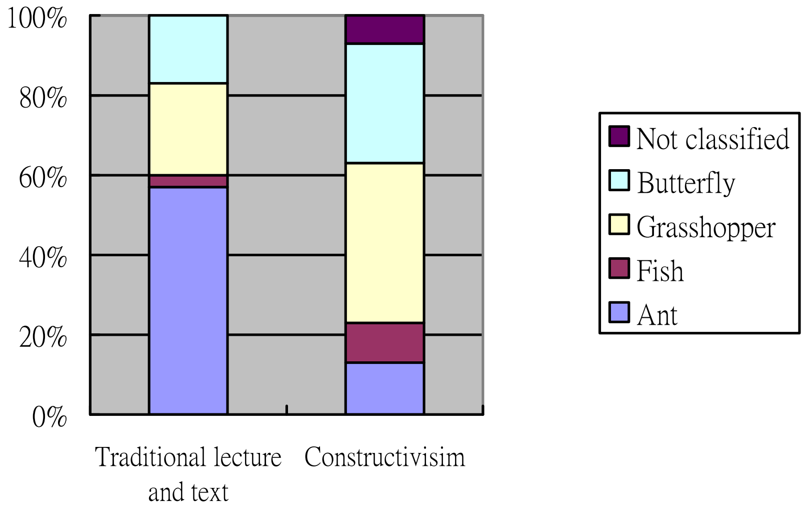


Figure 7.25 The percentage of the four visiting styles in the 3D exhibition

The linear exhibition space using **the traditional lecture and text** approach had the highest proportion of ant visiting style (57%) and lower proportions for the grasshopper (23%) and butterfly visiting style behaviours (17%). The three exhibition rooms employing **the constructivism** approach had the highest proportion of the grasshopper visiting style (40%) and a high proportion of the butterfly visiting style (30%). As might be expected, for both pedagogic approaches, the lowest proportion was for fish visiting style because the exhibits held most participants' attention for long periods of time. This did not suit the nature of the fish visiting style (i.e. the fish visitors take a cursory glance at the exhibits for a short time).

Having identified the relationship between the overall visiting styles and pedagogic approaches, the percentage of the participants' visiting styles in the 3D prototype exhibition is next classified according to the three groups of visitors as shown in Table 7.10 and Figures 7.26-7.28.

Visitor group	**Pedagogic approach**	**Visitor style**				
		Ant	**Fish**	**Grasshopper**	**Butterfly**	**Not classified**
General public	Traditional lecture and text	7 (70%)	0 (0%)	3 (30%)	0 (0%)	0 (0%)
	Constructivism	1 (10%)	1 (10%)	4 (40%)	4 (40%)	0 (0%)
Researchers and professionals	Traditional lecture and text	3 (30%)	1 (10%)	3 (30%)	3 (30%)	0 (0%)
	Constructivism	1 (10%)	2 (20%)	3 (30%)	3 (30%)	1 (10%)
Schools	Traditional lecture and text	7 (70%)	0 (0%)	1 (10%)	2 (20%)	0 (0%)
	Constructivism	2 (20%)	0 (0%)	5 (50%)	2 (20%)	1 (10%)

Table 7.10 The percentage of the three visitor groups of the participants' visiting styles in the 3D exhibition

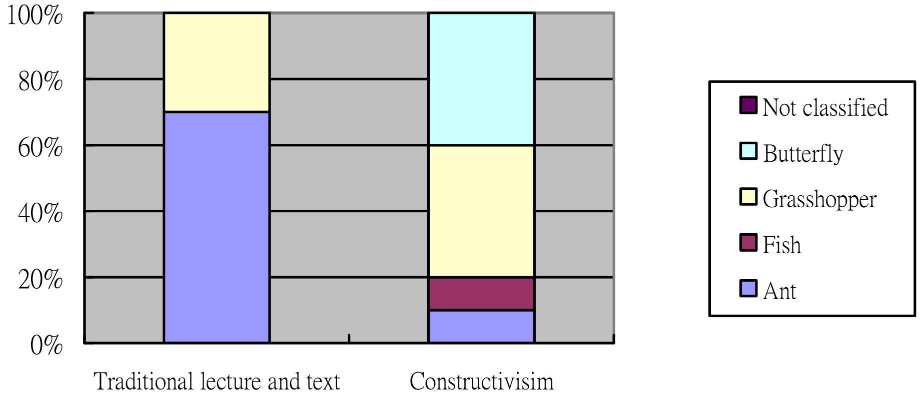


Figure 7.26 The percentage of the general public’s visiting styles in the 3D exhibition

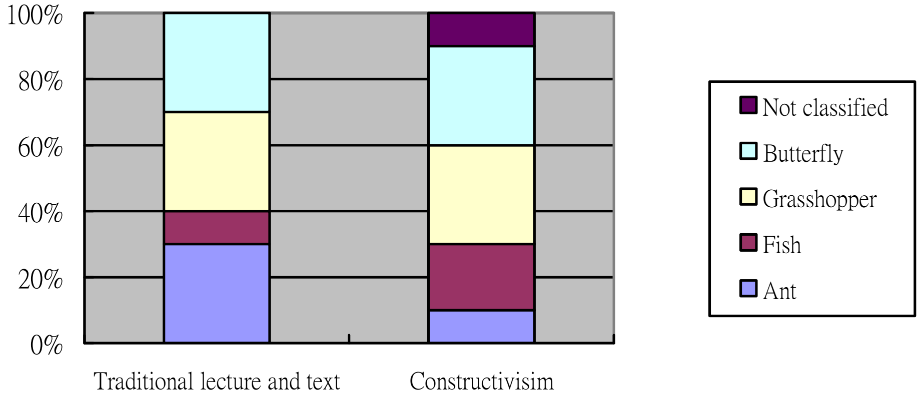


Figure 7.27 The percentage of researchers and professionals’ visiting styles in the 3D exhibition

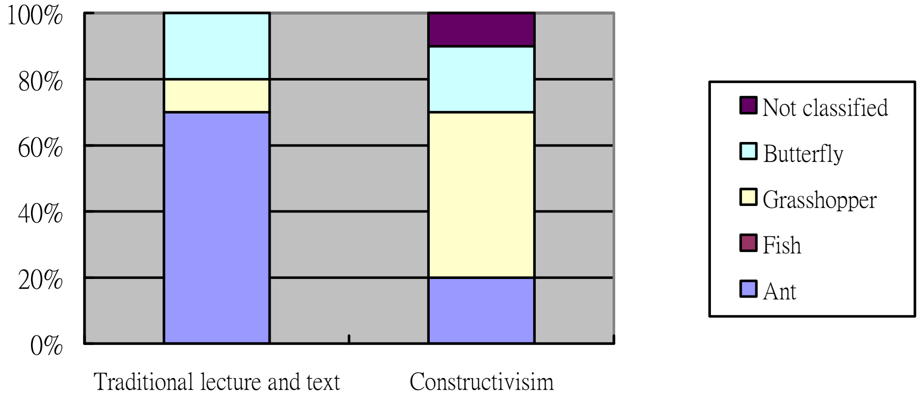


Figure 7.28 The percentage of schools’ visiting styles in the 3D exhibition

The linear exhibition space based on **the traditional lecture and text approach** had the highest number of participants from the general public (7 participants) and schools (7 participants) with an ant visiting style. These findings indicate that most participants from the general public and schools tended to see information content step by step in an orderly manner by following the fixed visitor pathway. It is noteworthy that this space had the same number of researcher and professional participants (3 participants) with ant, grasshopper and butterfly visiting styles. This was because some of this group is more knowledgeable about specific aspects of collections than the other two visitor groups. Thus they did not look at exhibit content step by step and did not need to be guided to follow the fixed visitor pathway. This may be the reason for researchers and professional participants having the lowest percentage with an ant style in the 3D exhibition among the three groups.

The three exhibition rooms based on **the constructivism approach** had the highest number of participants from the general public (8 participants), researchers and professionals (6 participants), and school participants (7 participants) with either grasshopper or butterfly visiting styles. These findings show that almost all the participants from each group tended to see information about the exhibits they desired, building on their own knowledge based on their pre-existing knowledge and experience in the non-fixed visitor pathway.

Moreover, these results show that the participants' visiting styles were strongly influenced by the exhibition environment based on its intended pedagogic approach through visitor pathways, the organisation of exhibit content and the layout of exhibit displays. Both pedagogic approaches used in the layout of the 3D exhibition encouraged visitors to follow the related visiting style(s) to these expected, leading to a deeper engagement (e.g. manipulates 2D image of artefacts and/or 3D model exhibits, looks at images, reads texts, watches the video "Blue and White Drawing" and plays the games "Recognising 5 Patterns" and "Jigsaw Puzzle") with the subject matter. These results seemed to support hypothesis 4 "the design of the museum environment based on **the traditional lecture and text approach** encourages visitors to follow 'ant' behaviour patterns, leading to a deeper engagement with the subject and hypothesis 6 "the design of the museum environment based on **the constructivism approach** encourages the features of grasshopper and butterfly visitors, allowing visitors to develop a deeper engagement with selected aspects of the subject." The only slight exception is researchers and professional visitors in the traditional lecture and text approach.

7.4.1.4 Testing performance through a range of tasks

In the next stage of the user testing, the thirty participants were asked to perform a series of the tasks on the prototype 3D exhibition after freely visiting. A series of the assigned tasks are as follows:

1. Look at the video: **Blue and White Drawing**.
2. View the photograph, **Tableware Production,** and associated information about it.
3. Find and play the game: **Jigsaw Puzzle**.
4. Look at the exhibit, **Colour Painted Plate with a Fish,** and additional information about it.

Three measures (refer to Chapter Five Section 5.6.2.2), percentage of success, average time and range of completion times, are employed in order to judge each task in the 3D exhibition. The testing performance results of tasks throughout the evaluation in terms of the percentage of success, average time spent and range of completion times are shown in Table 7.11. In addition, a comparison between the prototype 3D exhibition and the four museum websites discussed in the observation studies (Chapter 5) is presented in Table 7.12.

Task descriptions	**Percentage of success**	**Average time (in seconds)**	**Range of completion times (in seconds)**
1. Look at the video: **Blue and White Drawing**.	93.3%	24.2	9-150
2. View the photograph, **Tableware Production,** and associated information about it.	90.0%	25.5	5-162
3. Find and play the game: **Jigsaw Puzzle**.	100.0%	38.3	17-91
4. Look at the exhibit, **Colour Painted Plate with a Fish,** and additional information about it.	100.0%	47.6	21-237

Table 7.11 The results of the testing performance through the tasks

Website comparison	**Overall average**		
	Percentage of success	**Average time (in seconds)**	**Range of completion times (in seconds)**
London Science Museum	79.2%	98.2	15-257
Canadian Museum of Civilization	94.4%	51.7	6-238
Helsinki City Museum	70.0%	65.6	5-317
Philadelphia Museum of Art	55.0%	151.3	48-295
Prototype 3D exhibition	95.8%	33.9	13-160

Table 7.12 A comparison between the prototype 3D exhibition and the four museum websites

According to Table 7.11, almost all the participants successfully performed the four tasks in the prototype 3D exhibition. Except for task 2, all the assigned tasks had a completion rate of over 93 % i.e., task 1 (93.3%) with task 3 (100%) and task 4 (100%). However, task 2 had a slightly lower completion rate (90.0%) because a small number of the participants (3 out of 30 participants) did not recognise the stated exhibit due to its low level of visibility (a dull icon used to represent the exhibit).

Based on Table 7.12, the prototype 3D exhibition had the highest percentage of success (95.8%) and the lowest average time (33.9 seconds) compared to the four museum websites examined in the observation studies (see Chapter Five). In the prototype 3D exhibition, each of the virtual exhibits used interaction metaphors represented by an icon with additional indication of the exhibit name and rollovers when the cursor was moved over individual exhibit images. Thus almost all the participants were able to easily and quickly recognise each exhibit for completing the tasks. These results show that the interaction metaphor used in navigation paths was effectively used in the prototype.

The range of completion times that is the difference between the shortest and longest time (13-160 seconds) was the smallest among the five museum websites. This might be because information architecture is consistent in presenting information content to facilitate task completion. In addition, the findings indicated that almost all the participants quickly found specific exhibits and then successfully interacted with the exhibits with different presentation media formats in that they manipulated the 3D exhibit models, read textual information, viewed images and photographs, watched video content and played the game correctly within the 3D exhibition space during the learning experience.

7.4.1.5 Post-visit questionnaires

Each question was constructed using a five-point Likert Scale: “strongly agree” (5 points), “agree” (4 points), “neither” (3 points), “disagree” (2 points), and “strongly disagree” (1 point). The average point score for each question is the total number of points divided by the total number of 30 participants. Table 7.13 shows the user testing results of the post-visit questionnaire according to the participants’ subjective measurements for the prototype 3D exhibition.

Questions on the aspects for the use of 3D technology in improving access	**Likert Scale**					**Average Scores**
	5	**4**	**3**	**2**	**1**	
1. The visual quality of the 3D model exhibits was satisfactory.	37%	50%	13%	0%	0%	4.2
2. The visual quality of the 3D exhibition environment was satisfactory.	27%	60%	13%	0%	0%	4.1
3. The 3D model exhibits gave you a sense of presence with a feeling of actually seeing the physical artefacts themselves.	17%	53%	17%	13%	0%	3.7
4. The 3D exhibition environment gave you a sense of presence with a feeling of truly being in an actual museum.	10%	33%	33%	17%	7%	3.2
5. It was easy to manipulate the 3D model exhibits (e.g. zoom in, out, move and rotate).	37%	30%	23%	10%	0%	3.9
6. Instructions given for manipulation were easy to understand.	40%	50%	10%	0%	0%	4.3
7. It was easy to navigate the 3D exhibition environment.	27%	47%	20%	3%	3%	3.9
8. It was useful to click on the exhibit icons for associated information about the exhibits.	60%	40%	0%	0%	0%	4.6
9. The map helped you to know where you are in the 3D exhibition environment.	70%	23%	7%	0%	0%	4.6
10. The map helped you to know where the exhibits are in the 3D exhibition environment.	43%	33%	17%	7%	0%	4.1
11. It was useful to show exhibit names and rollovers when the mouse cursor was moved over individual exhibit icons.	47%	50%	3%	0%	0%	4.4
12. The video (“Blue and White Drawing”) provided you with additional useful information on the exhibits.	70%	27%	3%	0%	0%	4.7
13. The texts provided you with additional useful information on the exhibits.	50%	37%	13%	0%	0%	4.4
14. The images provided you with additional useful information on the exhibits.	50%	43%	7%	0%	0%	4.4
Questions on informational aspects	**Likert Scale**					**Average Scores**
	5	**4**	**3**	**2**	**1**	
15. It was easy to find information.	40%	50%	10%	0%	0%	4.3
16. It was easy to understand the information.	40%	43%	17%	0%	0%	4.2
17. The amount of information on exhibits was adequate.	37%	33%	20%	10%	0%	4.0
18. The 3D model exhibits’ visual expression (such as “Colour Painted Plate with a Fish”) provided you with more information than texts, images, etc.	40%	47%	10%	3%	0%	4.2

19. The 3D model exhibits provided you with sufficient information.	40%	47%	10%	3%	0%	4.2
Questions on learning aspects	**Likert Scale**					**Average Scores**
	5	**4**	**3**	**2**	**1**	
20. The content of exhibits was easy to understand.	47%	47%	3%	3%	0%	4.4
21. The organisation and structure of content was easy to follow.	27%	70%	3%	0%	0%	4.2
22. “Tableware Production” (learning activity) was useful to understand more information about exhibits.	37%	53%	7%	3%	0%	4.2
23. “Recognising 5 Patterns” (game) was useful to understand more information about exhibits.	20%	37%	33%	7%	3%	3.6
24. “Jigsaw Puzzle” (game) was useful to understand more information about exhibits.	23%	40%	23%	10%	3%	3.7
Total average score						4.2

Table 7.13 The post-visit questionnaire results

In terms of the use of 3D technology in improving access, the prototype 3D exhibition had an average score of over 4.0 for all questions, except questions 3, 4, 5 and 7. The highest average score was 4.7 points for question 12 on whether the video provided additional useful information on the exhibits, followed by questions 8 and 9 both of which both were ranked in second place on the same point score (4.6). However, when asked whether “the 3D exhibition environment gave a sense of presence with a feeling of truly being in an actual museum”, the response received the lowest average point score (3.2 points for question 4). A relatively low average score of 3.7 was also obtained for question 3 about whether the 3D model exhibits gave a sense of presence with a feeling of actually seeing the physical artefacts themselves. Several participants explained that the 3D exhibition and 3D model exhibits looked “fake” and “unreal”. However, it could be argued that the 3D exhibition was created in an imaginary space which did not intend to create a replica of the existing physical exhibition in order to present exhibits and associated information based on the intend pedagogic approaches being more flexible without physical constraints and geographic limitations. In addition, these comments perhaps reflect the limitations of current 3D technologies. A relatively low average score 3.9 points was obtained for question 5 on whether it was easy to manipulate the 3D model exhibits and question 7 on whether it was easy to navigate the 3D exhibition environment. Regarding question 5, a small number of participants complained that they needed to keep pressing the mouse button and moving the mouse up or down at the same time for zoom in or out. This operating method resulted in a low efficiency in the manipulation of 3D model exhibits. In terms of question 7, several participants pointed out that the movement speed was a little slow for navigation in the 3D exhibition environment.

Concerning questions 15, 16, 17, 18 and 19 about informational aspects, the prototype 3D exhibition had average scores ranging between 4.0 and 4.3 points. These results indicate that most participants (70% or more) responded “strongly agree” or “agree” to the statements in this section. 70% of participants or more thought that the information was easy to find and understand. Moreover, they stated that the amount of information on exhibits was adequate, the 3D model exhibits’ visual expression provided more information than texts, images, etc. and the 3D model exhibits provided sufficient information.

With regard to the learning aspects, the highest average point score was 4.4 points for question 20, followed by questions 21 and 22 both of which were ranked in second place with the same point score (4.2). Almost all participants (97%) regarded the organisation and structure of exhibit content as being easy to follow. 90% of participants thought that “Tableware Production was useful to understand more information about the exhibits. However, the lowest average point scores of 3.6 for question 23 and of 3.7 for question 24 were answers to the questions about the usefulness of games. This was because the games used in the 3D exhibition tended to engage the participants using play in order to provide basic knowledge about ceramic exhibits and fun rather than providing in-depth information.

Table 7.14 and Figure 7.29 present a comparison of post-visit questionnaires between the prototype 3D exhibition and the four museum websites examined in Chapter Five. The prototype 3D exhibition had the highest overall average score for two aspects: the use of 3D technology in improving access and information, but had a slightly lower overall average score of 4.03 in learning aspects compared to the Canadian Museum of Civilization (4.10 points). Moreover, the prototype 3D exhibition had the highest total average points score (4.2). This result indicates that overall the prototype exhibition environment seemed to be more effective than the other four museum websites tested earlier.

Website comparison	**Overall average**			**Total average score**
	The use of 3D technology	**Informational aspects**	**Learning aspects**	
London Science Museum	3.26	3.32	3.60	3.4
Canadian Museum of Civilization	4.04	4.02	4.10	4.0
Helsinki City Museum	2.49	2.52	2.42	2.5
Philadelphia Museum of Art	2.57	2.46	2.72	2.6
Prototype 3D exhibition	4.2	4.19	4.03	4.2

Table 7.14 A comparison of post-visit questionnaires results

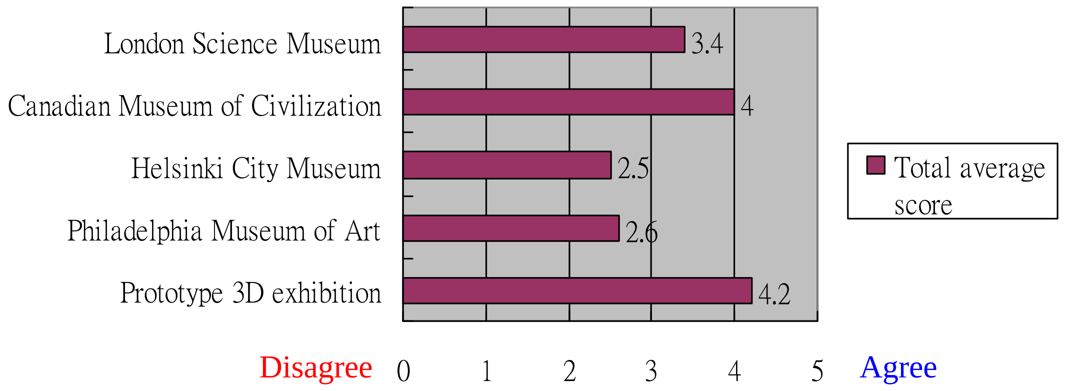


Figure 7.29 A comparison of post-visit questionnaires

- Participant comments about the prototype 3D exhibition

“Tableware Production” used a dull exhibit icon which proved unattractive to several participants to click on. Some participants liked the exhibit which was designed as an illustrated book for them to virtually flip. They also described that the presentation of information was quite interesting rather than normally providing information on standard web pages.

Moreover, most participants stated that the well-designed video content attracted them to see information about blue and white drawing skill through the ceramic artist’s performance. Some participants pointed out that Jigsaw Puzzle (game) provided more information than Recognising 5 Patterns (game) but Recognising 5 Patterns was more interesting and fun than Jigsaw Puzzle in terms of game format.

Several participants who have experience in visiting 3D environments commented that the movement speed was a little slow. In addition, a number of the participants said that they would like to click on the points which represent individual exhibits in the map and then jump there directly.

On the whole, most participants pointed out that the exhibits using the different presentation methods (i.e. the integration of multiple media formats, 3D model artefacts, game, and video) were more interesting and fun than exhibits which used images with textual description in standard museum websites.

7.4.2 The analysis of results of expert evaluations

Based on the assessment phase of the proposed theoretical design reference model, the expert evaluation of the prototype 3D exhibition was conducted through qualitative interviews using a semi-structured format. The purpose of this interview evaluation is to test the prototype 3D exhibition through expert assessment in order to improve the proposed theoretical model if necessary. Qualitative evaluations such as interviews always require a small sample size that is chosen for particular reasons (Diamond 1999). Two experts therefore were recruited for interviews on the basis of their extensive knowledge and expertise or ability in design of the 3D museum environment. The list of their institutions and positions is presented in Table 7.15:

Interviewee	**Institution**	**Position**
Interviewee #1	Computer Company	3D web designer
Interviewee #2	Museum	Museum curator

Table 7.15 The list of each specialist group and their institutions and positions

The qualitative interview data were analysed using the method of content analysis to organise the data under the established themes and issues (refer to Section 6.5). The analysis of the results is presented in four parts: 1) immersion and presence, 2) usability design of the prototype 3D exhibition, 3) the exhibits for a high level of attraction and holding power and 4) the prototype 3D exhibition based on the two pedagogic approaches in terms of visitor pathways, the organisation of exhibit content and the layout of exhibit displays. The interview questions can be found in Appendix 7C.

1. Immersion and presence

When asked about the visual quality of the 3D model exhibits, interviewee #1 responded, ‘They are of a high quality [and] the texture detail is clear’. Interviewee #2 simply commented that it was ‘excellent’. In response to the question on whether the 3D model exhibits gave you a sense of presence with a feeling of actually seeing the physical artefacts themselves, interviewee #2 thought that it was ‘exactly the same as physically being able to walk around the object.’ However, interviewee #1 disagreed and said that there is one concern; though the patterns on [3D model] plates are clear, there may be differences between the virtual and physical patterns when you look at the patterns on [real] chinaware and pottery.

In response to the question on the visual quality of the 3D exhibition environment, interviewee #2 simply stated it was ‘excellent’ and the other interviewee agreed that it was acceptable but both of them disagreed about whether the 3D exhibition gave them a sense of presence with a feeling of truly being in an actual museum, as indicated by the following quotes:

> ‘There is still some difference in the material feel (Interviewee #1)’

> ‘I think one of the problems with it is because you know it is a construct, whether this applies to virtual museums or not, there’s a sort of mental barrier (Interviewee #2).’

2. Usability design of the prototype 3D exhibition

When asked about the instructions for manipulating the 3D model exhibits and the instructions for navigating the 3D exhibition environment, both of them agreed that they are clear and acceptable. In response to the question on whether it is easy to navigate the 3D exhibition environment, interviewee #1 claimed that ‘strictly speaking, the speed is a little delayed’ and the other interviewee did not respond.

When asked how useful it is to click on the exhibit icons for associated information about the exhibits, both of them agreed with that, as shown by the following quotes:

> ‘All icons are clear and there are titles under icons (interviewee #1)’

> ‘I think that’s good, because it is a way of getting across [explaining] traditional information (interviewee #2).’

According to the response to the question about how useful is it to show exhibit names and rollovers when the mouse cursor is moved over individual exhibit icons, interviewee #1 stated, ‘I believe they are highly recognisable’ and interviewee #2 simply said, ‘That’s good.’

Both of them agreed that the map helped them to know where they were in the 3D exhibition space. In response to the question on whether the map helped to determine where the exhibits are in the 3D exhibition, interviewee #2 agreed. However, interviewee #1 said, ‘There is a problem with the round dots on the map. They are not very clear. The dot seems to be a pillar, not items on display’ and there could be some animations telling visitors that they are a guide. Moreover, ‘The map can be even related to the actual scenes. When I click a point, it could tell me what it is (interviewee #1).’

In response to the questions on the information content, both interviewees stated that it was easy to find information out about the exhibits; it was easy to understand the information about the exhibits; the amount of information provided for the exhibits was adequate and appropriate and the organisation and structure of the information content were easy to follow.

3. Exhibits for a high level of attraction and holding power

When asking about “Tableware Production” (multiple media formats) which provides a high level of attraction and holding power, Interviewee #1 said, ‘The content attracted me but the presentation form made no difference to me.’ Interviewee #2 pointed out, ‘I liked the illustrations in this actually. [It was] visually attractive and [had a] moderate level of holding power.’

In response to the question on 3D model artefacts (such as “Colour Painted Plate with a Fish” or “Imari Japan Bowl”) combined with in-depth information providing a **high level of attraction and holding power**, Interviewee #1 noted that the information content was clear so that he was attracted to stay and Interviewee #2 stated, ‘It’s got to build up the tension there as you move as towards it, build up the expectation.’

When asking about the games, “Recognising 5 Patterns” and “Jigsaw Puzzle”, which provide a **high level of attraction and holding power**, both of them agreed that “Jigsaw Puzzle” is better than “Recognising 5 Patterns”, as indicated in the following quotes:

> ‘At the initial page of Recognising 5 Patterns, there is no attraction. I did not feel

> like playing a game. The puzzle form is more attractive and engaging, as it is easy to understand and makes people want to complete the game (Interviewee #1).'

> 'For Recognising 5 Patterns, that's probably good for the young generation. I liked [Jigsaw Puzzle] better than the other one. For me, I came to recognise the patterns. As I said, there's something you can learn from that. So that would, I think, keep me engaged longer (Interviewee #2).'

According to responses to the question whether the video ("Blue and White Drawing") combining a control bar with high levels of interaction provides a **high level of attraction and holding power**, interviewee #1 said, 'Yes, it provides attraction and holding power' and interviewee #2 claimed that it has moderate attraction and holding power.

However, the experts' views on the effectiveness of exhibits using multiple media formats or 3D model artefacts combined with in-depth interpretive content and information for a high level of attraction and the exhibits employing games or videos with high interaction for a high level of holding power are a little different from the outcomes of the user testing. Expert interviewee #1 thought that these exhibits (i.e. Tableware Production, Blue and White Drawing, Imari Japan Bowl Recognising 5 Patterns and Jigsaw Puzzle) were attractive and engaging but did not state what the levels of attraction and holding power of the exhibits were. Expert interviewee #2 pointed out that some of the exhibits (i.e. Tableware Production using multiple media formats and Blue and White Drawing using video) had moderate attraction and holding power. However, the user testing indicated that the exhibit (Blue and White

Drawing) employing a video had the highest level of holding power, followed by the exhibit (Recognising 5 Patterns) using a game and the exhibit (Imari Japan Bowl) using a 3D model artefact with in-depth interpretive content had a higher level of attraction. This difference is because the experts emphasised the importance of information content rather than the rich multimedia presentation formats used in the exhibits. The issue of information content will be discussed in the recommendations for further research in the next chapter.

4. The prototype 3D exhibition based on the two pedagogic approaches

- Traditional lecture and text approach used in the linear exhibition space

In response to the question on whether the fixed **visitor's pathway** is suitable for ant visitors to follow the exhibition content step by step in a systematic manner, both of them agreed, 'Yes, quite appropriate for ant type (interviewee #1)' and 'Yes, I think that worked OK (interviewee #2)'. When asking whether **the organisation of exhibit content** in a sequential order is suitable for ant visitors to learn thematic content for learning from beginning to end, interviewee #1 simply said, 'Yes'. According to responses to the question on whether the **exhibit displays** with a hierarchical organisation of the subject encourage ant visitors to learn knowledge from the simple to the complex, interviewee #1 observed, 'The planning of gradual process from simple to complicated levels is very appropriate for the ant type of gradual learning' and the other stated, 'Yes, that's fine.'

- The constructivism approach used in the three exhibition rooms

When asking whether the use of no fixed **visitor's pathway** in the three exhibition rooms encourages grasshopper and butterfly visitors to create their own individual and exploratory routes to actively interact with exhibits for learning, interviewee

#1 stated, ‘I believe it is appropriate. The learning structure is suited to their activeness and higher level of control. This helps them focus on those things’ and the other said, ‘You’ve got to rely on the visitors creating some sense of it themselves.’

According to the question whether **the organisation of exhibit content** such as “Oval Plate with a Prawn” with various levels of knowledge using relevant links is suitable for grasshopper and butterfly visitors to choose exhibit content they desire, interviewee #1 stated that there are three issues, ‘The first one is that grasshopper and butterfly types of visitors have their own needs according to their own levels of knowledge. The second one is the level of exhibition content. The third one is the indication to guide them. To meet the needs of different visitors, we should offer knowledge and interest at different levels for an effective exhibition. However, this is not for all people.’

In response to the question whether the **organisation of exhibit content** such as “Oval Plate with a Prawn” allows grasshopper and butterfly visitors to construct the meanings of artefacts through their prior experiences and knowledge, both of them agreed, as shown in the following quotes:

> ‘Yes, based on their knowledge and experiences (interviewee #1).’
>
> ‘Yes, it should build on that (interviewee #2).’

In response to the question whether **the layout of exhibit displays** which provided multiple entry points was suitable for grasshopper and butterfly visitors

> to construct knowledge from which they can choose, interviewee #1 pointed out, ‘Yes, each exhibition hall has a theme’ and interviewee #2 observed, ‘So they can make their own choices and go back and forth between them. Yes, that works.’

Based on the experts’ responses to the question about the relationship between visiting styles and the two pedagogic approaches, the results of expert evaluations are similar to the user testing outcomes. The results of expert evaluations tended to support hypothesis 4 that the design of the museum environment based on **the traditional lecture and text approach** encourages visitors to follow ‘ant’ behaviour patterns, leading to a deeper engagement with the subject and hypothesis 6 that the design of the museum environment based on **the constructivism approach** encourages the features of grasshopper and butterfly visitors, allowing visitors to develop a deeper engagement with selected aspects of the subject.

When asked whether the prototype 3D exhibition had potential to promote learning, interviewee #1 advocated that it not only had the potential to promote learning, but also provided an advertisement to encourage virtual visitors to come back to the physical museum to visit real artefacts, supporting Schweibenz’s (2004) findings. Interviewee #2 said, ‘I think there could be a potential for that, because more and more people use things online and they also like to supplement their research, and they tend to now use IT in the classroom with whiteboards, and that kind of things.’

7.4.3 Comments from the Taipei County Yingge Ceramics Museum

The prototype 3D exhibition was also briefly assessed by a member of the museum staff at Archival Department in the Taipei County Yingge Ceramics Museum. The museum staff not only has experience of designing the museum website, but is knowledgeable about ceramic artefacts in Taiwan. The museum staff described the visual expression of the prototype exhibition as impressive and thought the Q&A (Question & Answering) provided in the "Jigsaw Puzzle" game was helpful for visitors to learn knowledge about the plate. However, the museum staff pointed out that the points which represent individual exhibits in the map were not clear. Despite this weakness, the museum staff was keen to use the prototype 3D exhibition environment as an information and learning resource on the museum website when its information content is translated from English into Chinese.

7.5 Summary

A theoretical design reference model was proposed based on the secondary and primary research findings for the development of a 3D virtual museum environment as both an informational and learning resource. The theoretical model consists of three phases (i.e. analysis, design and assessment phases) based on the Reeves multimedia design model and derived from the literature review and three stages of primary research. Each phase was discussed in terms of its specific tasks or activities. The model could be used as a tool for virtual museum designers to consider when building their 3D exhibition environments on the websites for learning purposes.

A working prototype 3D exhibition, "The Meanings behind the Patterns on Plates", was designed based on the analysis and design phase of the proposed theoretical model. This prototype was in collaboration with the Taipei County Yingge Ceramics Museum in Taiwan. The purpose of the prototype 3D exhibition was to experimentally validate the theoretical design reference model through two evaluation activities: user testing and expert evaluation.

On the whole, the results of expert evaluations are similar to the user testing results in terms of immersion, presence, usability design, information on exhibits and the prototype 3D exhibition based on the two pedagogic approaches to encourage the related visiting style(s), leading to a deeper engagement with subject matters.

The findings of user testing showed that “Recognising 5 Patterns” using a game and “Blue and White Drawing” using a video not only had a higher level of attraction but also had the highest level of holding power. It was found that most participants were attracted, and then they were held for a long time, interacting with these two exhibits, thus manifesting the necessary behaviours for learning to occur. These two types of exhibits hold great potential for visitor learning based on their high levels of attraction and holding power. In addition, these two exhibits combined high values for both high levels of attraction and holding power which did not exist in the four museum websites examined during the observation studies.

Moreover, the levels of visibility (i.e. vivid and big exhibit icons used and the spatial arrangement of exhibit display in visible positions) were found to influence the attraction of the exhibits in some cases. It is felt however this factor is not fully realised to ensure a fit between exhibits and 3D virtual museum space in an educational setting. It will be discussed in more detail in the recommendations for further research in the next chapter. Although in some cases this factor partly affects the attraction of the exhibits, the results of user testing tended to support hypothesis 1 that the exhibit which features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) provides a **high level of attraction** and there is a greater possibility to improve visitors’ learning experience such as in the case of “Imari Japan Bowl” (3D model artefact). The results also tend to support hypothesis 2 that the exhibit which features rich multimedia formats (i.e. games or a video with high levels of interaction) provides a **high level of holding power** and there is a greater possibility to improve visitors' learning experience as in the cases of "Recognising 5 Patterns" (game) and "Blue and White Drawing" (video).

However, the specialists' views on the effectiveness of exhibits using multiple media formats or 3D model artefacts combined with in-depth interpretive content and information for a high level of attraction and the exhibits which employed games or videos with high interaction for a high level of holding power are slightly different from the outcomes of the user testing. This is because the experts emphasised the importance of information content rather than the rich multimedia presentation formats used in the exhibits. Although information content is an important issue, the user testing indicates that the exhibit (Blue and White Drawing) employing a video had the highest level of holding power, followed by the exhibit (Recognising 5 Patterns) using a game and that the exhibit (Imari Japan Bowl) using a 3D model artefact with in-depth interpretive content had the highest level of attraction. These results indicate that the use of rich media is important as these exhibits seemed to effectively attract or engage the participants within the 3D exhibition during the learning experience. As Brown et al (2005) claimed, the different types of visitor learning experience need to be supported by using the different types of media forms corresponding with specific methods for exhibit content in a virtual museum.

Both user testing and expert evaluations showed that the linear exhibition space based on the traditional lecture and text approach leads to a deeper engagement (e.g. manipulates 2D image and 3D model exhibits, looks at images, reads texts and watches the video "Blue and White Drawing" and plays the game "Recognising 5

Patterns”) with the thematic subject by encouraging an ant visiting style behaviour; the three exhibition rooms based on the constructivism approach lead to a deeper engagement (e.g. manipulates 2D image and 3D model exhibits, looks at images, reads texts and plays the game “Jigsaw Puzzle”) with chosen aspects of the subject by encouraging grasshopper and butterfly visiting style behaviours. These findings seemed to support hypothesis 4 that the design of the museum environment based on **the traditional lecture and text approach** encourages visitors to follow ‘ant’ behaviour patterns, leading to a deeper engagement with the subject and hypothesis 6 that the design of the museum environment based on **the constructivism approach** encourages the features of grasshopper and butterfly visitors, allowing visitors to develop a deeper engagement with selected aspects of the subject.

The user testing also showed that the prototype was more effective than the other four museum websites in the testing performance throughout a series of the assigned tasks. It was found that almost all participants quickly found specific exhibits through effective interaction metaphors in navigation routes and then successfully interacted with the exhibits with different presentation media formats as they manipulated the 3D exhibit models, read textual information, viewed images and photographs, watched video content and played the game correctly within the 3D exhibition environment during the learning experience.

The participants’ subjective evaluation of the prototype 3D exhibition through the post-visit questionnaire was analysed. From this analysis, the prototype 3D exhibition was the most effective in presenting its exhibit content and associated information in the 3D web-based environment compared to the other four museum websites. According to the participants’ feedback, most participants stated that the different presentation methods (i.e. the integration of multiple media formats, 3D model artefacts, game and video) used in exhibit content were more interesting and fun than exhibits which used images with textual description in standard museum websites.

On the whole, the results of the prototype evaluation show that the design of the exhibits with rich multimedia formats had the potential for more effective visitor learning based on their high level of attraction and holding power. In addition, the 3D exhibition based on the two pedagogic approaches encouraged the related visiting style(s), leading to a deeper engagement with the thematic content and ultimately improving learning efficiency. Thus the theoretical model seems to be a valid design method for creating 3D virtual environments to improve access to museums as both an information and learning resource. The next and final chapter (Chapter Eight) draws conclusions and discusses the overall benefit of the main research findings and achievements of contributions to new knowledge. In addition, based on the results of the prototype evaluation, improvements to the proposed theoretical model and prototype 3D exhibition design will be discussed in more details in the recommendations for further research at the end of the next chapter.

Chapter Eight: Conclusions and Recommendations

8.1 Introduction

In this final chapter, the main research findings and their implications for the development of 3D virtual museum environments in terms of informational aspects and the learning context are discussed. As planned, the aim of this research was to propose a theoretical design reference model for the development of on-line 3D virtual environments in order to improve access to museums as both an informational and educational resource. From the positive results of the evaluation (Chapter Seven) of the theoretical design reference model and prototype 3D exhibition, the aim of this study seems to have been achieved.

The main research question of this study was defined by the literature review: what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy. This research question was addressed by the three primary research studies (critical review, observation studies and semi-structured interviews) and the evaluation of the prototype 3D exhibition based on the proposed theoretical design reference model.

In the following sections, the achievements and contributions to knowledge as well as a number of limitations emerging in this research are summarised. Moreover, recommendations are made to improve the theoretical design reference model and prototype 3D exhibition design at the end of this final chapter.

8.2 Implementation and outcomes of the research

8.2.1 Research implementation

The outcomes of this research relate to its aims and objectives which were set up in the beginning (Section 1.3). The objectives of the research project in relation to the chapters in which they are discussed are as shown in Table 8.1.

Chapter No.	The research objectives
Chapter 2	1. To review the relevant literature on web-based museum online environments focusing on information and learning, museum theory, visitor behaviours within physical and virtual museums, education theories, virtuality and simulation theory, existing 3D web technologies, suitability and effectiveness of online information design strategies in 3D environments.
Chapter 4	2. To examine the existing websites using 3D technology for online learning in a 3D virtual environment with a focus on museums by use of a critical review.
Chapter 5	3. To determine a potential relationship between the visiting styles and learning activities within 3D virtual museum environments based on the pedagogic approaches by use of observation combining performance tasks with questionnaire.
Chapter 6	4. To identify the existing problems and limitations of current 3D virtual learning and information environments and potential needs by use of expert interviews.
Chapter 7	5. To propose a theoretical design reference model for developing effective 3D virtual museum exhibition information and learning environments.
Chapter 7	6. To validate the theoretical model through the evaluation of a prototype 3D exhibition through user testing and expert evaluation.

Table 8.1 Chapter detailing research outcomes related to research objectives

Based on the research framework laid out in the earlier stage of the research (see Section 3.2), a literature review (Chapter Two) was initially conducted, covering virtual museums regarding the definition and types related to actual museums. Museum theory includes the role of museum artefacts in conveying messages and concepts of artefacts for interpretations based on semiotic approaches. Both physical museums and virtual museums as both an informational and learning resources were identified. Visitor studies on profile, expectations, experiences and behaviours in virtual museums were examined. Educational theories through coherent pedagogic strategies were explored to gain a better understanding of the learning context in virtual museums. The relationship between the degrees of virtuality and simulation in relation to levels of realism in museum collections and digital objects was further discussed. A number of innovative 3D web technologies for creating 3D museum environments was also researched to explore appropriate practices in museum website design and related design issues in terms of immersion, presence and usability.

Three forms of primary research studies (critical review in Chapter Four, observation studies in Chapter Five and semi-structured interviews in Chapter Six) were also carried out. The critical review undertaken examined the employment of novel 3D technologies in ten current virtual museum websites based on the main categories of museums. Current problems and the effectiveness and usability of informational and learning resources were identified from within the examined web-based museums. The observations were undertaken to investigate the relationship between visiting styles, pedagogic approaches and learning activities in the 3D museum environments. The effectiveness of exhibits using rich multimedia formats for high levels of attraction and holding power was analysed. The effective design of the 3D environments (i.e. three design key factors: visitor pathways, organisation of exhibit content and layout of exhibit displays) based on the intended pedagogic approaches to encourage the related visiting style behaviours was identified. This was followed by interviews with the eight experts to elicit a series of topics (e.g. pedagogic features, the biggest problems, important criteria and so on for designing 3D museum environments) and to test the research hypotheses generated from the previous observations. Hypothesis 1 that states on the exhibit which features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) provides a **high level of attraction** and hypothesis 2 which states on the exhibit which features rich multimedia formats (i.e. games or a video with high levels of interaction) provides a **high level of holding power** were supported. In addition, hypothesis 4 which states the design of the museum environment based on **the traditional lecture and text approach** encourages visitors to follow ‘ant’ behaviour patterns, leading to a deeper engagement with the subject and hypothesis 6 which states on the design of the museum environment based on **the constructivism approach** encourages the features of grasshopper and butterfly visitors, allowing visitors to develop a deeper engagement with selected aspects of the subject were also supported. In the same chapter, several important aspects for creating 3D museum environments which contributed to the development of the theoretical model and the 3D prototype design were identified.

A theoretical design reference model (Chapter Seven) based on the Reeves model was then proposed which consists of three phases for developing a 3D museum environment, namely an analysis phase, a design phase and an assessment phase. A working prototype 3D museum exhibition, “The Meanings behind the Patterns on Plates”, was created based on the analysis and design phase of the theoretical model. Finally, the prototype 3D exhibition was tested using an evaluation based on the assessment phase of the theoretical model to validate its effectiveness in terms of attraction and holding power of the exhibits and the use of the two pedagogic approaches to encourage the associated visiting styles, leading to a deeper engagement with the subject matter. From the positive results of the prototype evaluation, the theoretical model seems to be considered a valid design method for creating effective 3D museum environments to accommodate the associated visiting styles and ultimately improve learning efficiency. However, the experts pointed out that information content is an important element of the design of 3D museum exhibitions. This view will be discussed in more details on improvement of the theoretical model in Section 8.5.1.

8.2.2 Research outcomes

The research question was defined by the literature review (Section 2.9): what is the most appropriate relationship between pedagogic approaches, visiting styles and the design of 3D virtual museum environments to ensure learning efficacy. The research question was addressed by the three stages of primary research studies and the evaluation of the prototype 3D exhibition based on the proposed theoretical design reference model.

From the conclusions of the critical review (Chapter Four), the London Science Museum, Philadelphia Museum of Art, Canadian Museum of Civilization and Helsinki City Museum were identified as the four most effective and successful museum websites which present their cultural content in the 3D walkthrough environments based on the intended pedagogic approaches for the educational and interpretive needs. These four museums websites were used to conduct observational studies of virtual visitor behaviours with a focus on the identification of a potential relationship between the visiting styles and learning activities within the four 3D museum environments.

From the results of the observations (Chapter Five), the design of effective exhibits in a web-based 3D museum environment needs to both attract and engage visitors through the use of rich multimedia formats. The findings showed that attraction levels were highest for the exhibits which employed multiple media formats or 3D model artefacts combined with in-depth interpretive content and information; holding power was highest for the exhibits which used games or videos with high interaction. The interview results (Chapter Six) also revealed that the design of the exhibits with rich multimedia formats have a greater possibility to improve visitors' learning experience based on their high level of attraction and holding power.

In addition, the results of the observation studies and interviews indicated that the design of 3D museum environments based on the two pedagogic approaches, traditional lecture and text, and constructivism, seems to be more effective in presenting exhibits and associated information and encourage the related visitor style(s), leading to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject matters as shown in Table 8.2.

Pedagogic approach	**Visiting style**
Traditional lecture and text	• Ant visiting style (i.e. spending a long time to visit most exhibits, moving methodically from exhibit to exhibit and stopping frequently and physically next to walls and exhibits)
Constructivism	• Grasshopper visiting style (i.e. viewing only exhibits interesting to them and hopping from one to another and spending quite a long time to see individual chosen exhibits) • Butterfly visiting style (i.e. frequently changing the direction of visit, viewing most exhibits and pausing quite often and spending a variety of periods for viewing each exhibit)

Table 8.2 The design of 3D environment based on the two pedagogic approaches for the related visitor style(s)

The following detailed suggestions were made to improving learning efficiency based on the intended pedagogic approach in terms of the three key design factors: visitor pathway, the organisation of exhibit content and the layout of exhibit displays.

The design of the 3D environment based on the traditional lecture and text approach

- A fixed **visitor pathway** should be provided so that ant visitors can follow the exhibition content step by step in a systematic manner.
- **The organisation of exhibit content** should be arranged in a sequential order so that ant visitors can learn thematic content for from beginning to end.
- **The layout of exhibit displays** should provide a hierarchical organisation of the subject in order to encourage ant visitors to learn knowledge from the simple to the complex in a particular context.

The design of the 3D environment based on the constructivism approach

- A non fixed **visitor pathway** should be provided so that grasshopper and butterfly visitors can create their own individual and exploratory routes to actively interact with exhibits for learning.
- **The organisation of exhibit content** should provide various levels of knowledge in order to encourage grasshopper and butterfly visitors to choose the exhibit content they desire, constructing the meanings of artefacts through their prior experiences and knowledge.
- **The layout of exhibit displays** must provide multiple entry points for grasshopper and butterfly visitors to construct knowledge from which they can choose.

Based on the findings from earlier research (observations and interviews), the arrangement of exhibits with rich multimedia formats in a 3D museum environment based on its pedagogical approach in terms of visitor pathways, the organisation of exhibit content and the layout of exhibit displays have the greatest potential for learning efficacy. In Chapter Seven, the proposed theoretical design reference model was developed based on the two fundamental research findings as follows:

1. Attraction levels were highest for the exhibits which employed multiple media

formats or 3D model artefacts combined with in-depth interpretive content and information; holding power was highest for the exhibits which used games or videos with high interaction.

2. The design of the 3D museum environment (i.e. three key design factors: visitor pathways, the organisation of exhibit content and the layout of exhibit displays) based on the two pedagogic approaches (i.e. traditional lecture and text and constructivism) encourage the related visiting style(s), leading to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the thematic content.

In the same chapter, a working prototype 3D exhibition, “The Meanings behind the Patterns on Plates” for the Taipei County Yingge Ceramics Museum, was created to experimentally validate the theoretical design reference model. From the prototype evaluation, the results of user testing showed that the design of the exhibits with rich multimedia formats had the potential for more effective visitor learning based on their high level of attraction and holding power. However, the experts’ views on the design of exhibits using multiple media formats or 3D model artefacts combined with in-depth interpretive content and information for a high level of attraction and the exhibits which employed games or videos with high interaction for a high level of holding power are slightly different from the outcomes of the user testing. This is because the experts emphasised the importance of information content rather than the rich multimedia presentation formats used in the exhibits. Although information content is an important issue, the user testing indicates that the exhibit (Blue and White Drawing) employing a video had the highest level of holding power, followed by the exhibit (Recognising 5 Patterns) using a game and that the exhibit (Imari Japan Bowl) using a 3D model artefact with in-depth interpretive content had the highest level of attraction. These results indicate that the use of rich media is important as these exhibits seemed to effectively attract or engage the participants within the 3D exhibition during the learning experience. Moreover, the 3D prototype exhibition based on the two pedagogic approaches encouraged the related visiting style(s), leading to a deeper engagement with the thematic content and ultimately improving learning efficiency.

8.3 Achievements and contributions to knowledge

Through the implementation and outcomes of the research, this study achieved a number of contributions to knowledge in the development of 3D museum environments as both information and learning resources as follows:

1. A new theoretical design reference model with emphasis on facilitating the attraction and holding power of exhibits, visiting styles and the design of the 3D museum environment based on the intended pedagogic approaches for learning efficacy. This theoretical model could be employed as a tool for virtual museum designers to consider when building their 3D exhibition environments as both an informational and learning resource.
2. Determination that attraction levels were highest for the exhibits which employed multiple media formats or 3D model artefacts combined with in-depth interpretive content and information and holding power was highest for the exhibits which used games or videos with high levels of interaction (i.e. hypothesis 1 and 2).
3. Determination that the design of the 3D museum environment (i.e. three key design factors: visitor pathways, the organisation of exhibit content and the layout of exhibit displays) based on the two pedagogic approaches (i.e.

traditional lecture and text and constructivism) encourages the related visiting style(s), leading to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the thematic content (i.e. hypothesis 4 and 6).

4. Identification that the use of simulation (reconstruction, reproduction, and representation) in relation to different levels of visual realism in museum websites depends on their function and context for the effective presentation of artefacts, and thus museum websites' approaches to information and pedagogic interactions (aesthetic appreciation, comprehension of underlying scientific principles and understanding of object its historical context) vary depending on the museum types.
5. Two research papers which were published at international conferences (London EVA Conferences International and 2007 International Conference on Museum Audience Research) and a prototype 3D exhibition which was demonstrated at the CREATE Design Showcase conference (Appendix 8).

8.4 Research limitations

As with all research, there is a number of limitations to this research:

1. In the critical review (Chapter Four), although the criteria to assess the museum websites were established by the literature review to avoid research bias, the critical review results may be inclined to subjective bias because the nature of the critical review is a self-evaluation of the museum websites without objective visitor reactions.
2. In the observation studies, although the Philadelphia Museum of Art website provides a plug-in for the 3D environment, it was found that the 3D museum

environment was not able to be fully presented after the installation of the plug-in. Thus this factor may influence the results of observations as some participants pointed out the difficulty in using the mouse to navigate the 3D environment compared with the other three museum websites.

8.5 Recommendations for future research

Further research work on the relationship between attraction and holding power of exhibits, visiting styles and the design of the 3D virtual museum environment includes two aspects: extensions to the proposed theoretical design reference model and improvements to the prototype 3D exhibition design. The next sections describe some major areas and directions in future studies and recommendations which could take the current research project further.

8.5.1 Extensions to the proposed theoretical design reference model

Based on the prototype evaluation, two issues, levels of visibility and information content, need to be considered to improve the proposed theoretical design reference model. In addition, extensions to the proposed theoretical model could include an assignation of the responsibilities for each of the three phases through team work.

1. Levels of visibility (i.e. vivid and big exhibit icons used and the spatial arrangement of exhibit display in visible positions) were found to partly influence attraction of the exhibits in some cases. Future studies could be conducted into this factor in terms of the relationship between levels of visibility, attraction of exhibits and the spatial arrangement of exhibit displays in 3D museum environments for the learning context.
2. From the expert evaluation of the prototype 3D exhibition, the experts were

concerned with the importance of information content in the design of a 3D exhibition environment. The element of information content can be incorporated within task 4 of the analysis phase of the proposed theoretical model. An improved theoretical design reference model is shown in Figure 8.1:

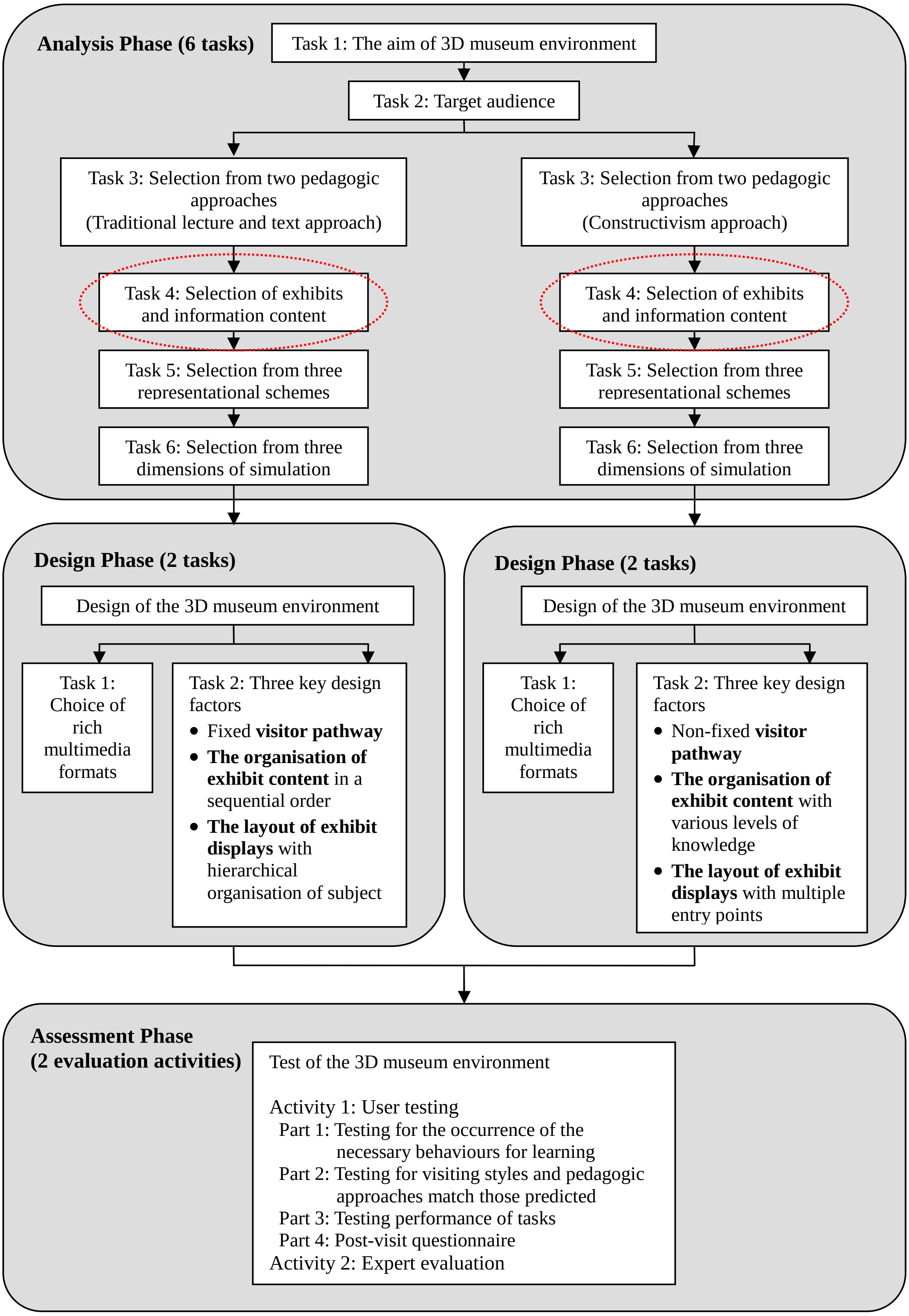


Figure 8.1 An overview of the improved theoretical design reference model

In this task, virtual museum designers should not only consider that exhibits with a number of accompanying museum artefacts need to be appropriately chosen with reference to the exhibit significance, meanings and messages but also need to arrange information content related to the selected exhibits. Further research would be needed to test these changes.

3. Extend the proposed theoretical model through assigning the responsibilities and different tasks for each of the three phases of the 3D virtual museum project in terms of sharing tasks within a team. For example, tasks in the analysis phase would be appropriate for museum staff who are familiar with their museum missions, collections, information content, educational goals, target audience and so on; multimedia or 3D web designers may be assigned to design tasks for creating 3D model artefacts, a museum space and educational games etc. during the design phase; the evaluation tasks in the assessment phase might be suitable for educators or a panel of experts.

8.5.2 Improvements to the prototype 3D exhibition design

The prototype 3D exhibition based on the theoretical model was validated by user-testing and expert evaluations. Based on the results of the prototype evaluation, there were three weaknesses of the prototype 3D exhibition: map, navigation speed and target audience(s). The prototype 3D exhibition could be improved in these three areas:

1. Additions to the map to make it more interactive and provide more information when clicking on a point in the map. For example, it could inform visitors of the exhibit names or by clicking on the points in the map allow the user to jump there directly.

2. Addition of navigation speed control to suit visitors' different experiences in visiting 3D environments. For example, navigation speed may need to be slow for novice visitors who have no or little experience in using 3D environments; navigation speed might need to be faster for those visitors who have more experience in navigating 3D environments.
3. A clearer definition of target audience(s) needs to be given in order to organise appropriate information content to cater for their needs and expectations.

8.6 Summary

This final chapter describes overall conclusions of the research and the main results of the research findings. The implementation and outcomes of the research related to research objectives are discussed. The research question of this study was addressed by the three primary research studies (critical review, observation studies and semi-structured interviews) and the evaluation of the prototype 3D exhibition based on the proposed theoretical design reference model.

Although the research undertaken has some limitations, the research findings indicated that the theoretical design reference model proposed is a valid design method based on the prototype evaluation. Recommendations have been made to improve the prototype 3D exhibition design and extend the theoretical design reference model through the testing of which would provide opportunities for further research.

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Appendixes

Appendix 4: Critical Review Results

The characteristics of the ten museum websites were evaluated in terms of effectiveness and suitability in online learning and informational resources based on the three fundamental components of assessment criteria.

1. Leading museums

Science Museum (accessed on 1st May, 2006)
(http://www.sciencemuseum.org.uk/)
The first component: the use of 3D technology in improving access

<table>
<tr><th colspan="3"><i>1. The first component: the use of 3D technology in improving access</i></th></tr>
<tr><td colspan="3">1.1 Simulation</td></tr>
<tr><td></td><td>Artefact/Object</td><td>Environment</td></tr>
<tr><td>1.1.1 Reconstruction</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.2 Reproduction</td><td>✓</td><td>✓</td></tr>
<tr><td>1.1.3 Representation</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.4 Hyper realities</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.5 Selective realities</td><td>✓</td><td>✓</td></tr>
<tr><td>1.1.6 Abstractions</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td colspan="3">• The 3D virtual exhibition is a reproduction of the Wellcome Wing space in which the virtual exhibits (Appendix Figure 4.1) were reproduced in the architectural environment.</td></tr>
<tr><td colspan="3">1.2 Interactivity</td></tr>
<tr><td>1.2.1 Immersion</td><td colspan="2">• Although the online virtual exhibits are displayed in the 3D high end site, the poor quality of visual information fails to contribute to an immersive exhibition environment.</td></tr>
<tr><td>1.2.2 Presence</td><td colspan="2">• Due to a lack of vivid visual information, the exhibition does not effectively enhance a sense of presence; although the panorama of virtual exhibitions is given as a scene of realistic space.</td></tr>
<tr><td>1.2.3 Manipulation</td><td colspan="2">• Several objects are integrated into the environment; each of them (Appendix Figure 4.2) can be viewed in a horizontal rotation from a variety of perspective viewpoints, and zoom in and out through using QTVR (QuickTime Virtual Reality).</td></tr>
<tr><td>1.2.4 Navigation</td><td colspan="2">• The provision of the instructions for navigation is located the side of the virtual environment, which is useful for visitors to grasp the spatial virtual arrangement of the exhibition.</td></tr>
<tr><td>1.2.5 Orientation</td><td colspan="2">• Virtual visitors would have difficulty in a walkthrough of the virtual exhibition environment due to lack of provision of a map, reducing their involvement with the environment.</td></tr>
<tr><td colspan="3">1.3 Metaphors</td></tr>
<tr><td colspan="3">• The interaction metaphors using each of virtual exhibits are represented as an icon for visitors to click for more information on the contents.</td></tr>
</table>

1.4 Integration of multiple media formats
• Provides the integration of multiple media formats through images, photographs and texts which are interlinked with the exhibition by means of hypermedia.

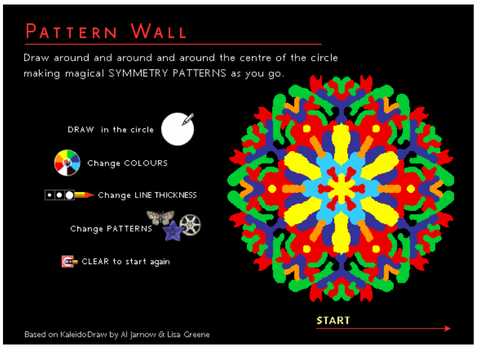
Appendix Figure 4.1 A virtual exhibit

Appendix Figure 4.2 An object using QTVR

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	• A series of scientific and technological subjects is conveyed through texts, images, photographs, learning activities and educational gaming environments with contextual information related to interpretation of the underlying online virtual exhibits.
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
• A small number of learning activities is clearly stated for school children. • Overall, the construction of content of the online exhibits was designed for teachers and young audiences such as students aged 11-18.	
2.2.2 Clarity of instructional objectives and strategies	
• Easily recognisable instructional objectives and strategies were designed based on the “constructivism” approach.	
2.2.3 Motivation and context for learning process	
• Provides multiple entry points designed as an engaging way by connecting particular objects and various activities within thematic content of learning materials throughout to stimulate the active learning process.	
2.2.4 Clarity of organisation and structure of content	
• The orderly organisation and structure of content is presented as a path into the subject. • Virtual visitors easily learn the messages of the virtual exhibits from an overview to highlight of scientific principles or modern technology and associated information.	
2.2.5 Provision of examples and help in how to use the application	
• Offers help on how to use the learning activities which are presented clearly.	
2.2.6 Provision of interactively practising task in learning process	
• The learning games such as the *“Pattern Wall”* (Appendix Figure 4.3), allowing visitors to construct their knowledge through interactively practising task in	

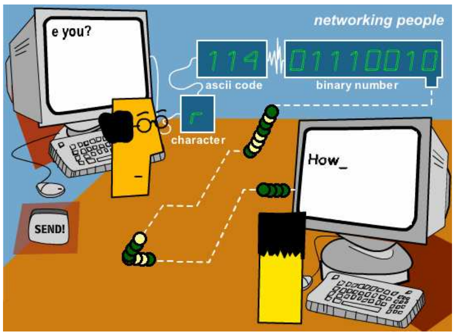
learning process.	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	- Virtual visitors are encouraged to broaden their attendance and apprehending through several linear media such as texts images and photographs.
2.3.2 Investigating, exploring	- A range of thematic content provided through links with layering of information using hypermedia, allowing individuals to broaden their investigation and exploration.
2.3.3 Discussing, debating	- Provides emails to underpin the communicative learning experience of virtual visitors by posing comments and feedback.
2.3.4 Experimenting, practising	- Through educational gaming environments such as the *"Networking People"* (Appendix Figure 4.4), visitors are able to effective understand knowledge by experiment for learning experience.
2.3.5 Articulating, expressing	- Virtual visitors are encouraged to present ideas in their own web pages by the *"In Touch"* system for expressing and articulating learning experience.



Draw around and around and around the centre of the circle making magical SYMMETRY PATTERNS as you go.

Based on KaleidoDraw by Al Jarnow & Lisa Greene

Appendix Figure 4.3 Pattern Wall



Appendix Figure 4.4 Networking People

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
- Presents a number of supplementary learning materials such as educational games, learning activities, etc., for schools and teachers.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
- Provides the supplementary learning materials designed for students of any age through the differentiated level of learning programmes and activities.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
- Offers interaction between museum staff and students, teachers through email for feedback, discussion and comments.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site

• The integration of experiences of real and virtual visits through online exhibits connecting various learning activities within the 3D environment, allowing visitors to evoke a previous physical visit already performed or to plan a visit to the actual museum.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Supporting non-curriculum-based learning experiences and lifelong learning activities through the content of the exhibits, including 3D objects together with multi-layered information: interpretative texts, imagery and photographs and educational games.
3.6 Easily identifiable target audience and clear pedagogical strategy
• Easily recognisable target audience and instructional strategies based on the “constructivism” approach.

2. Art museums

Philadelphia Museum of Art (accessed on 4th May, 2006)

(http://www.philamuseum.org/)

The first component: the use of 3D technology in improving access

1. The first component: the use of 3D technology in improving access		
1.1 Simulation		
	Artefact/Object	Environment
1.1.1 Reconstruction	Not applicable	✓
1.1.2 Reproduction	✓	Not applicable
1.1.3 Representation	Not applicable	Not applicable
1.1.4 Hyper realities	✓	Not applicable
1.1.5 Selective realities	Not applicable	✓
1.1.6 Abstractions	Not applicable	Not applicable
• The two Pogany sculptures (Appendix Figure 4.5) were accurately reproduced as iconic signifiers as close to the originals as possible providing a hyperreal level of virtuality in the environment.		
1.2 Interactivity		
1.2.1 Immersion	• The same proportions of the two Pogany sculptures with vividness and high resolution were designed to be displayed in the showcases which effectively contribute to immersion.	
1.2.2 Presence	• The forms of immersion were likely to enhance the virtual visitors’ experience of being inside an exhibition environment proving a sense of presence in viewing Mlle. Pogany I and III almost as good as in the physical environment itself.	
1.2.3 Manipulation	Not applicable (none provided)	
1.2.4 Navigation	• A brief description of navigation is given when encountering difficulties in viewing the sculptures. • There is a difficulty in using the mouse to navigate throughout the exhibition; although virtual visitors can walk through the whole environment at will.	
1.2.5 Orientation	• An interactive map (Appendix Figure 4.6) generated a red cursor which effectively helps for the acquisition of spatial knowledge.	

	• The layout of the exhibition includes entrances and exits so visitors can instantly recognise where they can enter a room and exit from rooms.
1.3 Metaphors	
• Information presentation metaphors are used through photographic and text panels for presenting sets of contextual information.	
1.4 Integration of multiple media formats	
• Few multiple media formats are combined in the exhibition space. Only photographs and texts can be found.	

☑ Lock your view on the sculpture

After you have checked the box above, we recommend that you move close to the sculpture.

Then, to walk around it, move your mouse sideways a short distance.

The shorter your stroke, the slower you will move; and you can adjust your speed as you walk, by shortening or lengthening that stroke.

Appendix Figure 4.5 One of the Brancusi sculptures

To lock your view on the sculpture as you walk round it, click below. To unlock, click below again.

☑ Lock your view on the sculpture

After you have checked the box above, we recommend that you move close to the sculpture.

Then, to walk around it, move your mouse sideways a short distance.

The shorter your stroke, the slower you will move; and you can adjust your speed as you walk, by shortening or lengthening that stroke.

Appendix Figure 4.6 An interactive map in the 3D virtual exhibition

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	• The online virtual exhibits are displayed in the 3D exhibition space with text panels to interpret the evolution of aesthetic concepts of the Pogany sculptures.
2.1.3 Information-centered	Not applicable
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
Not stated (implicitly providing learning resources and materials for the general public)	
2.2.2 Clarity of instructional objectives and strategies	
• Descriptions of exhibit content emphasize linear structure in the orderly sequence to illustrate contextual information and historical and cultural meanings based on the “behaviourist learning” approach.	
2.2.3 Motivation and context for learning process	
• Explicitly offering a sequence of narrative structures as storylines in an engaging way through a reflective comparison of the virtual exhibits and visual appreciation of aesthetic values to stimulate the learning process.	
2.2.4 Clarity of organisation and structure of content	
• Clearly providing a sequential structure of online virtual exhibit components encourages visitors to understand the artist Bracusi’s a series of sculptures from a clear beginning to end.	

<table>
<tr><td colspan="2">2.2.5 Provision of examples and help in how to use the application</td></tr>
<tr><td colspan="2">• Provision of help how to use the application during learning progress.</td></tr>
<tr><td colspan="2">2.2.6 Provision of interactively practising task in learning process</td></tr>
<tr><td colspan="2">Not applicable (none provided)</td></tr>
<tr><td colspan="2">2.2.7 Provision of feedback in learning activities</td></tr>
<tr><td colspan="2">Not applicable (none provided)</td></tr>
<tr><td colspan="2">2.2.8 Evaluation of learning outcomes</td></tr>
<tr><td colspan="2">Not applicable (none provided)</td></tr>
<tr><td colspan="2">2.3 The types of learning experience</td></tr>
<tr><td>2.3.1 Attending, apprehending</td><td>• The use of linear media, the photographic and text panels, enhance narrative experiences of virtual visitors and maintain a sense of overall structure of the narrative meanings.</td></tr>
<tr><td>2.3.2 Investigating, exploring</td><td>Not applicable (none provided)</td></tr>
<tr><td>2.3.3 Discussing, debating</td><td>• Provides emails, supports feedback and discussion for communicative learning experience through asking questions and posting comments.</td></tr>
<tr><td>2.3.4 Experimenting, practising</td><td>• The simulation of the Brancusi sculptures enriches learning experience in aesthetic appreciation through practising in the virtual exhibition.</td></tr>
<tr><td>2.3.5 Articulating, expressing</td><td>Not applicable (none provided)</td></tr>
</table>

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Supplementary materials through the 3D model artefacts, photographic and text panels suited for schools and teachers.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• No collaborative work spaces for students and supplementary materials for students of any age, except students aged 11-18.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Provision of interaction between museum staff and students, teachers through email for posting comments.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
• The exhibit content is arranged by a narrative method, conveying a message in invoking historical imagination of Brancusi's sculptures based on the time sequence of the events. This effectively reflects the integration of experiences of real visits to the museum and the website for educational groups.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Offers non-curriculum-based learning experiences and supports lifelong learning based on educational auxiliary media.
3.6 Easily identifiable target audience and clear pedagogical strategy
• Easily identifiable pedagogical strategy emphasizes linear structure to interpret aesthetic significances and contextual information based on the "behaviourist learning" approach. • Although the exhibition does not state target audience, the learning content of exhibits is easily identified for the general public.

3. History museums

Museum of National Antiquities (accessed on 12th June, 2006)

(http://www.historiska.se/)

The first component: the use of 3D technology in improving access

1. The first component: the use of 3D technology in improving access		
1.1 Simulation		
	Artefact/Object	Environment
1.1.1 Reconstruction	Not applicable	Not applicable
1.1.2 Reproduction	✓	✓
1.1.3 Representation	Not applicable	Not applicable
1.1.4 Hyper realities	✓	✓
1.1.5 Selective realities	Not applicable	Not applicable
1.1.6 Abstractions	Not applicable	Not applicable
• The reproduction of the virtual exhibits are displayed in a simulated spatial environment (Appendix Figure 4.7) which is a counterpart to its physical exhibition when compared to a photograph of the exhibition (Appendix Figure 4.8).		
1.2 Interactivity		
1.2.1 Immersion	• The poor quality of visual information such as exhibits, showcases, etc. fails to contribute to an immersive exhibition environment.	
1.2.2 Presence	• The doors can be opened by clicking; this effectively evokes a sense of environmental presence by actively responding to visitors. • Virtual visitors may not perceive a sense of presence with a feeling of actually seeing the physical exhibits themselves (Appendix Figure 4.9) due to a lack of vivid visual information.	
1.2.3 Manipulation	Not applicable (none provided)	
1.2.4 Navigation	• The provision of the instructions for navigation is useful for visitors to walk in different directions in the virtual reality environments at will through grasping the virtual spatial knowledge of the exhibition.	
1.2.5 Orientation	• Virtual visitors could have a difficulty in orienting within the 3D virtual exhibition environment because of lack of provision of a map.	
1.3 Metaphors		
• The interaction metaphors using each of exhibits are represented as an icon for virtual visitors to click for more details.		
1.4 Integration of multiple media formats		
• Videos, images, texts, photographs are integrated into the exhibition by means of hyperlinks on the museum website.		

Appendix Figure 4.7 The virtual Viking exhibition

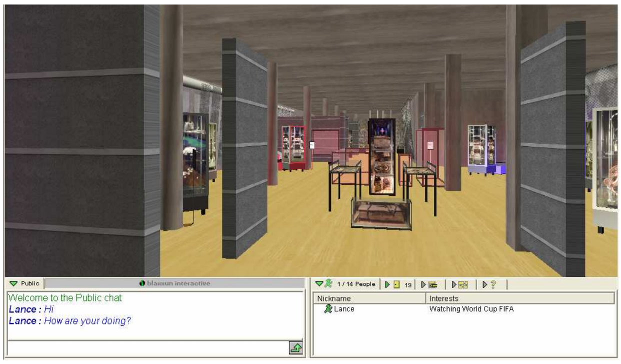
Appendix Figure 4.8 The actual Viking exhibition

Appendix Figure 4.9 The online exhibits

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	• A series of stories is conveyed through the arrangement of artefacts with the use of multiple media formats to interpret contextual information about the Viking's daily life, trade, wars etc., in a narrative format.
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	Not applicable
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
• Not stated (implicitly providing information about exhibition showcases, interpretive texts, photographs, video clips designed for students and teachers)	
2.2.2 Clarity of instructional objectives and strategies	
• Provides thematic content of artefacts organised based on the "traditional lecture and text" approach; however, this pedagogic strategy is not presented clearly.	
2.2.3 Motivation and context for learning process	
• Provision for a group visit with friends or others together to the exhibition environment with a chat platform to gain knowledge of artefacts through active participation and social interactions in the learning process.	
2.2.4 Clarity of organisation and structure of content	
• The organisation and structure of content are combined within the exhibition using hypermedia based on didactic and expository structure.	
2.2.5 Provision of examples and help in how to use the application	
• Provision of "Tips" how to use the application during the learning progress.	
2.2.6 Provision of interactively practising task in learning process	
Not applicable (none provided)	

2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	• Virtual visitors are able to effectively obtain information through several linear media such as videos, images, texts and photographs.
2.3.2 Investigating, exploring	• The employment of interactive media formats using hypertext links enhances the exploring experience by the consistent structure of pathways throughout the virtual exhibition.
2.3.3 Discussing, debating	• Provides two communicative tools: the virtual chat platform and email; the virtual chat platform (Appendix Figure 4.10) is integrated into the exhibition to enhance discussion and debating experience through an iterative dialogue between participants.
2.3.4 Experimenting, practising	• The simulation of exhibits and the exhibition environment enhances interactive learning experience of virtual visitors for comprehension of historical and cultural meanings.
2.3.5 Articulating, expressing	Not applicable (none provided)



Welcome to the Public chat
Lance : *Hi*
Lance : *How are your doing?*

Nickname	Interests
Lance	Watching World Cup FIFA

Appendix Figure 4.10 The virtual chat platform

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Effectively underpinning supplementary leaning materials for schools and teachers and for collaborative spaces for teachers to work together in the exhibition with a chat platform.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• Presents supplementary materials for students of any age, except high level students. • No collaborative work spaces for students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Provides interaction between museum staff and students, teachers through email or the chat platform system for posting comments or discussing exhibit content.

3.4 Integration of experiences of 'real' visits to museum and the educational Web site
• The integration of real and virtual visitor experience is effectively accomplished through the virtual exhibition duplicating the physical exhibition, allowing virtual visitors to prepare for a future visit to the physical museum or evoke a prior actual visit already performed.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Offers non-curriculum-based learning experiences and supporting lifelong learning activities by integrating video clips, images, photographs, texts and a chat room into the exhibition environment.
3.6 Easily identifiable target audience and clear pedagogical strategy
• Identifiable pedagogical strategy based on the "traditional lecture and text" approach but difficulty in identifying exact target audience.

4. Science museums

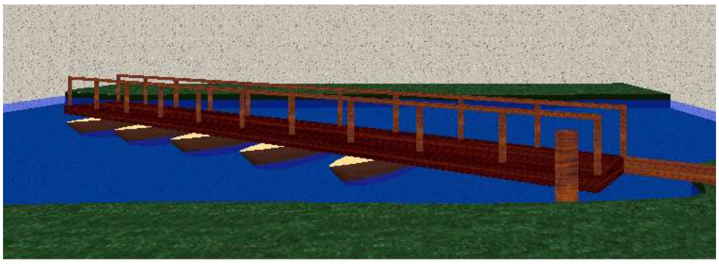
Museum of Science (Boston) (accessed on 21st May, 2006)

(http://www.mos.org/)

The first component: the use of 3D technology in improving access

1. The first component: the use of 3D technology in improving access		
1.1 Simulation		
	Artefact/Object	Environment
1.1.1 Reconstruction	✓	Not applicable
1.1.2 Reproduction	Not applicable	✓
1.1.3 Representation	Not applicable	Not applicable
1.1.4 Hyper realities	✓	✓
1.1.5 Selective realities	Not applicable	Not applicable
1.1.6 Abstractions	Not applicable	Not applicable
• The creation of the reconstructed exhibit (Appendix Figure 4.11), revolving bridge, was presented precisely through 3D simulation of computer-generated models.		
1.2 Interactivity		
1.2.1 Immersion	• Although a panoramic museum environment is given, the low-resolution of the reconstructed revolving bridge results in ineffective immersion.	
1.2.2 Presence	• Virtual visitors might not perceive a sense of presence with a feeling of actually seeing the constructed exhibits themselves in the actual museum due to lack of vivid visual information.	
1.2.3 Manipulation	• Several 3D model exhibits allow manipulation for a better viewing experience and more detailed information.	
1.2.4 Navigation	• Instructions for navigation are provided before moving around the exhibition environments. • It is easy to use the mouse to walk thought the whole exhibitions at will.	
1.2.5 Orientation	• Virtual visitors could have difficulties in orienting both museum environments due to lack of provision of a map.	
1.3 Metaphors		
• The interaction metaphors using a number of virtual exhibits are represented as an icon for visitors to click for more details.		
1.4 Integration of multiple media formats		

• Few multiple media formats such as texts, images and photographs are used to connect each thematic subject by using hypertext links in the pop up windows.



Appendix Figure 4.11 Revolving bridge

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	• A range of conceptual subjects is illustrated through texts and images with contextual information in relation to interpretation of the underlying online 3D model exhibits in the thematic content.
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
• Not stated (implicitly providing learning content for general public or students and teachers).	
2.2.2 Clarity of instructional objectives and strategies	
• Not stated (presumably pedagogic objectives and strategies were designed based on the “traditional lecture and text” approach using thematic content and relevant links)	
2.2.3 Motivation and context for learning process	
• Visitors are encouraged to learn by didactic interpretation during the learning process.	
2.2.4 Clarity of organisation and structure of content	
• Logical organisation of topic and structure of content are easily followed from each thematic topic by using the structured paths.	
2.2.5 Provision of examples and help in how to use the application	
• Not applicable (none provided)	
2.2.6 Provision of interactively practising task in learning process	
• Not applicable (none provided)	
2.2.7 Provision of feedback in learning activities	
• Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
• Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	• Provides linear media such as texts, photographs and graphics which enriches comprehending experience.
2.3.2 Investigating,	• Virtual visitors are encouraged to broaden their investigation

exploring	and exploration of each exhibit by following links to other information.
2.3.3 Discussing, debating	• Provides a virtual chat platform system (Appendix Figure 4.12) combined with the exhibitions to enhance discussion and debating learning experience through text chat communication between participants.
2.3.4 Experimenting, practising	• Through 3D simulation of the constructed exhibits, visitors are encouraged to gain practical experience for comprehension of contextual meanings.
2.3.5 Articulating, expressing	Not applicable (none provided)

```
192.168.0.102:1255>
User 192.168.0.1:1859 (192.168.0.1:1859) left the system.
192.168.0.12:1712> REMDIU
User 192.168.0.1:1869 (192.168.0.1:1869) has logged in.
192.168.0.1:1069>
User 192.168.0.3:1749 (192.168.0.3:1749) has logged in.
```

Appendix Figure 4.12 Virtual Leonardo’s chat platform system

(Source: http://www.museoscienza.org/english/leonardo/leonardovirtuale/istruzioni.asp)

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• The Virtual Leonardo environment provides supplementary material which allows teachers and schools to work together in the question-answering activity through the chat platform system.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• Presents supplementary materials for school students of any age, except high level students. • No collaborative work spaces for students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Effective interaction between museum staff and students, teachers or educational groups of any level through the chat platform system for discussion and feedback.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
• The integration of experiences of real and virtual visits is effectively accomplished through the virtual exhibitions duplicating the physical exhibitions, allowing virtual visitors to prepare for a future visit to the physical museum or evoke a prior actual visit already performed.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Poor non-curriculum-based learning experiences due to basic information on thematic content and minimum educational auxiliary media used.
3.6 Easily identifiable target audience and clear pedagogical strategy
• A difficulty in identifying target audience and pedagogic strategy through structure

of content.

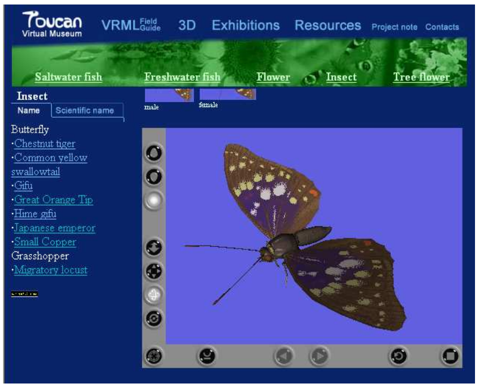
5. Natural history museums

Toucan Virtual Museum (accessed on 21st February, 2006)

(http://www.toucan.co.jp/indexE.html)

The first component: the use of 3D technology in improving access

<table>
<tr><th colspan="3"><i>1. The first component: the use of 3D technology in improving access</i></th></tr>
<tr><td colspan="3">1.1 Simulation</td></tr>
<tr><td></td><td>Artefact/Object</td><td>Environment</td></tr>
<tr><td>1.1.1 Reconstruction</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.2 Reproduction</td><td>✓</td><td>Not applicable</td></tr>
<tr><td>1.1.3 Representation</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.4 Hyper realities</td><td>✓</td><td>Not applicable</td></tr>
<tr><td>1.1.5 Selective realities</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.6 Abstractions</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td colspan="3">• The reproduction of artefacts was accurately created at a hyperreal level of virtuality in a 3D space.</td></tr>
<tr><td colspan="3">1.2 Interactivity</td></tr>
<tr><td>1.2.1 Immersion</td><td colspan="2">• The vivid 3D models of the artefacts in the site are dynamically displayed with animating movement.</td></tr>
<tr><td>1.2.2 Presence</td><td colspan="2">• The different categories of 3D models of insects (Appendix Figure 4.13) and fishes (Appendix Figure 4.14) with real-time animation would impress visitors through their animated movement which gives a realistic feeling of seeing the physical fishes and insects themselves.</td></tr>
<tr><td>1.2.3 Manipulation</td><td colspan="2">• The 3D models of the artefacts allow rotating through 360 degrees, moving and zooming in and out to provide a rich viewing experience.</td></tr>
<tr><td>1.2.4 Navigation</td><td colspan="2">• Lack of description of instruction in navigation for the 3D models of artefacts.</td></tr>
<tr><td>1.2.5 Orientation</td><td colspan="2">Not applicable</td></tr>
<tr><td colspan="3">1.3 Metaphors</td></tr>
<tr><td colspan="3">Not applicable</td></tr>
<tr><td colspan="3">1.4 Integration of multiple media formats</td></tr>
<tr><td colspan="3">• 2D videos, textual and graphic information cannot be found accompanying the 3D models of biological artefacts for interpretation.</td></tr>
</table>



Appendix Figure 4.13 A 3D model butterfly

Appendix Figure 4.14 A 3D model fish

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	• Offers minimum information related to the biological specimens with only their scientific names and natural habitats. • No content of the exhibits for interpretation.
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
Not stated (implicitly providing scientific names, habitats of biological specimens and high-resolution and geometrically accurate models of the 3D artefacts for scholars, curators, amateur enthusiasts and high level students)	
2.2.2 Clarity of instructional objectives and strategies	
• Although 3D objects were organised as a catalogue of biology based on the “constructivism” approach, these instructional objectives and strategies are not presented clearly due to lack of relevant information.	
2.2.3 Motivation and context for learning process	
• Offers these 3D models of objects for target audiences to employ as question-answer activities or open interpretation.	
2.2.4 Clarity of organisation and structure of content	
Not applicable (describing the structure of content as the type of taxonomy and collecting)	
2.2.5 Provision of examples and help in how to use the application	
Not applicable (none provided)	
2.2.6 Provision of interactively practising task in learning process	
Not applicable (none provided)	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	Not applicable (none provided)

2.3.2 Investigating, exploring	• Content organised as catalogues or database through the type of taxonomy for self-directed exploration.
2.3.3 Discussing, debating	• Provides email for communicative learning experience.
2.3.4 Experimenting, practising	• The simulation of fishes and insects with animated movement enhances interactive learning experience of virtual visitors for comprehension of underlying biological principles.
2.3.5 Articulating, expressing	Not applicable (none provided)

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Little supplementary material for schools and teachers. • No support for collaborative spaces for teachers to work together.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• Presentation of supplementary materials for high level students of any age; in particular for their studies or assignments. • No collaborative work spaces for students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Little provision of interaction between museum staff and students, teachers because teachers may be not target audience.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
Not applicable (impossibility of combining experiences of physical visits to museum and the educational website because it is an imaginary museum in cyberspace without physical equivalent)
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• The downloadable and vivid 3D models may engage amateur enthusiasts for their learning experiences and support lifelong learning.
3.6 Easily identifiable target audience and clear pedagogical strategy
• Easily identifiable target audience through structure of content but difficulty in identifying pedagogic strategy because the content seems to be intended only for question-answer activities.

6. Thematic museums

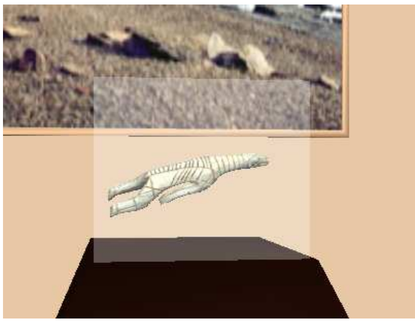
Canadian Museum of Civilization (accessed on 24th February, 2006)

(http://www.civilization.ca/)

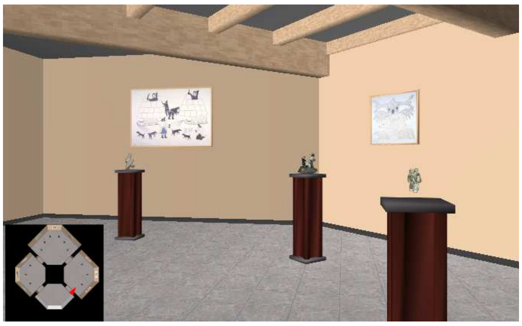
The first component: the use of 3D technology in improving access

1. The first component: the use of 3D technology in improving access		
1.1 Simulation		
	Artefact/Object	Environment
1.1.1 Reconstruction	Not applicable	✓
1.1.2 Reproduction	✓	Not applicable
1.1.3 Representation	Not applicable	Not applicable
1.1.4 Hyper realities	✓	Not applicable

1.1.5 Selective realities	Not applicable	✓
1.1.6 Abstractions	Not applicable	Not applicable
• The exhibits were created as a reproduction of authentic artefacts in the virtual exhibition which represents the spatial environment of selective reality; thus this effectively allows virtual visitors to easily navigate the architectural environment.		
1.2 Interactivity		
1.2.1 Immersion	• The online exhibits were created corresponding to the scale of the exhibition space with high-resolution and vivid spatial information in a panoramic exhibition environment which effectively contributes to immersion.	
1.2.2 Presence	• Virtual visitors may not generally perceive the presence throughout the Inuit 3D environment because the online exhibits were not appropriately placed but hovering within the showcases on display (Appendix Figure 4.15).	
1.2.3 Manipulation	• Provides little effective interaction while manipulating objects and only rotating is available.	
1.2.4 Navigation	• The provision of the instructions for navigation is located outside of the virtual space, which is useful for visitors to grasp the scope of the virtual spatial exhibition. • A clearly marked exit point is easy to find; thus a visitor is able to exit instantly without difficulty.	
1.2.5 Orientation	• Orientation through a map (Appendix Figure 4.16) is given by indications of the red cursor, which is useful to help for virtual visitors to recognise where they are.	
1.3 Metaphors		
• The interaction metaphors using each of virtual exhibits are represented as an icon for visitors to click for more details. • Symbols of the camera directly indicate more information available for access through videos.		
1.4 Integration of multiple media formats		
• The integration of these auxiliary media formats: photographs, images, texts and videos are successfully linked within Inuit 3D by means of hyperlinks.		



Appendix Figure 4.15 A virtual exhibit hovering within the showcase

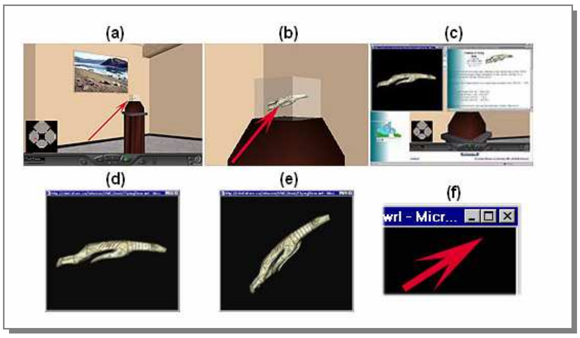


Appendix Figure 4.16 Orientation of the virtual visitor through a map

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources

2.1 Three modes of representation	
2.1.1 Narrative-centered	• A series of stories is conveyed through summaries and illustrated by images and photographs with contextual information related to interpretation of the underlying objects.
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	Not applicable
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
• Although the exhibition rooms do not state their target audience, they can be explicitly identified as researchers and high level students according to the references to information on history, folk and culture etc. relating Palaeo-Eskimo, Inuit History and Inuit Art.	
2.2.2 Clarity of instructional objectives and strategies	
• Easily recognisable instructional strategies were designed based on the "traditional lecture and text" approach through an overview of the historical period connecting particular objects by offering relevant links to associated information for the specification of the exhibition.	
2.2.3 Motivation and context for learning process	
• Provides a range of stories designed as an interesting way to stimulate the learning process.	
2.2.4 Clarity of organisation and structure of content	
• Provides a hierarchical organisation of topic from the simplest elements to progressively more complex by structuring the content to be learned; however, this structure is not presented clearly.	
2.2.5 Provision of examples and help in how to use the application	
• Offers help and examples of how to use the application, before navigating the virtual learning exhibition environments (Appendix Figure 4.17), which are presented clearly.	
2.2.6 Provision of interactively practising task in learning process	
Not applicable (none provided)	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	• Inuit 3D provides opportunities for learning activities designed for attendance and apprehending through linear media such as 2D images, interpretation texts and introductory videos using QuickTime technology, based on a narrative structure.
2.3.2 Investigating, exploring	• The integration of these auxiliary media formats by hypertext links and layering of information effectively enhances the exploring experience through the structured paths.
2.3.3 Discussing, debating	• Provides email to underpin the communicative learning experience through discussion and feedback.
2.3.4 Experimenting, practising	• The simulation of exhibits and imaginary exhibition rooms which enhance the practical learning experience of virtual visitors for the comprehension of historical and cultural meanings.
2.3.5 Articulating, expressing	Not applicable (none provided)



Appendix Figure 4.17 The examples of how to use the application

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Explicitly presenting supplementary learning materials for students and teachers through 3D models of artefacts together with layers of information. • No support for collaborative spaces for teachers to work together.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• No collaborative work spaces for students or supplementary materials for students of any age, except high level students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Little interaction between museum staff and students, teachers because teachers may be not target audience.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
• Reinforcing actual exhibitions, the content of the exhibits includes three dimensional models of artefacts together with multi-layered information: videos, interpretation texts and imagery and historic photographs as learning resources for the combination of experiences of actual and virtual visits.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• To underpin lifelong and non-curriculum-based learning activities, the site gives the virtual visitors access to videos, images, reference material and information to support learning.
3.6 Easily identifiable target audience and clear pedagogical strategy
• The target audience is easily identified as researchers, curators, amateur enthusiasts and high level students according to in-depth interpretation texts, content of the exhibits and references. • The pedagogic approach can be clearly identified as “traditional lecture and text”.

7. Regional and local museums

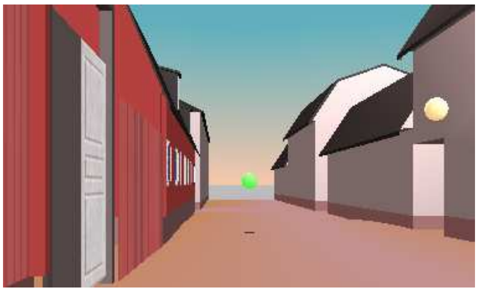
Helsinki City Museum (accessed on 4th June, 2006)

(http://www.hel2.fi/kaumuseo/)

The first component: the use of 3D technology in improving access

1. The first component: the use of 3D technology in improving access		
1.1 Simulation		
	Artefact/Object	Environment
1.1.1 Reconstruction	✓	✓

<table>
<tr><td>1.1.2 Reproduction</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.3 Representation</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.4 Hyper realities</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.5 Selective realities</td><td>✓</td><td>Not applicable</td></tr>
<tr><td>1.1.6 Abstractions</td><td>Not applicable</td><td>✓</td></tr>
<tr><td colspan="3">• The creation of the reconstructed buildings was built as a symbolic way to represent past life and time periods in relation to the history of Helsinki in the abstractive environment.</td></tr>
<tr><td colspan="3">1.2 Interactivity</td></tr>
<tr><td>1.2.1 Immersion</td><td colspan="2">• Lack of fidelity and quality of visual information which does not effectively contribute to immersion.</td></tr>
<tr><td>1.2.2 Presence</td><td colspan="2">• Although 3D clickable walkthrough of the reconstructed buildings gives virtual visitors an opportunity for engaging with the environment itself, the poor quality of visual information fails to enhance a sense of presence.</td></tr>
<tr><td>1.2.3 Manipulation</td><td colspan="2">Not applicable (none provided)</td></tr>
<tr><td>1.2.4 Navigation</td><td colspan="2">• The provision of the instructions is located at the side of the virtual space and is relevantly connected to the thematic content, allowing visitors to navigate the virtual spatial environment for information.</td></tr>
<tr><td>1.2.5 Orientation</td><td colspan="2">• Virtual visitors may encounter difficulty in walking through the 3D virtual environment in terms of orientation due to lack of provision of a map.</td></tr>
<tr><td colspan="3">1.3 Metaphors</td></tr>
<tr><td colspan="3">• Interaction metaphors using green and yellow balls (Appendix Figure 4.18) and silhouette figures (Appendix Figure 4.19) are represented as icons for visitors to click for detailed information.</td></tr>
<tr><td colspan="3">1.4 Integration of multiple media formats</td></tr>
<tr><td colspan="3">• The integration of multiple media formats: audios, texts, images and photographs can be easily found by hypertext links, located at the side of at the virtual environment.</td></tr>
</table>



Appendix Figure 4.18 A Green and a yellow ball

Appendix Figure 4.19 The silhouette figure

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources
2.1 Three modes of representation

2.1.1 Narrative-centered	• The messages are conveyed to interpret Helsinki history underlying particular objects with additional information in a narrative structure.
2.1.2 Object-centered	Not applicable (none provided)
2.1.3 Information-centered	Not applicable (none provided)
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
Not stated (explicitly providing the reconstructed site with information on the archaeological artefacts and the results of excavations for researchers, curators, amateur enthusiasts and high-level students)	
2.2.2 Clarity of instructional objectives and strategies	
• Providing the reconstructions of the historic heritage encourages virtual visitors to explore the environment based on the “discovery learning” approach.	
2.2.3 Motivation and context for learning process	
• Provides a series of stories about Helsinki history linked to the historic site to stimulate the active learning process through exploration.	
2.2.4 Clarity of organisation and structure of content	
• The organisation and structure of thematic content are easy to follow in the environment.	
2.2.5 Provision of examples and help in how to use the application	
• Offers help how to use the “Virtual Museum” application while interacting with the virtual environment.	
2.2.6 Provision of interactively practising task in learning process	
Not applicable (none provided)	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	• Provides a number of linear media such as texts, images, photographs, audios which effectively enrich the comprehending experience.
2.3.2 Investigating, exploring	• Employing hypermedia allows virtual visitors to broaden their investigation of the Helsinki history through following relevant links.
2.3.3 Discussing, debating	• Provides email to underpin the communicative learning experience of virtual visitors by posting their comments and feedback; however, the use of an exclamation mark to represent a symbol of feedback is not easily recognised.
2.3.4 Experimenting, practising	• Simulation of the virtual environment encourages visitors to learn Helsinki history through practical experience.
2.3.5 Articulating, expressing	Not applicable (none provided)

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Offers supplementary materials to effectively aid high level students and researchers in a narrative format which integrates the use of auxiliary media into

3D virtual space.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• No provision of collaborative work spaces for students and supplementary materials for students of any age, except high level students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Interaction between museum staff and students, teachers through email for discussion and feedback.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
• Despite lack of pictures of the buildings of the original Govinius plot to create high quality of visual information, the 3D reconstruction of the historical heritage environments, in some cases, may evoke awareness of the past life at certain historical events and time periods for reinforcing actual heritages.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Effectively supports non-curriculum-based learning experiences and supporting lifelong learning activities through thematic content with in-depth interpretive texts and layers of information in the virtual space.
3.6 Easily identifiable target audience and clear pedagogical strategy
• Easily identifiable pedagogical strategy based on the “discovery learning” approach. • Although the museum does not state its target audience, it can be explicitly identified as researchers and high level students.

8. Archaeology museums

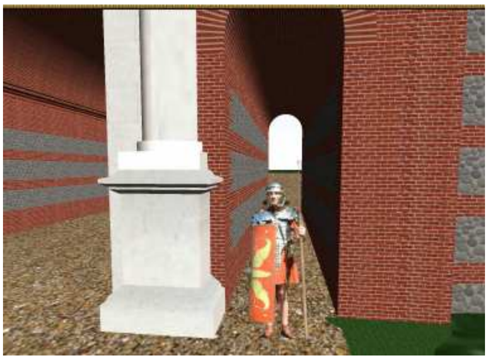
Colchester Castle Museum (accessed on 24th May, 2006)

(http://www.colchestermuseums.org.uk/)

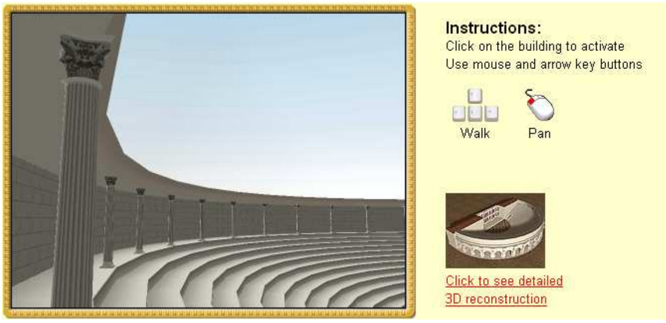
The first component: the use of 3D technology in improving access

1. The first component: the use of 3D technology in improving access		
1.1 Simulation		
	Artefact/Object	Environment
1.1.1 Reconstruction	✓(historic buildings)	✓(historic buildings)
1.1.2 Reproduction	✓(artefacts)	Not applicable
1.1.3 Representation	Not applicable	Not applicable
1.1.4 Hyper realities	✓(both artefacts and historic buildings)	Not applicable
1.1.5 Selective realities	Not applicable	✓(historic buildings)
1.1.6 Abstractions	Not applicable	Not applicable
• Reproduction: artefacts in the site were reproduced as iconic signifiers as authentic to the originals as possible in 3D spaces. • Reconstruction: historic places and cultural heritages were built through the hyperreal level of virtuality of computer-generated simulation reconstructions.		
1.2 Interactivity		
1.2.1 Immersion	• Reproduction: the artefacts provide high-resolution and vivid visual information which contribute to immersive environments. • Reconstruction: the creation of the reconstructed buildings and sites corresponding to a scale of their sizes to the human	

	models (Appendix Figure 4.20) with the quality of vivid architectural information in panoramic environments effectively contribute to immersion.
1.2.2 Presence	• Reproduction: the vividness and resolution of the artefacts are high and they are presented as realistically as possible as if viewing the original themselves. • Reconstruction: the features of the places and buildings through the forms of immersion offer an opportunity to effectively elicit the sense of cultural presence by conveying the experience of being truly there.
1.2.3 Manipulation	• Reproduction: the artefacts allow rotating through 360 degrees, moving and zooming in and out for enriching the viewing experience. • Reconstruction: none provided
1.2.4 Navigation	• Reproduction: the instructions are given for navigation by clicking mouse buttons to interact. • Reconstruction: the provision of the instructions for navigation is located outside of the virtual space, which is useful for visitors to acquire an understanding of the virtual spatial environment through mouse and arrow key buttons (Appendix Figure 4.21).
1.2.5 Orientation	• Virtual visitors could have difficulty in orienting the reconstructed historic places and cultural heritage sites because of lack of provision of a map.
1.3 Metaphors	
Not applicable (none provided)	
1.4 Integration of multiple media formats	
• Reproduction: using interpretation texts only; therefore it is an ineffective combination of multiple media formats. • Reconstruction: using interpretation texts and images is a less effective integration of auxiliary media formats.	



Appendix Figure 4.20 The scale of the reconstructed site is indicated by the use of a human model


Instructions:
Click on the building to activate
Use mouse and arrow key buttons

Appendix Figure 4.21 The instructions for navigation

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	• Reproduction: organisation of online virtual exhibits is devoted to presenting aesthetic values and cultural meanings; however, the minimum information provided may ineffectively interpret their significances. • Reconstruction: virtual visitors are encouraged to visually appreciate the original appearance of archaeological sites through accurate simulation of models; however, the minimum information offered might ineffectively explain the contextual significances.
2.1.3 Information-centered	Not applicable
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
Not stated (providing the artefacts and the reconstructed buildings with basic information for students and teachers)	
2.2.2 Clarity of instructional objectives and strategies	
Not stated (providing the elaborate reconstructions of historic buildings and cultural heritage encourages virtual visitors to explore the environment; however, they ineffectively enhance the learning experience due to lack of sufficient information)	
2.2.3 Motivation and context for learning process	
Not stated (providing both reproduction and reconstruction for the question-answering activity or open interpretation in learning process)	
2.2.4 Clarity of organisation and structure of content	
• Reproduction: organising content of 3D materials focuses on providing informational resources rather than learning resources. • Reconstruction: clearly provides the reconstructed historic buildings and cultural heritage representing the past for virtual visitors to discover; however, lack of in-depth interpretive content.	
2.2.5 Provision of examples and help in how to use the application	
Not applicable (none provided)	
2.2.6 Provision of interactively practising task in learning process	
Not applicable (none provided)	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	

Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	• Offers minimal information by texts and images; therefore may limit engagement and comprehension of experience.
2.3.2 Investigating, exploring	• Reproduction: not applicable (none provided) • Reconstruction: each image is linked by connecting its 3D reconstruction for details; however, although the detailed reconstructions are available to access by hyperlinks, they do not enhance exploring experience.
2.3.3 Discussing, debating	• Provides *"Feedback"* to underpin the communicative learning experience of virtual visitors by comments and feedback.
2.3.4 Experimenting, practising	• The 3D simulation of the replicas and the reconstructed buildings encourage virtual visitors to actively acquire information, enhancing their practical experiences.
2.3.5 Articulating, expressing	Not applicable (none provided)

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• The reconstruction of the heritage environments as supplementary materials allows teachers and schools to use them in the question-answering activity while discovering the virtual spaces. • No support for collaborative spaces for teachers to work together.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• The creation of the virtual heritage environments and appearance to enhance an evocative British culture in early Roman eras and the Norman era as supplementary materials in learning process; however, great depth of information and interpretive content cannot be found. • No provision of collaborative work spaces for students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Provides interaction for communication between museum staff and students, teachers through *"Feedback"*.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
• Reinforcing actual heritage, the 3D reconstruction of the virtual cultural heritage environments effectively evokes awareness of the past life at certain historical events and time periods.
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Poor non-curriculum-based learning experiences due to basic information and minimum educational auxiliary media used. • Poor lifelong learning because of lack of clear learning objectives and information through 3D reproduction of the artefacts and 3D reconstruction of the cultural heritages.
3.6 Easily identifiable target audience and clear pedagogical strategy
• Easily identifiable target audience through structure of content but difficulty in identifying pedagogic strategy because the content seems to be employed only for the question-answering or open interpretation activity.

9. University museums

Hofstra University (Department of Physics) (accessed on 24th May, 2006)

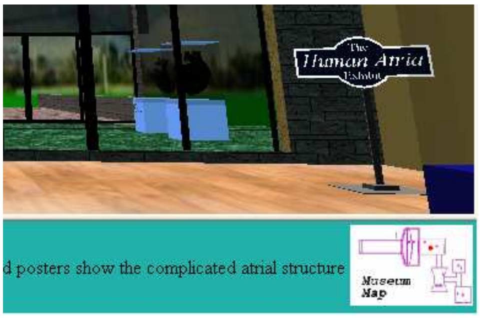
Cardiac Museum

(http://arrhythmia.hofstra.edu/vrml/museumn/museumn.html)

The first component: the use of 3D technology in improving access

<table>
<tr><td colspan="3"><i>1. The first component: the use of 3D technology in improving access</i></td></tr>
<tr><td colspan="3">1.1 Simulation</td></tr>
<tr><td></td><td>Artefact/Object</td><td>Environment</td></tr>
<tr><td>1.1.1 Reconstruction</td><td>Not applicable</td><td>✓</td></tr>
<tr><td>1.1.2 Reproduction</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.3 Representation</td><td>✓</td><td>Not applicable</td></tr>
<tr><td>1.1.4 Hyper realities</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.5 Selective realities</td><td>✓</td><td>✓</td></tr>
<tr><td>1.1.6 Abstractions</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td colspan="3">• The 3D models of artefacts (Appendix Figure 4.22) were created as symbolic signifiers to represent the structure of human atria and canine ventricles by cutting away unnecessary information in the virtual environment.</td></tr>
<tr><td colspan="3">1.2 Interactivity</td></tr>
<tr><td>1.2.1 Immersion</td><td colspan="2">• The poor visual quality of virtual exhibits and the gallery environments has resulted in a low level of immersion; although a panoramic museum environment is given.</td></tr>
<tr><td>1.2.2 Presence</td><td colspan="2">• The doors can be automatically opened in the environment when a visitor enters the museum, therefore effectively evoking a sense of environmental presence through actively responding to visitors.
• Dullness and low-resolution of visual information in the virtual exhibits and the gallery environments fails to help visitors perceive a sense of virtual presence.</td></tr>
<tr><td>1.2.3 Manipulation</td><td colspan="2">Not applicable (none provided)</td></tr>
<tr><td>1.2.4 Navigation</td><td colspan="2">• The provision of the basic instructions for navigation is located at the main entrance to the site for visitors to grasp the virtual spatial exhibitions.</td></tr>
<tr><td>1.2.5 Orientation</td><td colspan="2">• Orientation through a map (Appendix Figure 4.23) is given by the indication of the flashing red point, which is useful to help virtual visitors recognise where they are.</td></tr>
<tr><td colspan="3">1.3 Metaphors</td></tr>
<tr><td colspan="3">• Overall environment metaphor can be easily found though the signs of exhibit for indications of architectural information throughout the environment.</td></tr>
<tr><td colspan="3">1.4 Integration of multiple media formats</td></tr>
<tr><td colspan="3">• Integration of multiple media formats through animations, images and texts for interpretation of knowledge and information about tachycardia and fibrillations.</td></tr>
</table>

Appendix Figure 4.22 A 3D model exhibit

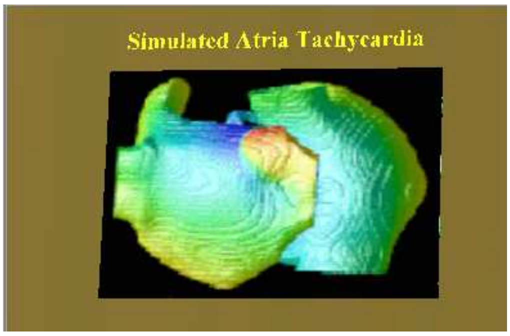


Appendix Figure 4.23 A 2D map and a sign for an exhibit

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	• The arrangement of the 3D exhibited artefacts with texts, animations and images focuses on the demonstration of the arrhythmia process.
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
• Provides 3D models of the artefacts or animations which present medical information on ventricular tachycardia and ventricular fibrillation for scholars, amateur enthusiasts and high level students.	
2.2.2 Clarity of instructional objectives and strategies	
• Easily recognisable instructional strategies were designed based on the “traditional lecture and text” approach through an overview of the arrhythmia process linking particular artefacts, animations and images.	
2.2.3 Motivation and context for learning process	
• Provides a range of thematic content designed in an interesting way to stimulate the learning process	
2.2.4 Clarity of organisation and structure of content	
• Provides an organisation of subject from the simplest elements to progressively more complex for virtual visitors to learn; however, this structure is not presented clearly because little information can be found.	
2.2.5 Provision of examples and help in how to use the application	
• Offers an example through a guided tour how to use the application, before navigating the virtual learning museum environment.	
2.2.6 Provision of interactively practising task in learning process	
Not applicable (none provided)	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	
2.3 The types of learning experience	
2.3.1 Attending, apprehending	• Although a small number of animations, images and texts can be found, the learning activities provide poor learning

	experiences due to a lack of contextual information.
2.3.2 Investigating, exploring	Not applicable (none provided)
2.3.3 Discussing, debating	• Provides email to support the communicative learning experience through discussion and feedback messages.
2.3.4 Experimenting, practising	• The simulation of exhibits using animations (Appendix Figure 4.24) enhances the practical learning experience for comprehension of arrhythmia process in the virtual learning environment.
2.3.5 Articulating, expressing	Not applicable (none provided)



Appendix Figure 4.24 The simulation of atria tachycardia using animation

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Offers supplementary materials to effectively enhance the knowledge of high level students and researchers through those 3D virtual exhibits, animations, texts and images. • No support for collaborative spaces for teachers to work together.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• No collaborative work spaces for students and supplementary materials for students of any age, except high level students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Little interaction for communication between museum staff and students, teachers because students and teachers are not target audience, except high level students.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
Not applicable (impossibility of combining experiences of physical visits to museum and the educational website because it is an imaginary museum in cyberspace without a physical museum equivalent)
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
None provided (content of the 3D exhibits only for researchers, amateur enthusiasts and high level students for gaining knowledge of arrhythmia and contextual information and of complicated atrial structures of human and dog heart)
3.6 Easily identifiable target audience and clear pedagogical strategy
• The target audience is easily identified as researchers, amateur enthusiasts and high level students according to complicated content of the exhibits and associated

medical terms.

- Explicit pedagogical strategy based on the “traditional lecture and text” approach.

10. Technical museums

B-Side-Museum (accessed on 26th February, 2006)

(http://www.b-side-museum.com/bsidenew/index.html)

The first component: the use of 3D technology in improving access

<table>
<tr><th colspan="3"><i>1. The first component: the use of 3D technology in improving access</i></th></tr>
<tr><td colspan="3">1.1 Simulation</td></tr>
<tr><td></td><td>Artefact/Object</td><td>Environment</td></tr>
<tr><td>1.1.1 Reconstruction</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>1.1.2 Reproduction</td><td>Not applicable</td><td>✓(partly)</td></tr>
<tr><td>1.1.3 Representation</td><td>✓</td><td>Not applicable</td></tr>
<tr><td>1.1.4 Hyper realities</td><td>Not applicable</td><td>✓(partly)</td></tr>
<tr><td>1.1.5 Selective realities</td><td>✓</td><td>Not applicable</td></tr>
<tr><td>1.1.6 Abstractions</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td colspan="3">• The 3D model aircraft and cars are represented as visual references without details; for example, the detailed propellers in some aircrafts were not completely reproduced.</td></tr>
<tr><td colspan="3">1.2 Interactivity</td></tr>
<tr><td>1.2.1 Immersion</td><td colspan="2">• High-resolution and vivid 3D model artefacts effectively contribute to immersion.</td></tr>
<tr><td>1.2.2 Presence</td><td colspan="2">• The vivid online exhibits may help virtual visitors to ignore the surroundings of physical reality for enhancing a sense of virtual presence.</td></tr>
<tr><td>1.2.3 Manipulation</td><td colspan="2">• The 3D model artefacts (Appendix Figure 4.25) allow virtual visitors to rotate three dimensional models of artefacts in 360 degrees and zoom in and out.
• Few 3D model artefacts are presented in virtual spaces which can be altered to simulate the environment for interpretation of contextual significance.</td></tr>
<tr><td>1.2.4 Navigation</td><td colspan="2">• Provides a basic set of instructions for navigation using input devices such as mouse or keyboard.</td></tr>
<tr><td>1.2.5 Orientation</td><td colspan="2">Not applicable</td></tr>
<tr><td colspan="3">1.3 Metaphors</td></tr>
<tr><td colspan="3">Not applicable (none provided)</td></tr>
<tr><td colspan="3">1.4 Integration of multiple media formats</td></tr>
<tr><td colspan="3">• Lack of integration of multiple media formats, except texts.</td></tr>
</table>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and much more...
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Appendix Figure 4.25 A 3D model aircraft in the virtual space

The second component: web-based museums as informational and learning resources

2. The second component: web-based museums as informational and learning resources	
2.1 Three modes of representation	
2.1.1 Narrative-centered	Not applicable
2.1.2 Object-centered	Not applicable
2.1.3 Information-centered	• Exhibits were organised to interpret technical information about electronic devices and aeronautic mechanics and so on through information-centered scheme.
2.2 Pedagogic design factors	
2.2.1 Clarity of target audience	
Not stated (implicitly organised the 3D presentation of the artefacts in an encyclopaedia of cars and aircraft for students and teachers)	
2.2.2 Clarity of instructional objectives and strategies	
• Although 3D model artefacts were arranged as an encyclopaedia of cars and aircraft based on the “constructivism” approach, these instructional objectives and strategies are not presented clearly due to lack of relevant information.	
2.2.3 Motivation and context for learning process	
• The 3D model artefacts provide contextual information, historical significances and specifications such as length, height, weight and so on for virtual visitors to actively construct knowledge in their own mind and build on their prior understanding through a range of structured thematic content.	
2.2.4 Clarity of organisation and structure of content	
• Structure of thematic content is logically organised according to the category of taxonomy and time periods; however, this organisation lacks a layer of information for visitors to actively construct knowledge.	
2.2.5 Provision of examples and help in how to use the application	
• Few examples of how to use the application for navigating the virtual environments.	
2.2.6 Provision of interactively practising task in learning process	
• Provides a simulation of mechanical structure of aircraft and classic cars, such as turning propeller which allows visitors to interact with the aeronautic mechanics and texts as part of the learning process.	
2.2.7 Provision of feedback in learning activities	
Not applicable (none provided)	
2.2.8 Evaluation of learning outcomes	
Not applicable (none provided)	

2.3 The types of learning experience	
2.3.1 Attending, apprehending	• The interpretative texts do not enrich the virtual visitor's knowledge of the types of artefacts.
2.3.2 Investigating, exploring	• Organising content as an encyclopaedia of the 3D presentation of the cars and aircraft enables virtual visitors to view them in order for self-directed discovery.
2.3.3 Discussing, debating	• Provides email for feedback and discussion to enable a dialogue between museum staff and virtual visitors.
2.3.4 Experimenting, practising	• The simulation of the environmental context surrounding the artefacts can help virtual visitors learn the contextual significance by practical experience (for example, the sky can be imitated to represent the flight of an aircraft). • The realistic simulation of rotating propeller and opening canopy of aircraft enhances experience for comprehension of mechanical structure.
2.3.5 Articulating, expressing	Not applicable (none provided)

The third component: the Archives & Museum Informatics Standards

3. The third component: the Archives & Museum Informatics Standards
3.1 Presentation of supplementary material for schools and teachers, and support for collaborative spaces for teachers to work together
• Supplementary material through the simulation of aeronautic mechanics support collaboration for students and teachers.
3.2 Presentation of supplementary materials for students of any age, and provision of collaborative work spaces for students
• Provides supplementary materials through the simulation of mechanical structure with interpretative texts for school students of age 11-18. • No underpinning collaborative work spaces for students.
3.3 Interaction between museum staff and students, teachers, or educational groups of any level
• Provides interaction between museum staff and students, teachers through email for asking questions and posting comments.
3.4 Integration of experiences of 'real' visits to museum and the educational Web site
Not applicable (impossibility of combining experiences of physical visits to museum and the educational website because it is a virtual museum without physical equivalent)
3.5 Provision of non-curriculum-based learning experiences and support of lifelong learning activities
• Overall, the 3D content and associated information may not be designed for formal learning and lesson structure. However, the aeronautic knowledge and history of modern aviation, in some cases, could not only be used in a formal teaching environment, but also employed in a non-curriculum-based learning experience and lifelong learning activities.
3.6 Easily identifiable target audience and clear pedagogical strategy
• No identifiable target audience through organisation of content. • Although exhibit content can be identified as an encyclopaedia of the 3D presentation of the cars and aircraft, pedagogical strategy is not clearly presented.

Appendix 5A: Orientation Script

Dear participant,

I, Chao-Yu Lin, am a PhD student in the Faculty of Art and Design at De Montfort University. As part of my research, I am conducting observational studies to investigate the relationship between the visiting styles and learning activities in 3D environments on museum websites.

Here are the objectives for the observation studies:

1. How can the factors of interactivity (i.e. immersion, presence, manipulation and so on) in a 3D virtual environment influence the types of visiting styles?
2. How does the organisation and layout of the exhibition and content of online virtual exhibits influence visitor behaviour patterns, leading to learning activities in 3D virtual museum environments?
3. How can the types of pedagogic approach be adapted to match visiting styles in terms of the presentation of information and organisation of learning materials in exhibits in a 3D virtual environment?
4. What is the informational architecture and paths which give virtual visitors the most clear and effective orientation to progress over time and across learning programmes within 3D virtual spatial environments?

I will be working with you today throughout the performance test. This process may take around 1 hour. There are two parts in the test:

i. Part one – a free exploration of museum websites:
   You will be given 10 minutes to freely explore each museum website.
ii. Part two – performance of a range of tasks:
   You will be given several tasks to perform on the museum website.

After performing tasks on each museum website, you will be given a post-observation questionnaire to fill in.

You will be given an ID number to replace your name to maintain anonymity. If you are uncomfortable or stressed during the performance test, you can quit any section at any time. Please note I will be unable to answer you questions during the test process. Do you have any questions before we start?

Appendix 5B: Behavioural Codes

Museums **Behaviours**		**London Science Museum**	**Canadian Museum of Civilization**	**Helsinki City Museum**	**Philadelphia Museum of Art**
Interactivity	Manipulate artefacts			N/A	N/A
	Manipulate incorrectly			N/A	N/A
	Look for help or instructions for manipulation			N/A	N/A
Navigation	Look for help or instructions for navigation				
	Show frustration on navigation				
Media formats	Read labels and texts				
	Listen to audios	N/A	N/A		N/A
	Watch videos	N/A		N/A	N/A
	Look at images				
	Look at animations		N/A	N/A	N/A
Information and pedagogic interactions	Click on the exhibit images for further information				N/A
	Interact with learning activities or games		N/A		N/A
	Look for help or examples in programmes and activities		N/A		N/A
Visiting styles	Ant				
	Fish				
	Grasshopper				
	Butterfly				

NOTE: N/A = No applicable

Appendix 5C: Subject Background Questionnaire

Sex: ☐ Male ☐ Female

Age: ☐ 11-18 ☐ 19-30 ☐ 31-40 ☐ 41-50 ☐ 51+

Occupation: ____

Education: (please tick the highest grade level achieved)
☐ GCSE ☐ A level ☐ First degree ☐ Master’s degree ☐ Doctoral degree
☐ Other ________________________

Internet experience:

1. Have you ever used the Internet before?
   ☐ Yes ☐ No

2. How often do you visit websites on the Internet in general?
   ☐ Every day
   ☐ 3-6 times per week
   ☐ Once or twice per week
   ☐ Once or twice per month
   ☐ Once or twice per year

Museum website experience:

1. Have you ever visited a museum website before? (e.g. British Museum, National History Museum, Science Museum London, New Walk Museum & Art Gallery …etc.)
   ☐ Yes ☐ No
   If yes, which?____

2. If yes, how often do you visit museum websites in general?
   ☐ Every day
   ☐ Once or more per week
   ☐ Once or twice per month
   ☐ Once or twice per year
   ☐ Less than once per year

3. Why do you visit museum websites (tick all that apply)

☐ For general interest
☐ For schoolwork and homework
☐ For research
☐ For occupational need
☐ For entertainment
☐ For buying books, CDs, gifts, etc.
Other-please specify ______________________________

4. What would you normally look at when visiting a museum website? (tick all that apply)
☐ General information (opening hours, admission fee, direction…etc.)
☐ Schedule of events (exhibitions, films, lectures…etc.)
☐ Images of artefacts in the collections
☐ Virtual exhibitions
☐ Learning resources (school programmes, activities and games…etc.)
☐ Forum or discussion board
☐ Online question or requirement sections with museum staff
☐ Online shopping
Other-please specify ______________________________

3D web-based environment experience:

1. Have you ever visited a 3D environment on the website before? (3D virtual environments on the E-Commerce, museum, game, E-Learning websites…etc.)
☐ Yes ☐ No ☐ Unsure
If yes which? ______________________________

2. If yes, how often do you visit those 3D environments on the websites in general?
☐ Every day
☐ Once or more per week
☐ Once or twice per month
☐ Once or twice per year
☐ Less than once per year

3. What are your opinions of these 3D environments on the websites?
☐ Easy to use
☐ Fun
☐ Useful
☐ Attractive
Other-please specify ______________________________

Appendix 5D: Post-Observation Questionnaire

Please answer the following questions based on your experience of visiting the museum website

The aspects of the use of 3D technology:

Legend: 5=Strongly Agree 4=Agree 3=Neither 2=Disagree 1=Strongly Disagree N/A=Not Applicable

1.	The quality of the 3D model artefacts was satisfactory.	5	4	3	2	1	N/A
2.	The quality of the 3D museum environment was satisfactory.	5	4	3	2	1	N/A
3.	The 3D model artefacts gave you a sense of presence with a feeling of seeing the physical artefacts themselves.	5	4	3	2	1	N/A
4.	The 3D museum environment gave you a sense of presence with a feeling of being truly in the actual museum.	5	4	3	2	1	N/A
5.	It was easy to manipulate the 3D model artefacts (e.g. zoom in, out, move and rotate).	5	4	3	2	1	N/A
6.	Instructions given for manipulation were easy to understand.	5	4	3	2	1	N/A
7.	It was easy to navigate the 3D museum environment.	5	4	3	2	1	N/A
8.	The map provided helped you to acquire spatial knowledge of the 3D museum environment.	5	4	3	2	1	N/A
9.	The videos provided you with additional information on exhibits.	5	4	3	2	1	N/A
10.	The audios provided you with additional information on exhibits.	5	4	3	2	1	N/A
11.	The images provided you with additional information on exhibits.	5	4	3	2	1	N/A
12.	The animations provided you with additional information on exhibits.	5	4	3	2	1	N/A

Informational aspects:

Legend: 5=Strongly Agree 4=Agree 3=Neither 2=Disagree 1=Strongly Disagree N/A=Not Applicable

13.	It was easy to find information.	5	4	3	2	1	N/A
14.	It was easy to understand the information.	5	4	3	2	1	N/A
15.	The amount of information on exhibits was adequate.	5	4	3	2	1	N/A
16.	The 3D model artefacts provided you with more information than texts, images, etc.	5	4	3	2	1	N/A
17.	The 3D model artefacts provided you with sufficient information.	5	4	3	2	1	N/A

Learning aspects:

Legend: 5=Strongly Agree 4=Agree 3=Neither 2=Disagree 1=Strongly Disagree
N/A=Not Applicable

18.	Content of exhibits was easy to understand.	5	4	3	2	1	N/A
19.	The organisation and structure of content were easy to follow.	5	4	3	2	1	N/A
20.	It was useful to click on the exhibit images for learning activities or games.	5	4	3	2	1	N/A
21.	The learning activities or games were useful to understand more information about exhibits.	5	4	3	2	1	N/A
22.	The example and help were useful for you to know how to use the learning activities or games.	5	4	3	2	1	N/A

Overall impression of the museum website

How would you rate this museum website as both informational and learning resources? (On a scale of 1 to 10, 1= the worst; 10= the best)

the worst 1 2 3 4 5 6 7 8 9 10 the best

Any comments or suggestions on improvements of this museum website

____

____

____

Appendix 5E: Observation Data

I. Data of participant profile

II. Data of the overall participants' behaviours

III. Data of attraction and holding power of exhibits

IV. Data of visiting styles from 4 museum websites

V. Performance data of the assigned tasks

VI. Post-observation questionnaire data

I. Data of participant profile

General public

Participant / Demographic data		GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10
Gender		F	F	M	M	M	F	M	F	F	M
Age		19-30	19-30	19-30	19-30	19-30	19-30	19-30	31-40	31-40	19-30
Education		First degree	First degree	Other	First degree	First degree	First degree	First degree	First degree	First degree	First degree
Internet experience		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internet usage		Every day	3-6 times per week	Every day	3-6 times per week	Every day	Every day	Every day	Every day	3-6 times per week	Every day
Museum website experience		Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes
Museum website usage		Once or twice per month	Once or twice per year	N/A	N/A	Once or twice per year	Once or twice per year	Once or twice per year	N/A	N/A	Once or twice per year
Reasons for visiting museum websites	For general interest	✓				✓					✓
	For schoolwork and homework										
	For research	✓					✓				✓
	For occupational need					✓					
	For entertainment	✓	✓				✓				✓
	For buying books, CDs, gifts, etc.										✓
Sections on a museum website in general	General information	✓	✓				✓	✓			✓
	Schedule of events	✓	✓				✓	✓			✓
	Images of artefacts in the collections	✓					✓				
	Virtual exhibitions										
	Learning resources	✓									
	Forum or discussion board										
	Online question or requirement sections with museum staff										
	Online shopping	✓									✓
3D web-based environment experience		Yes	Yes	Yes	Yes	No	Yes	Unsure	Yes	No	Yes
3D web-based environment usage		Once or twice per month	Once or twice per year	Once or twice per month	Once or twice per month	N/A	Once or twice per year	N/A	Once or more per week	N/A	Once or twice per year
Opinions of the 3D environments on the Internet	Easy to use			✓					✓		✓
	Fun	✓		✓	✓						✓
	Useful		✓	✓			✓				
	Attractive	✓									

NOTE: GP = General public N/A = Not applicable

Researchers and professionals

Participant Demographic data		RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10
Gender		M	M	M	F	F	F	F	M	F	M
Age		31-40	41-50	31-40	19-30	19-30	19-30	19-30	41-50	19-30	41-50
Education		Master degree	Master degree	Master degree	First degree	First degree	Master degree	First degree	Master degree	Master degree	Other
Internet experience		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internet usage		Every day	Every day	Every day	Every day	Every day	Every day	Every day	Every day	Once or twice per week	Every day
Museum website experience		No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Museum website usage		N/A	Once or twice per year	Once or twice per year	Less than once per year	Once or twice per month	Once or twice per year	Once or twice per year	N/A	Once or more per week	Once or twice per month
Reasons for visiting museum websites	For general interest		✓	✓		✓	✓			✓	
	For schoolwork and homework			✓							
	For research			✓				✓		✓	✓
	For occupational need									✓	✓
	For entertainment		✓		✓		✓				
	For buying books, CDs, gifts, etc.										
Sections on a museum website in general	General information		✓	✓	✓		✓	✓		✓	✓
	Schedule of events		✓	✓	✓		✓	✓		✓	✓
	Images of artefacts in the collections					✓		✓		✓	✓
	Virtual exhibitions		✓								
	Learning resources									✓	
	Forum or discussion board										
	Online question or requirement sections with museum staff									✓	
	Online shopping										
3D web-based environment experience		Yes	Yes	Yes	No	No	Unsure	Yes	Yes	Unsure	Yes
3D web-based environment usage		Once or twice per year	Once or twice per year	Once or twice per month	N/A	N/A	N/A	Once or twice per year	Once or twice per month	N/A	Once or twice per year
Opinions of the 3D environments on the Internet	Easy to use						✓				✓
	Fun	✓		✓			✓	✓	✓		✓
	Useful										
	Attractive		✓				✓	✓			

NOTE: RP= Researchers and professionals N/A = Not applicable

Schools

Participant **Demographic data**		**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**
Gender		F	F	M	F	M	F	F	F	F	M
Age		19-30	19-30	11-18	19-30	19-30	11-18	19-30	11-18	11-18	19-30
Education		First degree	First degree	GCSE	First degree	First degree	A level	First degree	A level	A level	First degree
Internet experience		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internet usage		Every day	Every day	Once or twice per month	Every day	Every day	Every day	Every day	Every day	Every day	Every day
Museum website experience		Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes
Museum website usage		Once or twice per year	Once or twice per month	N/A	Once or twice per year	Once or twice per month	Once or more per week	Once or twice per year	N/A	N/A	Once or twice per month
Reasons for visiting museum websites	For general interest	✓	✓		✓	✓		✓			
	For schoolwork and homework		✓			✓	✓				
	For research	✓	✓		✓	✓	✓				✓
	For occupational need	✓	✓			✓		✓			
	For entertainment		✓								✓
	For buying books, CDs, gifts, etc.										✓
Sections on a museum website in general	General information	✓	✓		✓	✓	✓	✓			✓
	Schedule of events	✓	✓			✓	✓				✓
	Images of artefacts in the collections		✓			✓		✓			
	Virtual exhibitions	✓	✓		✓	✓		✓			✓
	Learning resources	✓	✓			✓					
	Forum or discussion board										
	Online question or requirement sections with museum staff										
	Online shopping										
3D web-based environment experience		No	Unsure	No	Yes	Yes	Unsure	Unsure	No	No	Unsure
3D web-based environment usage		N/A	N/A	N/A	Once or twice per year	Once or more per week	N/A	N/A	N/A	N/A	N/A
Opinions of the 3D environments on the Internet	Easy to use										
	Fun		✓		✓	✓					
	Useful										✓
	Attractive										

NOTE: S = Schools N/A = Not applicable

II. Data of the overall participants’ behaviours

Behaviours

No.1	Manipulate artefacts
No.2	Manipulate incorrectly
No.3	Look for help or instructions for manipulation
No.4	Look for help or instructions for navigation
No.5	Show frustration on navigation
No.6	Read labels and texts
No.7	Listen to audios
No.8	Watch videos
No.9	Look at images
No.10	Look at animations
No.11	Click on the exhibit images for further information
No.12	Interact with learning activities or games
No.13	Look for help or examples in programmes and activities

London Science Museum

B. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Frequency**
1.	0	0	1	2	0	0	1	0	0	0	7	2	0	0	0	1	0	2	0	0	3	2	0	0	2	1	0	0	0	3	27(2.8%)
2.	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	3	0	0	0	0	0	0	0	1	0	0	0	0	7(0.7%)
3.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.	2	0	2	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	10(1.0%)
5.	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
6.	9	8	9	5	12	11	7	4	12	10	17	8	15	3	5	15	4	14	2	9	7	6	10	8	10	4	5	3	5	10	247(25.7%)
7.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9.	8	8	8	5	12	11	7	4	11	10	16	7	15	3	5	14	4	14	2	9	8	3	10	8	10	4	5	3	5	11	240(25.0%)
10.	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	8(0.8%)
11.	10	15	16	5	15	13	11	5	16	12	26	8	18	5	7	17	6	19	2	11	13	13	15	12	13	7	7	3	7	13	340(35.4%)
12.	1	0	3	0	3	1	3	1	3	1	4	4	2	2	2	2	2	5	0	1	2	5	5	2	2	3	1	0	2	2	64(6.7%)
13.	1	0	2	0	0	1	0	0	0	2	0	1	0	0	0	1	2	0	0	0	1	0	1	1	0	3	0	0	2	0	18(1.9%)

NOTE: B. No. = Behaviour number N/A = Not applicable GP = General public RP = Researchers and professionals S = Schools

Canadian Museum of Civilization

B. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Frequency**
1.	11	0	8	6	6	0	12	0	3	6	11	4	0	0	4	8	0	0	0	0	0	3	10	5	8	11	2	0	0	0	118(7.3%)
2.	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	2	0	0	2	1	0	0	0	0	0	10(0.6%)
3.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1(0.1%)
4.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	4(0.2%)
5.	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
6.	22	23	16	14	12	16	23	15	5	12	24	18	12	13	18	19	8	16	2	9	13	24	10	23	12	22	5	18	6	20	450(28.0%)
7.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8.	1	1	6	1	3	3	0	0	1	1	4	5	4	5	4	5	1	1	0	0	0	0	0	0	4	0	2	0	0	2	54(3.4%)
9.	22	28	16	14	12	16	23	15	5	12	24	17	12	13	18	19	8	16	2	9	14	25	10	23	12	22	5	18	5	20	455(28.3%)
10.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11.	23	28	22	15	15	19	23	15	8	13	28	23	17	18	22	24	9	17	3	9	12	27	10	23	16	22	7	18	6	23	515(32.0%)
12.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

NOTE: B. No. = Behaviour number N/A = Not applicable GP = General public RP = Researchers and professionals S = Schools

Helsinki City Museum

B. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Frequency**
1.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.	0	0	4	0	0	0	0	3	0	0	0	1	1	1	0	1	0	0	3	1	0	0	0	0	0	0	0	0	0	0	15(2.2%)
5.	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	7(1.0%)
6.	3	5	12	13	2	11	18	8	11	3	6	20	7	10	0	18	3	4	1	1	2	2	3	9	7	5	7	2	0	5	198(29.6%)
7.	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5(0.7%)
8.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9.	4	10	14	15	3	11	16	9	12	4	7	21	9	15	0	18	3	4	1	1	3	2	3	11	8	8	8	2	0	4	226(33.8%)
10.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11.	4	11	12	15	3	11	15	9	11	4	7	20	9	10	0	19	3	4	1	1	4	2	3	10	8	8	8	2	0	4	218(32.6%)
12.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

NOTE: B. No. = Behaviour number N/A = Not applicable GP = General public RP = Researchers and professionals S = Schools

Philadelphia Museum of Art

B. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Frequency
1.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.	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	1(0.4%)
5.	0	3	4	2	0	0	2	0	1	0	0	1	2	0	1	0	0	0	2	0	0	0	1	0	0	0	1	2	0	0	22(7.8%)
6.	3	7	4	2	5	6	1	6	5	2	5	3	3	6	4	3	4	3	4	4	4	2	4	2	3	6	2	4	1	3	111(39.2%)
7.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9.	5	3	8	2	2	6	3	7	7	6	7	11	5	8	4	7	1	2	2	7	3	4	3	6	3	7	5	4	1	10	149(52.7%)
10.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
13.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

NOTE: B. No. = Behaviour number N/A = Not applicable GP = General public RP = Researchers and professionals S = Schools

III. Data of attraction and holding power of exhibits

London Science Museum

Exhibit Number:

Gallery	Exhibits
Antenna & Pattern Pod	No. 1 IMAX and Virtual Voyages No. 2 Pattern Wall (game) No. 3 Growing Patterns (game) No. 4 Pattern Pod No. 5 Antenna No. 6 Talking Points No. 7 Deep Blue Cafe
Who am I	No. 8 Who am I No. 9 Radio Babel (game) No. 10 Bleadon Man (artefact) No. 11 Bleadon Man (game) No. 12 Live Science No. 13 Cryogenic Head Freezer (artefact) No. 14 White Peacock (artefact) No. 15 Personality (game) No. 16 Tell us what you think No. 17 Teletubbies Favourite Things No. 18 Art Guild No. 19 Highlights (x2) *
Digitopolis	No. 20 Networking People (game) (x2) * No. 21 Musical Jacket (artefact) No. 22 Highlights (x2) * No. 23 Wheatstone Printing Telegraph (x2) * No. 24 Tell us what you think (x2) * No. 25 Sound Editor (game) (x2) * No. 26 Audio Tutu (artefact) (x2) * No. 27 Art Guild No. 28 Pixel Revolutions (game) (x2)* No. 29 Frigate 2000 (artefact) (x2) *
In Future	No. 30 In Future (x2) * No. 31 Screensavers

* The two exhibit icons represent the same exhibit on display in the same gallery

Attraction of exhibits in London Science Museum

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Attraction (number)
1.					✓	✓		✓		✓			✓	✓	✓								✓								8
2.			✓			✓	✓			✓			✓	✓	✓	✓	✓				✓		✓	✓		✓	✓		✓		15
3.	✓		✓		✓	✓	✓	✓	✓	✓			✓	✓	✓		✓						✓	✓		✓			✓		16
4.			✓			✓	✓		✓	✓			✓		✓									✓					✓		9
5.	✓	✓	✓		✓	✓		✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓	✓	22
6.		✓				✓			✓				✓				✓	✓		✓			✓	✓	✓				✓		11
7.						✓	✓			✓					✓		✓						✓						✓		7
8.			✓		✓				✓			✓	✓			✓		✓		✓			✓		✓	✓				✓	12
9.											✓	✓						✓				✓	✓		✓					✓	7
10.									✓		✓	✓	✓					✓												✓	6
11.											✓	✓	✓													✓					4
12.									✓		✓	✓				✓		✓							✓						6
13.	✓								✓		✓		✓					✓		✓					✓	✓				✓	9
14.	✓								✓		✓	✓	✓			✓		✓		✓		✓								✓	10
15.												✓				✓		✓		✓		✓									5
16.											✓	✓						✓		✓		✓									5
17.					✓				✓		✓					✓		✓		✓										✓	7
18.					✓																						✓				2
19.	✓				✓						✓	✓				✓		✓		✓		✓		✓	✓					✓	11
20.					✓																✓	✓								✓	4

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Attraction of exhibits in London Science Museum (continued)

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Attraction (number)
21.	✓			✓			✓															✓									4
22.																✓															1
23.	✓	✓		✓							✓	✓									✓	✓			✓						8
24.		✓		✓												✓					✓										4
25.					✓						✓	✓										✓									4
26.	✓		✓						✓							✓					✓										5
27.									✓		✓					✓					✓			✓							5
28.		✓	✓				✓															✓					✓				5
29.			✓													✓					✓										3
30.	✓	✓	✓		✓		✓		✓		✓		✓			✓								✓	✓						11
31.		✓	✓				✓		✓		✓													✓	✓						7

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in London Science Museum

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
1.					9	12		15		8			16	87	11	4							9				3				174	17.4
2.			61			46	46			123			23	27	183	47	73				74		49	35		76	5		20		888	59.2
3.	29		31		20	9	43	41	25	55			33	42	57		39						55	34		36			16		565	35.3
4.			23			17	15	3	29	16			11		25				1				20	22					7		189	15.8
5.	38	13	17		14	42	4	50		43			51	5	12	10	13	25	81	54	33		43		10		56	16	12	14	656	28.5
6.		11				32			67	3			30				5	19		6			18	32	6				16		245	20.4
7.				2		13	8			7					12		22						11				1		14		90	10.0
8.			25		7				13			35	10			12		21		101			26		16	19				35	320	26.7
9.											42	39						50				41	26		35					31	264	37.7
10.									13		25	38	8					10												22	116	19.3
11.											46	82	13													95					236	59.0
12.									5		7	27				32		13							16						100	16.7
13.	28								10		22		5					12		47					31	65				34	254	28.2
14.	16		2						8		57	90	7			5		40		18		83								56	382	34.7
15.												45				28		44		43		70									230	46.0
16.											8	10				3		12		18		14									65	10.8
17.			3		18				7		13					17		51		21										17	147	18.4
18.					8						4															3	5				20	5.0
19.	8				7						15	18	3			8		14		31		32		20	8	4				93	261	20.1
20.		1			17																81	35								40	174	34.8

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in London Science Museum (continued)

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
21.	17	3		5			23															41									89	17.8
22.		2							2							22															26	8.7
23.	17	16		38	1						12	6									71	27			10					4	202	20.2
24.		5		5												10					9										29	7.3
25.		1			12						47	22										13									95	19.0
26.	27		18						18		30					42					62										197	32.8
27.									7		5					12					10			20							54	10.8
28.		6	22				14															12					6				60	12.0
29.			7													11					26										44	14.7
30.	41	16	29		11		31		7		12		24			14								47	19		3				254	21.2
31.		7	39				16		14		17													20	6						119	17.0

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Canadian Museum of Civilization

Exhibit Number:

No.1	Palaeo-Eskimo (video)
No.2	Ivory Swans (artefact)
No.3	Floating or Flying Bear (artefact)
No.4	Tyara Maskette (artefact)
No.5	Challenger Mountains
No.6	Discovery Harbour
No.7	Archer Fiord
No.8	Inuit Art (video)
No.9	Hunter in Kayak (artefact)
No.10	Fish (artefact)
No.11	Fish Jigger (artefact)
No.12	Snow Goggles (artefact)
No.13	Caribou (artefact)
No.14	Ring & Pin Game (artefact)
No.15	The Travellers
No.16	Two Inuit
No.17	Caribou Skin Tent
No.18	Inuit History (video)
No.19	Dancing Bear (artefact)
No.20	Bear Hunt (artefact)
No.21	Woman with Child on Back (artefact)
No.22	Building the Winter Camp
No.23	Owl & Bears
No.24	Festive Bird
No.25	The Archer

Attraction of exhibits in Canadian Museum of Civilization

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Attraction (number)**
1.			✓		✓	✓					✓	✓	✓	✓	✓	✓		✓							✓		✓			✓	13
2.	✓	✓		✓			✓	✓	✓		✓		✓		✓	✓		✓		✓		✓	✓	✓	✓	✓			✓	✓	19
3.	✓		✓				✓			✓	✓	✓	✓	✓	✓	✓						✓	✓	✓	✓	✓			✓		16
4.	✓	✓	✓	✓		✓	✓			✓	✓	✓		✓				✓					✓	✓	✓	✓		✓		✓	17
5.	✓					✓	✓			✓											✓	✓	✓	✓		✓		✓			10
6.	✓				✓	✓	✓					✓		✓		✓				✓	✓		✓			✓		✓		✓	13
7.	✓				✓		✓													✓	✓		✓	✓		✓					8
8.	✓		✓	✓		✓			✓		✓	✓	✓	✓	✓	✓		✓							✓		✓			✓	15
9.	✓	✓	✓		✓	✓	✓					✓			✓	✓	✓	✓				✓	✓	✓	✓			✓			16
10.	✓		✓	✓	✓		✓				✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓				✓	19
11.	✓		✓	✓	✓		✓				✓		✓	✓	✓	✓		✓						✓	✓	✓				✓	15
12.	✓	✓	✓		✓		✓				✓				✓	✓	✓	✓						✓	✓	✓	✓			✓	15
13.	✓		✓		✓	✓	✓				✓		✓	✓		✓		✓			✓	✓				✓				✓	14
14.	✓	✓				✓	✓			✓	✓			✓	✓	✓		✓							✓	✓				✓	13
15.	✓	✓			✓	✓			✓						✓	✓				✓	✓	✓	✓	✓		✓					13
16.	✓					✓	✓																	✓		✓			✓		6
17.	✓					✓							✓	✓	✓																5
18.			✓		✓	✓				✓	✓	✓	✓	✓		✓	✓								✓						11
19.	✓		✓			✓	✓				✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓		✓		✓	19
20.	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓		✓	✓	✓		✓			✓	✓			✓	✓				✓	19

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Attraction of exhibits in Canadian Museum of Civilization (continued)

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Attraction (number)**
21.	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓		✓			✓	✓		✓	✓	✓	✓			✓	21
22.	✓	✓							✓			✓		✓	✓	✓					✓	✓				✓				✓	11
23.		✓	✓	✓		✓	✓		✓	✓		✓	✓	✓		✓				✓	✓			✓		✓					15
24.	✓	✓			✓								✓	✓		✓					✓	✓			✓	✓					10
25.				✓		✓	✓								✓	✓										✓					6

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in Canadian Museum of Civilization

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
1.			50		53	48					55	38	59	46	61	51		57							53		54			55	680	52.3
2.	27	7	2	7		3	15	6	6		8		9		26	9		6		16		60	34	9	6	16		3	5	9	289	13.1
3.	19	2	10				27	2		23	7	57	9	72	7	9		4				35	31	11	14	14			12		365	19.2
4.	28	15	11	21		8	65	3		10	6	44		6		4		6	4			3	34	6	38	10		9		33	364	17.3
5.	19	3				7	3			26	4	3				3				3	5	10	19	26		6		5			142	9.5
6.	33	4			11	6	29				3	12	4	13		7				6	7	2	29			8		9		24	207	12.2
7.	8	3	3		6		24						3						3	22	7		19	7		7					112	9.3
8.	30	4	94	6	1	56			57		74	52	72	64	56	64		36							65		56			58	845	49.7
9.	18	8	14		22	12	13	1				5			6	6	7	17				19	14	41	12			5			220	12.9
10.	17	3	6	12	43		10			4	7	25	5		10	23		22		50	48	42	23	7	7	8		4		5	381	17.3
11.	28	4	13	12	9		13	4			7		5	7	14	20		17				4		32	17	18		4	3	18	249	12.5
12.	18	28	21		8		24	3			14				7	16	23	23				3		7	34	33	18	3		24	307	17.1
13.	9	3	8		17	13	9	4		4	7		5	7		22		14			12	69		2		27		4		23	259	13.6
14.	13	16				25	17			9	15			6	37	26		5				3		4	7	22				14	219	14.6
15.	19	5		3	9	11		1	5			2			17	8	3			15	5	5	26	96		21		2			253	14.1
16.	24	3		1		10	45			3	3	2										1	2	31		9		2	10		146	10.4
17.	21	4	2			8						3	6	7	6	3	1					1		3				3	4		72	5.1
18.			52		38	52				28	49	41	15	52	1	55	54								56						493	41.1
19.	12	4	18		4	8	8	3			33	15	5	5	17	15	12	4		52	8	35		21	23	12		5	4	6	329	13.7
20.	19	8	25	25		30	14		9	14	45	33		5	35	13		5			7	12			14	21		4		10	348	17.4

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in Canadian Museum of Civilization (continued)

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
21.	21	7	28	18	8		14	12	18	15	16			7	12	16		9			22	6		9	8	19	20	3		7	295	13.4
22.	7	19	4	1	2		2		5		2	18	1	6	5	17	1				9	12		3		29	2	2		8	155	7.4
23.		25	15	7		9	9	4	8	6	3	13	8	7	3	8				11	6	4		10		7		2		2	167	8.0
24.	13	6		4	10	4	2	2			2		7	6		22	1				9	7		4	8	11	4	2		3	127	6.4
25.				7		10	10	3		3	4	4			7	7										8	3				66	6.0

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Helsinki City Museum

Exhibit Number:

No.1	Govinius plot
No.2	Gate and shop
No.3	A house on the square
No.4	Warehouse and wood stone
No.5	Pig sty and privy
No.6	Bakehouse and sauna
No.7	Shed, stable, cowshed and granary
No.8	A house on Suurkatu
No.9	Well
No.10	Profile
No.11	Clay pipes
No.12	Yard paving
No.13	Old buildings
No.14	Cellar

Attraction of exhibits in Helsinki City Museum

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Attraction (number)
1.			✓	✓			✓	✓	✓					✓		✓									✓						8
2.	✓		✓	✓	✓		✓		✓	✓	✓			✓		✓		✓			✓		✓	✓	✓	✓	✓	✓			18
3.							✓																								1
4.									✓			✓																			2
5.																✓								✓							2
6.			✓				✓					✓				✓							✓								5
7.			✓				✓	✓				✓																			4
8.		✓	✓			✓	✓					✓																			5
9.			✓				✓																								2
10.		✓	✓			✓	✓	✓																							5
11.			✓					✓			✓					✓								✓							5
12.		✓						✓				✓	✓	✓		✓			✓					✓	✓					✓	10
13.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓		✓		✓	✓	✓	✓			23
14.		✓	✓								✓			✓								✓									5

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in Helsinki City Museum

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9***	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
1.	1		7	10	1		11	20	13	2			4	5		10								1	5	4	2				96	6.4
2.	11		11	11	31	1	28		5	9	5	1	3	19		18	2	9			11	1	20	39	44	7	11	15			312	13.6
3.			3				30																								33	16.5
4.			4	4		2			5			21				3															39	6.5
5.						1										5								12							18	6.0
6.			11				42	4				6				10							10	4							87	12.4
7.			11				5	5				5				2								4							32	5.3
8.		7	7	1		6	31					6		1																	59	8.4
9.			22	1			6					4				2											2				37	6.2
10.		5	8			9	8	5	2			2		3				3												1	46	4.6
11.		3	17			4		9	1		7	4	4	2		8								56	4		3			3	125	8.9
12.		11				2	2	6			3	5	7	33		5			11					30	6					5	126	9.7
13.	9	29	16	10	7	8	10	14	14	6	8	9		34		23	9	5		11	18		20		9	15	5	7			296	12.9
14.		18	11	1		1	2		3		6	2		23		2		3				10					4			1	87	6.2

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

* School participants #9 did not click on any exhibit image for viewing information about it

Philadelphia Museum of Art

Exhibit Number:

No.1	Constantin Brancusi (x2) *
No.2	Margit Pogany
No.3	Mademoiselle Pogany [I] (artefact)
No.4	Mlle. Pogany I (bronze)
No.5	Mlle. Pogany II (bronze)
No.6	Mlle. Pogany II (veined marble)
No.7	Mlle. Pogany III (bronze)
No.8	Mlle. Pogany III (white marble)
No.9	I1912 II1919 III 1931
No.10	Mademoiselle Pogany [III] (artefact)
No.11	Grave Markers
No.12	Peasant House
No.13	Brancusi’s Studio
No.14	Eternal Springtime
No.15	Head of Balzac
No.16	The Visitation
No.17	Fang Guarsian
No.18	Avalokiteshvara
No.19	Brancusi, The kiss
No.20	Brancusi, Maiastra
No.21	Bird in space
No.22	Brancusi, Newborn
No.23	Mlle. Pogany I (white marble)

* The two exhibit icons represent the same exhibit on display in the same exhibition

Attraction of exhibits in Philadelphia Museum of Art

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Attraction (number)
1.								✓					✓					✓		✓											4
2.														✓						✓			✓								3
3.	✓		✓				✓	✓					✓	✓	✓	✓					✓	✓	✓			✓	✓				13
4.											✓											✓		✓							3
5.																												✓			1
6.																															0
7.	✓							✓		✓																				✓	4
8.										✓	✓																				2
9.												✓																			1
10.	✓						✓																								2
11.																															0
12.								✓																							1
13.								✓																							1
14.																															0
15.																															0
16.																															0
17.																															0
18.																															0
19.																															0
20.																															0

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Attraction of exhibits in Philadelphia Museum of Art (continued)

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Attraction (number)
21.																															0
22.																															0
23.																✓															1

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in Philadelphia Museum of Art

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
1.	1	2	3	3	3	1		7	4			4	6	1	3	2	1	11	2	14	2	1	1		1	2	3			3	81	3.4
2.	3	2		1	2			3	1	3				7		1		2	1	9	3	1	7	1		1	1		1	1	51	2.6
3.	26	4	22			2	37	11		1		2	5	5	14	8					13	9	11	2	3	32	16				223	11.7
4.					2	4		2	1		6	2		3								11		9		2		2			44	4.0
5.												1		1														5		1	8	2.0
6.						1																		1				4		1	7	1.8
7.	8					2	1	12	2	6	3	3	2																	6	45	4.5
8.	2								2	6	6	4	1																	2	23	3.3
9.	5								1			12																		2	20	5.0
10.							22								2											1					25	8.3
11.																															0	0.0
12.							1	7																							8	4.0
13.								8																							8	8.0
14.																															0	0.0
15.															2																2	2.0
16.																															0	0.0
17.																															0	0.0
18.								1								1															2	1.0
19.																															0	0.0
20.																															0	0.0

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits in Philadelphia Museum of Art (continued)

E. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**	**Holding power (seconds)**
21.																															0	0.0
22.																1															1	1.0
23.																5															5	5.0

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

IV. Data of visiting styles from 4 museum websites

London Science Museum	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total number**
Ant																	✓			N/C		✓							✓		3
Fish				✓																N/C							✓	✓			3
Grasshopper	✓		✓		✓		✓	✓											✓	N/C	✓			✓	✓	✓					10
Butterfly		✓				✓			✓	✓	✓	✓	✓	✓	✓	✓		✓		N/C			✓							✓	13
Canadian Museum of Civilization	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total number**
Ant	✓	✓			✓		✓				✓			✓		✓		✓				✓	✓	✓	✓			✓			13
Fish								✓											✓										✓		3
Grasshopper									✓								✓			✓							✓				4
Butterfly			✓	✓		✓				✓		✓	✓		✓						✓					✓				✓	10
Helsinki City Museum	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total number**
Ant															N/C														N/C		0
Fish				✓				✓	✓	✓	✓		✓		N/C		✓	✓	✓	✓		✓				✓	✓	✓	N/C	✓	15
Grasshopper	✓	✓			✓										N/C						✓		✓		✓				N/C		6
Butterfly			✓			✓	✓					✓		✓	N/C	✓								✓					N/C		7
Philadelphia Museum of Art	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total number**
Ant								✓																					N/C	✓	2
Fish		✓		✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓		✓	✓			✓	N/C		19
Grasshopper	✓		✓				✓														✓		✓			✓	✓		N/C		7
Butterfly															✓														N/C		1

NOTE: GP = General public RP = Researchers and professionals S = Schools N/C = Not classified

V. Performance data of the assigned tasks

Task lists for London Science Museum

Task No.	**Task description**
1	Look at the exhibit, **Pattern Wall,** on display in "***Pattern Pod"*** in the ground floor, and additional information about it.
2	Find the educational game: **Networking People** from the gallery, "***Digitopolis"***.
3	Find the exhibit: **Wheatstone printing telegraph** and additional information from the gallery, "***Digitopolis",*** on second floor.
4	View the picture, **Live science,** on display in the gallery, ***"Who am I?"*** and associated information about it.

Task lists for Canadian Museum of Civilization

Task No.	**Task description**
5	Find the 3D exhibit, **Dancing Bear,** and additional information.
6	Look at the picture, **Two Inuit**, and then find more information on it.
7	Find the **Inuit history** video clip for information on the history of the Inuit.

Task lists for Helsinki City Museum

Task No.	**Task description**
8	Find **Gate and shop** and associated information.
9	Look at the photographs and textual information about **Yard paving**.

Task lists for Philadelphia Museum of Art

Task No.	**Task description**
10	Look at the 3D sculpture, **Mademoiselle Pogany I**, and then lock your view on the 3D sculpture.
11	Find the picture of **Mademoiselle Pogany I** (bronze), **II** (bronze) and **III** (bronze)**.**

T. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (seconds)**
1.	13	X	78	X	199	33	57	235	268	14	41	70	137	69	45	118	76	X	45	93	40	120	X	38	107	256	76	X	X	281	2509
2.	107	55	43	176	50	166	28	X	207	139	26	308	183	X	X	40	165	X	184	X	88	X	25	7	78	100	36	48	X	209	2468
3.	12	11	32	47	82	65	44	X	91	7	21	75	7	187	X	19	133	X	6	X	54	124	23	38	92	160	122	6	100	37	1595
4.	133	X	50	67	158	35	37	X	108	77	X	99	120	X	X	53	110	X	153	X	197	X	105	117	76	178	143	122	238	253	2629
5.	10	75	24	12	54	19	46	40	57	16	16	45	73	11	94	23	41	143	268	34	15	7	220	84	107	16	19	16	17	17	1619
6.	18	X	10	15	36	24	12	192	42	36	14	35	23	16	25	78	59	X	32	136	60	20	7	120	131	24	41	37	54	22	1319
7.	69	34	4	23	9	6	253	61	7	5	X	25	13	7	5	29	87	9	7	63	50	44	X	49	X	132	25	155	102	183	1456
8.	15	143	4	59	321	X	12	39	32	13	21	38	14	16	32	7	21	X	X	X	11	127	17	13	60	14	27	X	181	14	1251
9.	X	124	44	66	65	89	X	133	30	X	11	15	135	60	X	76	313	X	X	X	X	X	X	6	X	X	103	X	98	11	1379
10.	77	X	123	X	196	93	90	X	139	146	X	310	139	160	171	216	170	X	223	X	213	X	51	X	79	X	254	124	X	X	2974
11.	73	121	X	X	173	79	45	279	192	172	X	X	272	104	X	153	137	X	X	X	X	X	X	X	X	X	174	X	70	X	2044

NOTE: T. No. = Task number GP = General public RP = Researchers and professionals S = Schools X = Failed the task

	Overall average		
	Percentage of success	**Average time (in seconds)**	**Range of completion times (in seconds)**
London Science Museum	79.2%	98.2	15-257
Canadian Museum of Civilization	94.4%	51.7	6-238
Helsinki City Museum	70.0%	65.6	5-317
Philadelphia Museum of Art	55.0%	151.3	48-295

VI. Post-observation questionnaire data

London Science Museum

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree N/A =Not Applicable N/R= Not Responded

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
1.	2	2	5	4	4	4	3	3	4	2	3	3	3	3	3	4	4	3	4	4	3	3	4	2	4	3	4	4	2	3	3.3
2.	4	2	5	4	2	4	2	3	4	2	3	2	3	3	3	4	4	3	4	4	4	2	4	3	3	3	4	4	2	3	3.2
3.	4	2	5	3	1	2	3	3	4	2	2	2	2	3	2	4	4	2	3	4	3	2	2	4	4	4	5	2	4	2	3.0
4.	3	2	5	4	1	2	2	4	3	2	1	2	2	3	4	4	4	3	2	3	3	3	2	3	4	4	5	2	4	2	2.9
5.	2	2	5	4	4	4	2	2	5	3	2	3	2	4	5	5	3	3	2	3	2	1	5	4	4	2	4	2	4	3	3.2
6.	2	3	5	4	3	4	3	2	3	2	2	2	4	2	4	4	3	2	3	2	4	3	4	4	5	4	4	4	4	4	3.3
7.	4	2	5	4	3	4	1	2	3	3	2	4	3	4	5	4	4	3	3	3	3	3	4	3	1	1	5	2	2	3	3.1
8.	Not provided																														
9.	Not provided																														
10.	Not provided																														
11.	3	4	5	4	4	3	4	4	5	2	4	4	4	4	4	4	4	4	5	4	4	4	4	4	5	3	3	4	3	2	3.8
12.	N/A	3	5	4	3	N/A	2	4	4	N/A	5	4	N/A	4	N/A	4	N/A	5	N/A	4	5	3	4	2	2	N/A	2	2	N/A	3	3.5
13.	4	3	5	4	2	3	3	2	2	2	2	4	2	2	3	5	4	3	4	4	4	2	4	4	5	4	4	4	4	3	3.4
14.	4	3	5	3	4	3	3	2	4	3	2	3	3	3	4	4	4	3	4	3	4	3	2	4	4	4	3	4	4	4	3.4
15.	2	2	5	4	1	4	4	2	3	2	3	3	4	4	4	3	4	3	4	4	3	2	4	3	5	3	4	4	3	4	3.3
16.	5	3	3	4	2	4	2	2	2	2	1	4	4	5	5	4	3	4	2	3	3	3	3	2	5	4	3	2	4	3	3.2
17.	3	3	4	4	2	3	4	3	4	3	2	3	4	4	3	3	4	4	2	2	3	2	4	4	5	4	4	2	4	3	3.3
18.	4	3	4	4	3	3	4	3	4	2	2	3	4	4	4	4	4	4	4	4	3	3	4	4	4	3	5	4	4	3	3.6
19.	4	3	4	4	3	4	4	2	4	3	2	4	3	2	4	5	3	2	4	3	3	1	2	4	4	3	3	4	4	2	3.2
20.	4	4	5	3	2	4	5	4	5	3	2	3	4	4	5	4	4	4	5	2	5	3	4	4	4	2	3	4	4	2	3.7
21.	4	4	5	4	2	4	5	2	5	3	4	3	4	5	5	5	4	3	4	3	5	N/A	5	4	4	3	2	4	4	3	3.9
22.	4	4	4	4	2	3	5	2	4	3	4	3	4	5	4	4	4	2	N/A	3	N/A	3	4	4	5	3	4	4	4	3	3.6

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Canadian Museum of Civilization

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree N/A =Not Applicable N/R= Not Responded

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
1.	5	4	5	4	4	3	4	4	5	4	4	2	5	5	5	4	4	4	4	4	3	4	5	4	4	3	5	4	5	4	4.1
2.	5	3	5	4	4	4	4	4	4	4	4	2	5	5	5	4	4	4	4	4	3	3	5	4	4	4	5	4	5	3	4.1
3.	5	3	5	4	3	3	4	4	4	4	4	3	4	5	5	4	4	4	2	3	3	2	4	2	3	4	4	3	5	4	3.7
4.	4	3	5	4	3	3	3	4	4	4	3	2	4	5	5	4	4	3	2	2	4	3	2	2	3	4	3	4	4	4	3.5
5.	5	4	5	4	4	4	4	4	5	4	3	3	5	4	5	5	4	4	4	4	4	3	4	3	5	4	4	4	3	4	4.1
6.	4	4	5	4	4	4	4	4	4	3	4	3	5	5	5	4	4	4	4	4	2	4	4	5	2	4	5	4	4	3	4.0
7.	3	4	5	4	5	4	3	4	5	4	4	4	5	4	5	5	5	4	4	4	2	3	4	3	5	4	5	5	5	4	4.2
8.	4	4	5	N/A	5	4	5	3	5	4	4	4	5	4	5	5	5	4	5	5	4	5	N/R	4	5	5	3	4	5	3	4.4
9.	4	4	5	4	4	4	4	4	4	4	5	4	5	4	5	4	5	4	5	4	4	4	4	4	5	4	5	4	5	4	4.3
10.	Not provided																														
11.	5	3	5	4	4	4	4	4	4	4	4	4	5	4	5	4	5	4	5	5	4	4	4	4	3	3	4	4	5	3	4.1
12.	Not provided																														
13.	4	4	5	3	4	4	2	4	4	4	4	1	5	5	5	4	5	3	4	4	4	4	4	5	4	5	5	5	5	4	4.1
14.	5	5	4	4	3	4	4	4	4	4	4	3	5	5	5	4	5	4	5	4	4	5	4	5	4	3	5	5	4	3	4.2
15.	4	4	4	4	4	4	4	4	3	3	5	2	4	3	5	4	5	3	5	5	2	4	4	5	4	3	5	5	4	3	3.9
16.	5	4	5	4	3	4	5	4	5	4	5	2	5	5	5	4	5	4	3	5	4	3	2	2	4	4	5	2	3	3	3.9
17.	4	4	5	4	4	4	4	4	4	4	5	2	5	4	5	3	5	4	4	5	3	3	4	2	4	4	4	4	4	3	4.0
18.	4	5	4	3	3	4	5	4	4	4	4	3	4	4	5	5	5	4	4	5	3	5	4	4	5	4	5	5	2	4	4.1
19.	4	5	5	4	4	4	4	4	4	4	4	3	4	5	5	5	4	4	4	5	3	3	4	4	4	4	3	5	3	4	4.1
20.	Not provided																														
21.	Not provided																														
22.	Not provided																														

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Helsinki City Museum

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree N/A =Not Applicable N/R= and Not Responded

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
1.	1	3	5	2	1	4	1	3	4	2	1	2	2	3	4	2	4	4	4	4	2	2	2	4	3	2	1	2	1	3	2.6
2.	1	3	2	2	1	3	1	4	3	2	1	1	1	3	3	3	4	3	4	3	1	2	2	4	3	2	2	2	1	3	2.3
3.	2	3	3	3	1	4	1	3	3	2	1	1	1	3	4	4	4	3	3	3	2	1	2	3	1	1	2	2	1	4	2.4
4.	4	4	4	2	1	3	2	3	3	2	1	1	1	2	3	4	4	3	2	2	2	1	2	2	1	1	1	1	1	4	2.2
5.	Not provided																														
6.	Not provided																														
7.	3	2	1	2	1	2	2	3	2	2	1	1	1	3	2	2	3	1	4	2	2	1	2	3	1	2	2	1	1	3	1.9
8.	Not provided																														
9.	Not provided																														
10.	N/A	2	N/A	N/A	2	N/A	4	4	N/A	N/A	N/A	N/A	N/A	2	N/A	N/A	N/A	4	N/A	4	2	N/A	2	N/A	2	2	3	N/A	N/A	N/A	2.8
11.	4	4	4	N/A	3	3	3	N/A	5	2	3	3	3	4	3	4	5	4	4	3	2	2	4	4	1	3	2	2	3	2	3.2
12.	Not provided																														
13.	1	3	1	2	1	2	2	4	2	2	1	1	1	2	2	3	3	1	3	1	3	2	2	4	1	2	1	2	4	3	2.1
14.	1	3	4	3	3	2	4	3	4	2	3	2	2	3	2	4	3	3	4	2	3	3	3	4	1	3	4	1	1	3	2.8
15.	1	3	4	2	3	3	4	4	3	2	3	3	2	4	3	4	4	3	4	2	2	2	4	3	1	2	2	1	4	3	2.8
16.	1	3	3	2	N/A	4	2	3	3	3	1	2	N/A	2	3	4	4	3	3	4	1	1	2	2	1	2	3	1	3	3	2.5
17.	3	3	4	2	2	4	2	3	4	2	1	2	N/A	3	3	3	4	3	3	2	1	1	2	2	1	3	3	1	3	3	2.5
18.	3	4	2	3	3	3	2	3	4	2	1	3	1	2	3	4	4	4	4	2	2	1	4	2	1	2	4	1	4	4	2.7
19.	2	2	1	2	1	3	1	3	4	2	1	1	1	1	2	3	4	1	3	2	2	1	4	2	1	2	3	1	4	3	2.1
20.	Not provided																														
21.	Not provided																														
22.	Not provided																														

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Philadelphia Museum of Art

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree N/A =Not Applicable N/R= and Not Responded

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
1.	1	4	2	1	3	3	3	2	3	1	1	1	3	4	4	2	3	4	4	4	2	3	4	4	4	2	3	1	4	3	2.8
2.	3	4	2	1	4	2	1	2	3	1	1	1	3	3	3	4	3	1	1	4	1	2	3	2	4	2	4	1	4	3	2.4
3.	4	4	3	1	2	4	2	2	4	2	1	1	3	4	3	3	4	1	3	3	1	2	2	3	1	2	4	1	4	2	2.5
4.	4	3	3	2	2	4	2	2	4	1	1	1	2	3	3	4	4	1	2	2	2	3	2	2	3	3	5	1	4	2	2.6
5.	Not provided																														
6.	Not provided																														
7.	1	2	1	1	2	1	1	2	1	2	1	1	1	1	1	1	2	2	1	2	1	1	1	3	1	2	3	1	1	3	1.5
8.	4	4	1	N/A	2	4	4	4	5	3	1	1	2	5	1	5	3	4	4	2	3	2	N/A	2	1	4	4	4	5	3	3.1
9.	Not provided																														
10.	Not provided																														
11.	3	3	4	N/A	3	2	3	N/A	4	2	N/A	1	3	4	2	3	3	4	4	4	3	3	4	2	1	3	5	4	4	3	3.1
12.	Not provided																														
13.	1	2	1	2	2	1	1	2	5	2	1	1	2	2	1	3	2	1	4	2	1	1	2	1	1	2	3	3	1	2	1.8
14.	2	2	2	3	3	2	3	3	4	2	1	1	4	4	2	4	3	2	4	3	4	N/A	2	2	1	4	5	3	4	3	2.8
15.	1	3	2	2	4	3	2	2	3	2	1	1	4	3	2	3	3	1	2	4	2	N/A	2	2	1	3	5	3	4	3	2.5
16.	3	3	2	2	3	2	4	3	4	2	1	1	4	2	2	4	3	3	3	4	2	N/A	2	1	1	3	2	3	3	3	2.6
17.	2	3	2	2	3	2	4	2	3	2	1	1	4	3	2	3	3	2	3	3	2	N/A	4	2	1	3	4	3	4	3	2.6
18.	3	2	2	2	4	3	2	3	5	2	1	1	4	4	3	4	3	1	5	4	4	2	2	2	1	3	5	3	3	3	2.9
19.	3	2	1	2	4	2	2	4	4	2	1	1	3	4	2	4	2	1	4	2	4	3	2	2	1	3	3	3	3	3	2.6
20.	Not provided																														
21.	Not provided																														
22.	Not provided																														

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Overall impression of the museum websites

On a scale of 1 to 10, 1= the worst; 10= the best

	GP #1	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
London Science Museum	6	5	8	8	3	8	5	4	6	7	6	7	6	7	8	8	7	9	7	7	7	3	6	7	10	3	9	6	3	7	6.4
Canadian Museum of Civilization	9	8	9	8	8	8	8	8	8	9	8	5	8	9	9	8	8	8	9	9	5	6	8	6	10	6	9	9	10	8	8.0
Helsinki City Museum	3	5	3	5	1	5	2	7	5	5	1	3	2	3	5	6	5	5	4	4	3	4	3	4	1	2	7	3	1	7	3.8
Philadelphia Museum of Art	2	4	1	4	5	3	1	3	7	2	1	1	5	4	3	4	3	2	1	4	2	3	1	1	1	4	5	2	5	5	3.0

NOTE: GP = General public RP = Researchers and professionals S = Schools

Appendix 6A: Questions for the Research Hypotheses

Hypothesis 1:

If an exhibit features rich multimedia formats (i.e. multiple media formats or 3D models combined with rich information) it will provide a **high level of attraction** and there will be a greater possibility to improve visitors' learning experience.

- Do you think that the exhibits which feature rich multimedia formats (i.e. multiple media formats or 3D models combined with in-depth information) provide a **high level of attraction?** (H1)
- Do you think that the exhibits with a **high level of attraction** improve visitors' learning experience? (H1)

Hypothesis 2:

If the exhibit features rich multimedia formats (i.e. games or a video with high levels of interaction) it will provide a **high level of holding power** and there will be a greater possibility to improve visitors' learning experience.

- Do you think the exhibits which feature rich multimedia formats (i.e. games or a video with high levels of interaction) provide a **high level of holding power?** (H2)
- Do you think that the exhibits with a **high level of holding power** improve visitors' learning experience? (H2)

Hypothesis 3:

If a web-based museum presents its information and learning resources for all **the three visitor groups** in a 3D environment, **the traditional lecture and text approach** will provide a greater potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject in ant visiting style.

- Do you think that **the traditional lecture and text approach** used in a 3D museum environment provides a greater potential to encourage all **the three visitor groups** (e.g. general public, school students and teachers, researchers and professionals) and lead to a deeper engagement with the subject through an ant visiting style? (H3)

Hypothesis 4:

If the design of the museum environment is based on **the traditional lecture and text approach** it will encourage visitors to follow 'ant' behaviour patterns and it will lead visitors to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the subject.

- Do you think that a fixed **visitor's pathway** is suitable for ant visitors to follow the exhibition content step by step in a systematic manner? (H4)
- Do you think that **the organisation of exhibit content** in a sequential order is suitable for ant visitors to learn thematic content for learning from beginning to end? (H4)
- Do you think that **exhibit displays** with hierarchical organisation of subject encourage ant visitors to learn knowledge from the simple to the complex in a contextual orientation? (H4)

Hypothesis 5:

If a web-based museum needs to present its information and learning resources for **researcher and professional visitors** as a target audience using a 3D environment, **the constructivism approach** will provide the greatest potential to lead them to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) and encourage a butterfly visiting style.

- Do you think that **the constructivism approach** used in a 3D museum environment provides a greater potential to lead **researcher and professional visitors** as a target audience to a deeper engagement through encouraging a butterfly visiting style? (H5)

Hypothesis 6:

If the design of the museum environment is based on **the constructivism approach** it will encourage the features of grasshopper and butterfly visitors and it will allow visitors to develop a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with selected aspects of the subject.

- Do you think that without any fixed **visitor's pathway,** it will encourage grasshopper and butterfly visitors to create their own individual and exploratory routes to actively interact with exhibits for learning? (H6)
- Do you think that **the organisation of exhibit content** with various levels of knowledge and interests is suitable for grasshopper and butterfly visitors to choose exhibit content they desire? (H6)
- Do you think that the constructivist **organisation of exhibit content** allow grasshopper and butterfly visitors to construct the meanings of artefacts through their prior experiences and knowledge? (H6)
- Do you think that **exhibit displays** with a constructivist layout in multiple entry points are suitable for grasshopper and butterfly visitors to construct knowledge from which they can choose? (H6)

Appendix 6B: Use of Questions in the Interviews with Museum Project Managers and Multimedia Experts

1. Do you have experience with developing 3D virtual museum environments? If you do, could you give a summary of these projects?

2. How many 3D web-based museum environments have you designed/developed?

3. What was most challenging for you as a museum manager/multimedia developer in developing a 3D virtual museum environment project?

4. What do you think about information and learning resources on your 3D museum environments?

5. What do you think are the most effective ways of interacting with exhibits in a 3D environment?

6. What do you think are the biggest problems in designing exhibits in a 3D environment?

7. Do you think that the exhibits which feature rich multimedia formats (i.e. multiple media formats or 3D models combined with in-depth information) provide a **high level of attraction?** (Hypothesis 1)

8. Do you think that the exhibits with a **high level of attraction** improve visitors' learning experience? (Hypothesis 1)

9. Do you think the exhibits which feature rich multimedia formats (i.e. games or a video with high levels of interaction) provide a **high level of holding power?** (Hypothesis 2)

10. Do you think that the exhibits with a **high level of holding power** improve visitors' learning experience? (Hypothesis 2)

11. What are the pedagogic features in your 3D web-based museum environment as learning resources?

12. Do you think that **the traditional lecture and text approach** used in a 3D museum environment provides a greater potential to encourage all **the three visitor groups** (e.g. general public, school students and teachers, researchers and professionals) and lead to a deeper engagement with the subject through an ant visiting style? (Hypothesis 3)

13. Do you think that a fixed **visitor's pathway** is suitable for ant visitors to follow the exhibition content step by step in a systematic manner? (Hypothesis 4)

14. Do you think that **the organisation of exhibit content** in a sequential order is suitable for ant visitors to learn thematic content for learning from beginning to end? (Hypothesis 4)

15. Do you think that **exhibit displays** with hierarchical organisation of subject encourage ant visitors to learn knowledge from the simple to the complex in a contextual orientation? (Hypothesis 4)

16. Do you think that **the constructivism approach** used in a 3D museum environment provides a greater potential to lead **researcher and professional visitors** as a target audience to a deeper engagement through encouraging a butterfly visiting style? (Hypothesis 5)

17. Do you think that without any fixed **visitor's pathway,** it will encourage grasshopper and butterfly visitors to create their own individual and exploratory routes to actively interact with exhibits for learning? (Hypothesis 6)

18. Do you think that **the organisation of exhibit content** with various levels of knowledge and interests is suitable for grasshopper and butterfly visitors to choose exhibit content they desire? (Hypothesis 6)

19. Do you think that the constructivist **organisation of exhibit content** allow grasshopper and butterfly visitors to construct the meanings of artefacts through their prior experiences and knowledge? (Hypothesis 6)

20. Do you think that **exhibit displays** with a constructivist layout in multiple entry points are suitable for grasshopper and butterfly visitors to construct knowledge from which they can choose? (Hypothesis 6)

21. What criteria did you think is important in the development of 3D online exhibitions on the museum websites?

22. What is your age?

23. What is your highest degree achieved?

24. How long have you been a museum project manager/multimedia developer?

Appendix 7A: Prototype CD-ROM

Instructions:

1. Copy a folder called “3D Exhibition Design” into your computer’s hard drive
2. Connect your computer to the Internet
3. Download Adobe Flash Player and install it for Windows Internet Explorer
4. Click on “index.html” from the folder to visit the prototype 3D virtual exhibition.
5. Depending on your security settings, you may see a Security Warning dialogue. Click Install to install the ActiveX control for installation of the required plug-ins: Cult 3D Viewer and 3D Life Player (3DVIA player)
6. This website is best viewed with a screen resolution of 1024 x 768

Basic system requirements:

1. Operating systems (OS): Windows XP
2. 3D graphics card (recommended)
3. Internet Browsers: Windows Internet Explorer 6
4. Internet connection

Appendix 7B: User Testing Data for Evaluation of the Prototype 3D Exhibition

I. Data of participant profile

II. Data of attraction and holding power of exhibits

III. Data of visiting styles

IV. Performance data of the assigned tasks

V. Post-visit questionnaire data

I. Data of participant profile

General public

Participant / **Demographic data**		**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**
Gender		M	M	F	M	F	F	F	M	M	F
Age		19-30	19-30	19-30	19-30	19-30	19-30	31-40	19-30	19-30	19-30
Education		A level	First degree	First degree	First degree	First degree	A level	Other	First degree	First degree	A level
Internet experience		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internet usage		Every day	Every day	Every day	Every day	Every day	Every day	Every day	Every day	Every day	Every day
Museum website experience		No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
Museum website usage		N/A	Less than once per year	Once or twice per year	Once or twice per month	Once or twice per year	Once or twice per year	N/A	N/A	Less than once per year	N/A
3D web-based environment experience		Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
3D web-based environment usage		Every day	Once or twice per month	N/A	Once or twice per month	Once or twice per month	N/A	N/A	Once or twice per month	Once or twice per month	Once or twice per month
Opinions of the 3D environments on the Internet	Easy to use	✓	✓								
	Fun	✓	✓		✓	✓			✓	✓	✓
	Useful	✓	✓			✓					✓
	Attractive	✓	✓		✓	✓					✓

NOTE: GP = General public N/A = Not applicable

Researchers and professionals

Participant / Demographic data		RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10
Gender		M	M	M	M	M	F	F	F	M	M
Age		19-30	41-50	19-30	31-40	19-30	19-30	19-30	31-40	19-30	31-40
Education		Master degree	First degree	Master degree	Master degree	First degree	Master degree	Master degree	Master degree	Master degree	Master degree
Internet experience		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internet usage		Every day	Every day	Every day	Every day	Every day	Every day	3-6 times per week	Every day	Every day	Every day
Museum website experience		Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Museum website usage		Once or twice per year	N/A	Less than once per year	Once or twice per year	N/A	Once or twice per month	Once or twice per month	N/A	Once or twice per month	Once or twice per month
3D web-based environment experience		Yes	Unsure	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3D web-based environment usage		Once or twice per month	N/A	N/A	Once or twice per month	Every day	Once or twice per year	Once or twice per year	Once or more per week	Every day	Once or twice per month
Opinions of the 3D environments on the Internet	Easy to use	✓				✓				✓	
	Fun	✓				✓	✓			✓	✓
	Useful	✓			✓			✓	✓	✓	
	Attractive	✓	✓		✓			✓		✓	

NOTE: RP= Researchers and professionals   N/A = Not applicable

Schools

<table>
<tr><th colspan="2">Participant
Demographic data</th><th>S #1</th><th>S #2</th><th>S #3</th><th>S #4</th><th>S #5</th><th>S #6</th><th>S #7</th><th>S #8</th><th>S #9</th><th>S #10</th></tr>
<tr><td colspan="2">Gender</td><td>F</td><td>F</td><td>F</td><td>F</td><td>M</td><td>M</td><td>F</td><td>M</td><td>F</td><td>M</td></tr>
<tr><td colspan="2">Age</td><td>41-50</td><td>19-30</td><td>31-40</td><td>31-40</td><td>51+</td><td>41-50</td><td>11-18</td><td>11-18</td><td>11-18</td><td>11-18</td></tr>
<tr><td colspan="2">Education</td><td>Master degree</td><td>First degree</td><td>Master degree</td><td>Master degree</td><td>Other</td><td>A level</td><td>GCSE</td><td>GCSE</td><td>GCSE</td><td>GCSE</td></tr>
<tr><td colspan="2">Internet experience</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="2">Internet usage</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td><td>Every day</td></tr>
<tr><td colspan="2">Museum website experience</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="2">Museum website usage</td><td>Once or twice per month</td><td>Once or twice per month</td><td>Once or twice per month</td><td>Once or twice per month</td><td>Less than once per year</td><td>Less than once per year</td><td>Once or twice per year</td><td>N/A</td><td>Less than once per year</td><td>Less than once per year</td></tr>
<tr><td colspan="2">3D web-based environment experience</td><td>Yes</td><td>Unsure</td><td>No</td><td>Yes</td><td>No</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>Unsure</td></tr>
<tr><td colspan="2">3D web-based environment usage</td><td>Once or twice per year</td><td>N/A</td><td>N/A</td><td>Once or more per week</td><td>N/A</td><td>Less than once per year</td><td>Once or twice per year</td><td>N/A</td><td>Once or twice per year</td><td>N/A</td></tr>
<tr><td rowspan="4">Opinions of the 3D environments on the Internet</td><td>Easy to use</td><td>N/R</td><td>✓</td><td></td><td></td><td></td><td>N/R</td><td></td><td></td><td>✓</td><td>✓</td></tr>
<tr><td>Fun</td><td>N/R</td><td>✓</td><td></td><td>✓</td><td></td><td>N/R</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Useful</td><td>N/R</td><td></td><td></td><td></td><td></td><td>N/R</td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td>Attractive</td><td>N/R</td><td></td><td></td><td>✓</td><td></td><td>N/R</td><td></td><td></td><td></td><td></td></tr>
</table>

NOTE: S = Schools N/A = Not applicable N/R = Non-response

II. Data of attraction and holding power of exhibits

Exhibit Number:

No.1 History of Plates
No.2 Tableware Production
No.3 Stoneware Blue and White Lines Plate
No.4 Blue and White Drawing (video)
No.5 Imari Japan Bowl (3D model artefact)
No.6 Plate Decorated with Floral Pattern
No.7 Colour Painted Plate with a Rooster
No.8 Recognising 5 Patterns (game)
No.9 Small Blue and White Plate with Crab Patterns (3D model artefact)
No.10 Colour Painted Plate with a Shrimp and Waterweeds
No.11 Oval Plate with a Prawn (3D model artefact)
No.12 Jigsaw Puzzle (game)
No.13 Blue and White Plate with Floral Patterns (3D model artefact)
No.14 Three triple-lobed Plates with Grassy and Floral Patterns (3D model artefact)
No.15 Colour Painted Plate with Peony
No.16 Blue and White Dish with a Small Fish (3D model artefact)
No.17 Blue and White Plate with Fishes (A) (3D model artefact)
No.18 Blue and White Plate with Fishes (B) (3D model artefact)
No.19 Colour Painted Plate with a Fish (3D model artefact)
No.20 Colour Painted Dish with a Small Fish

Attraction of exhibits

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Attraction (number)
1.	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓			✓	✓				✓		✓			✓				✓	17
2.	✓		✓						✓	✓	✓		✓		✓			✓				✓			✓		✓		✓	✓	13
3.		✓		✓	✓			✓	✓	✓		✓			✓	✓				✓	✓			✓		✓	✓		✓	✓	16
4.	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	24
5.	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓			✓		✓	✓	✓	✓	✓	✓		✓	✓	23
6.		✓	✓	✓		✓	✓	✓		✓	✓		✓	✓				✓	✓	✓	✓	✓	✓			✓	✓			✓	19
7.	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓	✓		✓	✓	✓		✓	23
8.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	27
9.			✓	✓	✓	✓		✓		✓			✓	✓		✓			✓	✓							✓		✓		13
10.				✓	✓	✓		✓	✓		✓		✓			✓			✓		✓			✓		✓	✓	✓	✓		15
11.			✓	✓	✓	✓		✓		✓			✓		✓	✓			✓	✓	✓			✓		✓	✓	✓	✓		16
12.	✓		✓	✓	✓	✓		✓	✓	✓	✓		✓		✓	✓	✓			✓	✓			✓		✓	✓	✓			19
13.				✓		✓	✓	✓		✓			✓	✓	✓		✓			✓			✓	✓		✓	✓		✓		15
14.	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓				✓	✓			✓		✓	✓	✓		✓		19
15.	✓		✓			✓	✓	✓					✓		✓						✓		✓	✓	✓		✓		✓		13
16.		✓	✓	✓	✓	✓			✓	✓	✓				✓	✓	✓			✓		✓		✓		✓	✓	✓	✓		18
17.	✓					✓				✓	✓				✓					✓		✓		✓	✓	✓	✓		✓		12
18.			✓	✓	✓	✓				✓										✓				✓	✓	✓	✓	✓	✓		12
19.	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓	✓						✓		✓		✓	✓	✓	✓	✓	✓		19
20.	✓		✓	✓					✓	✓	✓	✓		✓	✓									✓			✓		✓		12

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

Holding power of exhibits

E. No.	GP #1	GP #2	GP #3	GP #4	GP #5	GP #6	GP #7	GP #8	GP #9	GP #10	RP #1	RP #2	RP #3	RP #4	RP #5	RP #6	RP #7	RP #8	RP #9	RP #10	S #1	S #2	S #3	S #4	S #5	S #6	S #7	S #8	S #9	S #10	Total time (seconds)	Exhibit Stopped (number)	Holding power (seconds)
1.	9	5	11	3	37	12	25		23	5	22	45	44	3		34	6				45		33			7				51	420	19	22.1
2.	29		55						28	56	26		38		20	2		39				39			55		48		13	141	589	14	42.1
3.		16		33	27			22	8	17		41	2		19	42			2	21	58			27	4	33	18		13	56	459	19	24.2
4.	33	28	23	13	32			48	42	6	34	152	31	44	48	152			31		151	76	88	138	84	36	21	30	3	153	1497	25	59.9
5.	37	5	29	35	34		25	53		26	31	2	10	16	30	45	13			50		70	45	7	10	14	18		24	38	667	24	27.8
6.		5	7	5	2	18	43	17		31	23		16	7	3			19	21	74	9	40	44	4		10	19			32	449	22	20.4
7.	32	11	25	5	19	20		25		12	5	35	17	6	8	12			5	10		5	64	7		10	10	32	4	31	410	24	17.1
8.	72	13	68	99	103	17	106	62	37	91	48		13	10	20		11	12	13	56	55	78	20	23	56	55	66	144	2	33	1383	28	49.4
9.			11	8	14	31		74		9	2		27	5		40			21	26							11		21		300	14	21.4
10.		2		6	6	27		20	19	4	19		13	4		13			16		25			5		22	5	37	31		274	17	16.1
11.			10	6	23	24		39		9	2		14	2	23	45			20	37	51			25			15	46	49		440	18	24.4
12.	68		15	8	6	7		16	24	45	61		32	4	36	70	8	2	3	9	41			13		23	58	51			600	22	27.3
13.				10		23	35	42		20		2	10	6	13		10			20			45	25		25	18		6		310	16	19.4
14.	15		14	10	18	15	39	34		7	40	48	23	5	8				19	25		3	51	3	26	33	12		4		452	22	20.5
15.	6	2	5	3		41	46	12		2			13	4	8				4		6		30	15	18	2	7		7		231	19	12.2
16.		8	20	15	24	22			26	18	43			4	26	7	7			23		22		38		11	21	28	13		376	19	19.8
17.	30	4				19				10	17		2	4	10					19		28		21	21	10	16		17		228	15	15.2
18.		4	54	9	24	44	1			10			4	2	3					38				23	22	10	26	28	9		311	17	18.3
19.	22	10	9	8	11	27			25	9		92	23	5						26		27		34	14	8	15	50	15		430	19	22.6
20.	13		16	6					6	9	29	43		6	6									23			7		9		173	12	14.4

NOTE: E. No. = Exhibit number GP = General public RP = Researchers and professionals S = Schools

III. Data of visiting styles

Visiting style (in the 3D linear exhibition)	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total number**
Ant	✓	✓	✓	✓	✓			✓		✓		✓		✓	✓						✓		✓	✓	✓	✓	✓		✓		17
Fish																	✓														1
Grasshopper						✓	✓		✓									✓	✓	✓								✓			7
Butterfly											✓		✓			✓						✓								✓	5
Visiting style (in 3 the exhibition rooms)	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total number**
Ant					✓									N/C						✓						✓	✓			N/C	4
Fish		✓												N/C			✓	✓												N/C	3
Grasshopper	✓						✓	✓	✓			✓		N/C		✓			✓		✓	✓	✓		✓			✓		N/C	12
Butterfly			✓	✓		✓				✓	✓		✓	N/C	✓									✓					✓	N/C	9

NOTE: GP = General public RP = Researchers and professionals S = Schools N/C = Not classified

IV. Performance data of the assigned tasks

Task Number:

No.1 Look at the video: **Blue and White Drawing**

No.2 View the photograph, **Tableware Production,** and associated information about it

No.3 Find and play the game: **Jigsaw Puzzle**

No.4 Look at the exhibit, **Colour Painted Plate with a Fish,** and additional information about it

T. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Total time (in seconds)**
1.	23	14	14	17	20	19	X	12	27	11	14	29	150	25	13	9	21	X	22	37	12	48	43	25	19	10	12	9	12	10	677
2.	7	X	X	13	12	19	5	8	9	7	5	12	5	10	10	7	27	155	97	7	162	9	X	9	10	11	47	9	10	7	689
3.	42	22	82	25	44	34	42	22	20	21	26	66	29	25	32	53	33	32	48	59	60	37	37	23	91	18	17	40	32	36	1148
4.	30	26	29	58	31	39	49	56	21	30	37	38	46	61	35	46	32	38	237	33	21	65	58	71	41	28	42	40	49	40	1427

NOTE: T. No. = Task number GP = General public RP = Researchers and professionals S = Schools X = Failed the task

Task No.	**Percentage of success**	**Average time (in seconds)**	**Range of completion times (in seconds)**
1.	93.3%	24.2	9-150
2.	90.0%	25.5	5-162
3.	100.0%	38.3	17-91
4.	100.0%	47.6	21-237

V. Post-visit questionnaire data

Questions on the aspects for the use of 3D technology in improving access:

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
1.	5	4	5	4	5	4	3	4	4	4	5	3	4	4	3	5	5	4	5	4	5	4	3	4	4	4	5	5	4	5	4.2
2.	4	4	4	4	5	3	4	4	4	4	5	4	5	4	3	5	5	4	5	4	4	3	3	4	4	4	5	4	4	5	4.1
3.	5	4	3	4	4	4	2	4	3	4	5	2	4	4	3	4	4	4	5	4	4	4	4	5	2	2	5	3	3	4	3.7
4.	5	4	3	4	2	2	3	4	3	3	5	2	3	3	3	3	4	3	5	4	4	3	1	4	2	1	4	4	2	4	3.2
5.	5	4	4	5	5	3	3	3	4	4	5	4	4	5	2	4	4	2	3	3	3	4	3	5	5	2	5	5	5	5	3.9
6.	5	4	5	5	5	4	4	3	4	4	5	4	5	4	4	5	4	3	5	4	4	4	3	4	5	4	5	4	5	5	4.3
7.	5	4	4	5	5	3	3	3	4	4	4	4	5	4	2	4	4	3	4	3	5	4	1	5	4	4	3	4	5	5	3.9
8.	5	4	5	5	5	4	4	4	4	4	5	4	4	5	4	5	5	5	5	5	5	4	5	5	5	4	5	5	4	5	4.6
9.	5	4	5	5	5	4	4	5	4	5	5	3	5	5	4	5	5	3	4	5	5	5	5	5	5	5	5	4	5	5	4.6
10.	5	3	5	5	4	4	4	5	4	5	5	3	4	4	2	3	5	3	3	4	5	4	5	5	2	5	5	4	5	4	4.1
11.	5	4	5	5	4	4	4	4	4	4	5	4	5	5	4	5	5	3	4	5	5	4	4	4	4	5	5	5	4	5	4.4
12.	5	4	5	4	5	4	4	5	5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	4	5	5	5	4	3	4.7
13.	5	4	5	4	5	4	3	5	4	4	5	3	3	5	4	5	5	5	5	4	5	4	3	5	4	5	5	4	4	5	4.4
14.	5	4	5	4	5	4	3	5	3	4	5	4	4	5	4	5	5	5	5	5	5	4	4	4	4	5	5	4	4	5	4.4

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Questions on informational aspects:

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
15.	5	4	5	4	5	4	4	5	4	4	5	4	4	4	3	5	5	4	4	5	4	4	3	5	5	4	5	3	5	4	4.3
16.	5	4	5	4	5	4	4	5	4	5	5	3	3	4	4	5	5	5	4	4	5	4	3	4	5	4	5	3	4	3	4.2
17.	5	4	5	4	3	3	4	3	4	4	5	3	3	4	4	5	5	2	3	4	5	4	2	5	5	2	5	4	5	5	4.0
18.	4	4	5	5	4	3	4	5	3	5	5	4	5	3	4	4	4	5	4	4	5	4	4	5	4	2	5	4	5	5	4.2
19.	5	4	4	4	4	4	4	3	4	5	5	3	3	4	4	4	5	5	5	5	5	5	2	5	4	4	5	4	4	5	4.2

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Questions on learning aspects

Legend: 5 = Strongly Agree 4 = Agree 3 = Neither 2 = Disagree 1 = Strongly Disagree

Q. No.	**GP #1**	**GP #2**	**GP #3**	**GP #4**	**GP #5**	**GP #6**	**GP #7**	**GP #8**	**GP #9**	**GP #10**	**RP #1**	**RP #2**	**RP #3**	**RP #4**	**RP #5**	**RP #6**	**RP #7**	**RP #8**	**RP #9**	**RP #10**	**S #1**	**S #2**	**S #3**	**S #4**	**S #5**	**S #6**	**S #7**	**S #8**	**S #9**	**S #10**	**Average Scores**
20.	5	4	4	5	5	4	4	4	4	4	5	3	4	4	4	5	5	5	5	4	5	4	5	5	4	4	5	2	5	5	4.4
21.	5	4	4	4	5	4	4	4	4	4	5	4	5	4	4	4	5	5	4	4	5	4	4	4	4	4	4	3	5	4	4.2
22.	5	4	4	4	5	4	4	4	4	4	5	4	3	5	3	5	5	5	4	4	5	4	5	5	4	2	5	4	4	4	4.2
23.	4	4	5	4	4	3	4	4	4	3	5	2	4	4	2	5	3	5	5	4	4	3	3	3	3	1	5	3	3	3	3.6
24.	4	4	5	4	4	3	4	4	4	3	5	2	3	4	2	5	4	5	5	3	4	4	3	3	3	1	5	2	4	5	3.7

NOTE: Q. No. = Question number GP = General public RP = Researchers and professionals S = Schools

Appendix 7C: Expert Interview Questions

1. Do you have experience with developing or evaluating 3D virtual museum environments? If you do, could you give a summary of these projects?

Issues of immersion and presence

2. What do you think of the visual quality of the 3D model exhibits?

3. Did the 3D model exhibits give you a sense of presence with a feeling of actually seeing the physical artefacts themselves?

4. What do you think of the visual quality of the 3D exhibition environment?

5. Did the 3D exhibition environment give you a sense of presence with a feeling of truly being in an actual museum?

6. How could it be improved?

Usability issues

7. What do you think of the instructions for manipulating the 3D model exhibits?

8. What do you think of the instructions for navigating the 3D exhibition environment?

9. Do you think it is easy to navigate the 3D exhibition environment?

10. How useful do you think it is to click on the exhibit icons for associated information about the exhibits?

11. How useful is it to show exhibit names and rollovers when the mouse cursor is moved over individual exhibit icons?

12. Did the map help you determine where you are in the 3D exhibition space?

13. Did the map help you to determine where the exhibits are in the 3D exhibition space?

14. How easy is it to find information about the exhibits?

15. How easy is it to understand the information about the exhibits?

16. Do you think the amount of information provided for the exhibits was adequate and appropriate?

17. Do you think the organisation and structure of the information content was easy to follow?

Issues of attraction and holding power:

18. Do you think that the exhibit, “Tableware Production”, using multiple media provides a **high level of attraction and holding power**?

19. Do you think that 3D model artefacts (such as “Colour Painted Plate with a Fish”) combined with in-depth information provide a **high level of attraction and holding power**?

20. Do you think that the games (“Recognising 5 Patterns” and “Jigsaw Puzzle”) provide a **high level of attraction and holding power**?

21. Do you think that the video (“Blue and White Drawing”) combined a control bar with high levels of interaction provides a **high level of attraction and holding power**?

Issues of the pedagogic approaches:

Traditional lecture and text approach

22. Do you think that the fixed **visitor’s pathway** is suitable for ant visitors to follow the exhibition content step by step in a systematic manner?

23. Do you think that **the organisation of exhibit content** in a sequential order is suitable for ant visitors to learn thematic content for learning from beginning to end?

24. Do you think that the **exhibit displays** with a hierarchical organisation of the subject encourage ant visitors to learn knowledge from the simple to the complex?

The constructivism approach

25. Do you think that no fixed **visitor's pathway** in the three exhibition rooms encourages grasshopper and butterfly visitors to create their own individual and exploratory routes to actively interact with exhibits for learning?

26. Do you think that **the organisation of exhibit content** such as "Oval Plate with a Prawn" with various levels of knowledge using relevant links is suitable for grasshopper and butterfly visitors to choose exhibit content they desire?

27. Do you think that the **organisation of exhibit content** such as "Oval Plate with a Prawn" allow grasshopper and butterfly visitors to construct the meanings of artefacts through their prior experiences and knowledge?

28. Do you think that **the layout of exhibit displays** which provided multiple entry points was suitable for grasshopper and butterfly visitors to construct knowledge from which they can choose? (for example, each exhibition room has its theme)

29. Do you think that the prototype 3D exhibition has potential to promote learning?

30. What is your overall view of the prototype 3D exhibition?

31. What is your age?

☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 60+

32. What is your highest degree achieved?

33. What is your occupation and role?

Appendix 8: Published Works from this Research

1. Chao-Yu Lin, Nick Higgett and Emily Baines (2007), Exhibit content and learning-related behaviours in 3D on-line museum environments, **London EVA Conferences International: Proceedings**, pp. 7.1-7.8
2. Chao-Yu Lin, Nick Higgett and Emily Baines (2007), Virtual visitors' behaviours and their associated learning activities within 3D virtual museum environments, **2007 International Conference on Museum Audience Research**, National Science and Technology Museum, Taiwan
3. Chao-Yu Lin, Nick Higgett and Emily Baines (2008), A 3D online virtual environment to improve access to a museum as both a learning and information resource, London 2008 **CREATE Design Showcase,** UK

CONTENTS

EXHIBIT CONTENT AND LEARNING-RELATED BEHAVIOURS IN 3D ON-LINE MUSEUM ENVIRONMENTS

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Abstract – This paper describes an observational study of virtual visitors within 3D web-based museum environments. Two measures, attraction and holding power, were employed to assess the effectiveness of the educational settings in the 3D museum environments. Attraction levels were highest for the exhibits which employed multiple media formats or 3D models with the presentation of in-depth interpretive content and information. Holding power was highest for the exhibits which used games or videos with high interaction. This paper provides recommendations for consideration in the design of exhibit content in 3D museum environments to improve learning efficiency.

INTRODUCTION

New technological possibilities are creating a virtual space in which the repository of physical artefacts can be migrated into the realm of a virtual museum through digitally recorded imaging. A new form of electronic learning is emerging, which employs 3D technologies in a virtual museum environment as a learning resource. Much has been written about attraction and holding power in museums to measure the effective design of exhibit content in educational settings [1][5][6]. These two measures were employed in this study in order to evaluate the effectiveness of the virtual exhibits in the four selected museum websites through observations. Moreover, this study examined the relationship between level of attraction and holding power and the key design features of these exhibits in 3D museum environments which when applied enrich visitors' learning experience and learning efficiency.

METHODS

These observational studies were conducted by user testing to determine visitor behaviours while interacting with the learning content of online exhibits within the four 3D museum environments: London Science Museum, Canadian Museum of Civilization, Helsinki City Museum and Philadelphia Museum of Art. These four museum websites were selected from preliminary conclusions of a critical examination because they were shown to effectively and clearly present their content in 3D virtual environments for the educational and interpretive needs of the target audiences. The research instruments and guidelines employed to observe visitors' behaviours involved with virtual exhibits in museums for validity and reliability were those proposed by Diamond's (1999) recommendation [4]. These research instruments and guidelines are as follows [4]:

The instruments:

- 'Conduct informal observations to determine the nature and complexity of the environment.'
- 'Generate categories of behaviour from the environment.'
- 'Make periodic review of the environment.'

The guidelines:

- 'Make sure that the observer is in a similar condition each time the observations are made.'
- 'Don't let too much time pass between observations.'
- 'Make sure your behavioural categories are clear and unambiguous.'
- 'If your raw data is to be transferred into another format (transcribed from tape, typed into a computer), be sure you make the transfer as soon after the original observations as possible.'
- 'Keep your recording method the same each time you observe.'

However, although these instruments and guidelines are used in the traditional museum environments, it is argued they are also applicable to the domain of the virtual museum as well since the conceptual behaviours of virtual visitors are similar to the actual visitors' behaviours when viewing the artefacts in a virtual exhibition environment [3].

Sample selection

Museum visitors can be classified into three main categories, namely general public, researchers and schools [2]. Diamond (1999) suggested that in museum educational settings, 'about five to ten subjects may be useful for exploratory evaluations [4].' For this study, therefore, ten subjects in each visitor groups were recruited, giving a total number of subjects needed as thirty. Each subject was required to test all the four museum websites for an overall comparison.

ANALYSIS OF THE RESULTS

The analysis of results consists of two types of visitor behaviour data: the overall behaviours and the occurrence of the necessary behaviour for learning. These two kinds of data were gathered from observing 30 participants interacting with the total number of 93 exhibits. The distribution of exhibits in the four museum websites is shown in Table 1.

Name	**Number of exhibits**
London Science Museum	31
Canadian Museum of Civilization	25
Helsinki City Museum	14
Philadelphia Museum of Art	23
Total	**93**

Table 1. The number of exhibits in each museum website.

The overall behaviours

Thirty subjects were observed in order to record their behaviours. The frequency and equivalent percentage for the different types of behaviour in all four museum websites are shown in Table 2.

Behaviours	**Frequency**	**Percentage**
Manipulate artefacts	145	4.1%
Manipulate incorrectly	17	0.5%
Look for help or instructions for manipulation	1	0.0%
Look for help or instructions for navigation	30	0.9%
Show frustration on navigation	29	0.8%
Read labels and texts	1006	28.6%
Listen to audios	5	0.1%
Watch videos	54	1.5%
Look at images	1070	30.4%
Look at animations	8	0.2%
Click on the exhibit images for further information	1073	30.5%
Interact with learning activities or games	64	1.8%
Look for help or examples in programmes and activities	18	0.5%

Table 2. The overall frequencies and percentage of the participants' behaviours in the 3D environments on the four museum websites.

"Read labels and texts" (28.6%), "look at images" (30.4%) and "click on the exhibit images for further information" (30.5%) were identified as the three dominant behaviours of all the behaviours observed among the four museums websites. These three main behaviours were used as indicators of the development of the participants' learning about a subject in 3D museum environments. This result suggests that the participants want to understand the virtual exhibits by clicking on the exhibit images through hypertext links to obtain additional texts and images.

The occurrence of the necessary behaviour for learning

With regard to the learning process in museums, Wolf (1985) and Boisvert and Slez (1995) identified attraction, holding power, and visitor engagement as necessary steps to learning: attraction (visitors who stop at the exhibit), holding power (time spent by visitors at the exhibit) and visitor engagement (visitors pay attention to the exhibits) [1] [5]. Wolf (1985) and Yahya (1997) suggested that attraction and holding power are important variables in understanding the museum learning environment [5] [6]. Moreover, holding power relates to the visitor engagement factor. The duration of time spent by visitors at an exhibit indicates the level that they are engaged in terms of paying attention to exhibits by viewing them, reading associated information about the exhibits and manipulating the exhibits.

Although these two measures tend to be used in assessing educational settings in an actual space rather than in a virtual space, they can still be applied as it is also possible to measure physical aspects such as the frequency of stops at the exhibits and the duration of viewing exhibits in 3D virtual museum environments. For this research, these two observational measures were collected through the user testing as prerequisite behaviour for learning to occur:

- Attraction: number of subjects who stop at exhibit images or click on exhibit images for further information about them for more than 5 seconds.
- Holding power: amount of time spent by subjects interacting with virtual exhibits.

Exhibits	**Name of museum**	**Attraction (in number)**	**Holding power (in seconds)**
Old buildings (multiple media formats)	Helsinki City Museum	23 (77%)	12.9
Antenna (multiple media formats)	London Science Museum	22 (73%)	28.5
Woman with Child on Back (3D model combined with rich information)	Canadian Museum of Civilization	21 (70%)	13.4
Pattern Wall (game)	London Science Museum	15 (50%)	59.2
Bleadon Man (game)	London Science Museum	4 (13%)	59
Palaeo-Eskimo (video)	Canadian Museum of Civilization	13 (43%)	52.3

Table 3. The exhibits which either attracted more than 20 participants or held those who spend for more than 50 seconds.

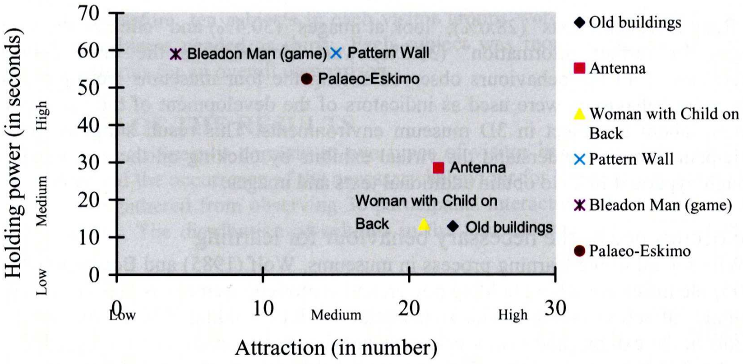

Figure 1. Scatter plot indicating the rating of the six exhibits through holding power and attraction.

The six most effective and successful exhibits

After assessing 93 exhibits, there are six exhibits which seem to have the greatest potential for learning in terms of attraction and holding power and are the most effective among the four museum websites as shown in Table 3 and Figure 1. These successful exhibits were selected against either of the two evaluation criteria: the exhibit must stop more than 67 percent of the total participants (i.e., more than 20 out of the total 30 participants) or it must hold the participants on average for more than 50 seconds looking at it or clicking on its image to see information about it.

These results indicate that attraction levels were highest for the exhibits which employed multiple media formats or 3D models combined with rich information content; holding power was highest for the exhibits which used games or a video with high levels of interaction. On the whole, the high values for the holding power of the exhibits was matched by low levels of attraction and the high values for attraction of the exhibits coincided with relatively low values for the holding power. No exhibit combined high values for both.

Each exhibit provides information using multimedia formats, including the following key features in terms of success and effectiveness.

Old buildings: Helsinki City Museum (High level of attraction and Low level holding power): This exhibit (Figure 2) is dedicated to presenting detailed information on the construction of the old buildings through photographs and texts. Compared with the 3D model buildings in the museum environment, visitors can easily see contextual information about the destroyed old buildings. Besides, this exhibit was designed in a highly visible position within the environment.

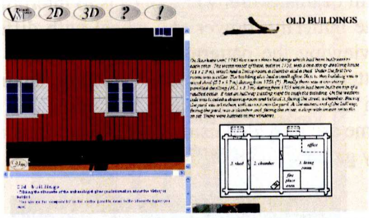

Figure 2. Old buildings.

Antenna: London Science Museum (High level of attraction and Medium level holding power): This exhibit (Figure 3) presents science news connecting to different subjects by links to scientific knowledge through texts, images, photographs and graphics. Logical organisation of subject is easily followed from each thematic topic by the structured paths (Figure 4). This exhibit provides in-depth information and learning resources to encourage visitors to learn.

Figure 3. Antenna.

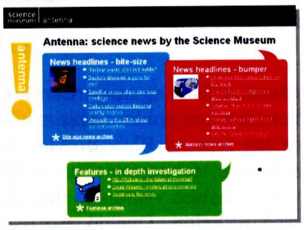

Figure 4. Antenna presenting thematic topics through relevant links.

Woman with Child on Back: Canadian Museum of Civilization (High level of attraction and Low level holding power): This exhibit (Figure 5) provides a 3D model combined with in-depth interpretive content using a photograph and texts. The textural and spatial information is available for visitors to rotate for viewing various angles of the 3D model artefact. Such a 3D model engaged subjects through increased interaction and greater spatial information.

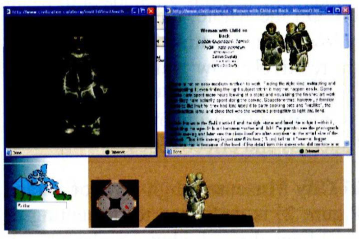

Figure 5. Woman with Child on Back.

Pattern Wall: London Science Museum (Medium level of attraction and High level holding power): The aim of this exhibit (Figure 6) is to interpret how symmetry patterns can be produced by the butterfly, flower and wheel with different turns and flips that mirror themselves as viewing the patterns in a kaleidoscope. The exhibit presents its information about patterns in an educational gaming environment, generating the different patterns with colours by drawing from individual visitors. Instructions for interacting with the game are provided using both illustrations and texts at the beginning so that visitors can play game without difficulty.

Figure 6. Pattern Wall.

Bleadon Man (game): London Science Museum (Low level of attraction and High level holding power): This exhibit (Figure 7) attempts to demonstrate the reconstruction of the face of Bleadon Man built by medical artist Caroline Wilkinson using new scientific techniques. This exhibit presents its content through an educational game which enables visitors to drag the pieces of skull and pick up the lumps of clay for the reconstruction. Due to the use of the small exhibit image on display in the 3D environment, this exhibit only attracted four participants. Although this exhibit did not attract a large number of subjects, it held the subjects for a long period (59 seconds).

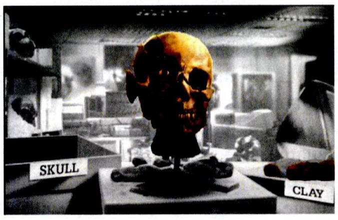

Figure 7. Bleadon Man.

Palaeo-Eskimo: Canadian Museum of Civilization (Medium level of attraction and High level holding power): This exhibit (Figure 8) presents the history of Palaeo-Eskimo and additional information using a video. The exhibit was identified as holding the participants for a long period of time (52.3 seconds). This was long because the video gave participants an introduction of the history and associated information on exhibits. Besides, the video enabled the participants to manipulate the bar to look at the specific information based on their personal preference.

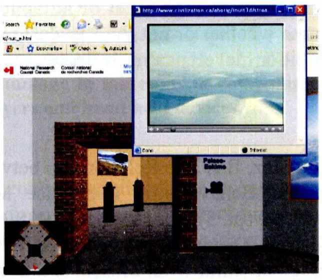

Figure 8. Palaeo-Eskimo.

Implications for the design of effective exhibits

To succeed exhibits need to both attract and engage visitors. This can be achieved by using exhibits that feature rich multimedia formats in a 3D virtual space. These exhibits have the potential to maximize the level of a visitor's learning experiences. The following detailed suggestions are provided to help with the improvement of learning efficiency through the design of a virtual exhibit and its content:

- The exhibits using multiple media formats (e.g. texts, images, audios and so on) should provide levels of knowledge in order to accommodate the various visitors' interests and preferences. Such exhibits not only attract visitors to the topic through rich multimedia formats but also hold visitors' attention on the topic through levels of knowledge, reflecting their individual preferences.
- 3D models should provide high interaction through manipulation combined with the presentation of contextual and in-depth information for both attraction and engagement. Therefore, the exhibits can attract visitors to 3D models through high

interaction while they can engage visitors' attention on learning knowledge of artefacts through a comparison between spatial information and textual information.

- The exhibits employing games should be simple and provide instructions. Thus this can help them to play games and lead visitors to a deeper engagement with the subject in gaming environments.
- The exhibit using a video should offer high levels of interaction so that visitors can be engaged by manipulating the bar to look at the specific information based on their individual preferences.
- Exhibits should be large enough to be seen, with dynamic imagery and be positioned so that they are clearly visible. Thus they can effectively attract visitor's attention.

CONCLUSION

Thirty subjects in the four different museum websites were observed as they freely interacted with exhibits in the 3D environments. Three dominant behaviours were shown as the observable forms of the process of the development of virtual visitors' learning knowledge about a subject. The relationship between level of attraction and holding power and the key features of these exhibits was analysed. The design of the virtual exhibits with rich multimedia formats can induce greater visitors' learning experiences through combining both high level of attraction and holding power. The further research will examine whether or not the key design features of exhibits can be applied in 3D virtual exhibition development, reflecting a variety of learning theories for effective museum education.

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會議手冊

2007 International Conference on Museum Audience Research

目錄

Virtual visitors' behaviours and their associated learning activities within 3D virtual museum environments

3D 虛擬博物館環境中，虛擬觀眾的參觀行為與及其相關的學習活動

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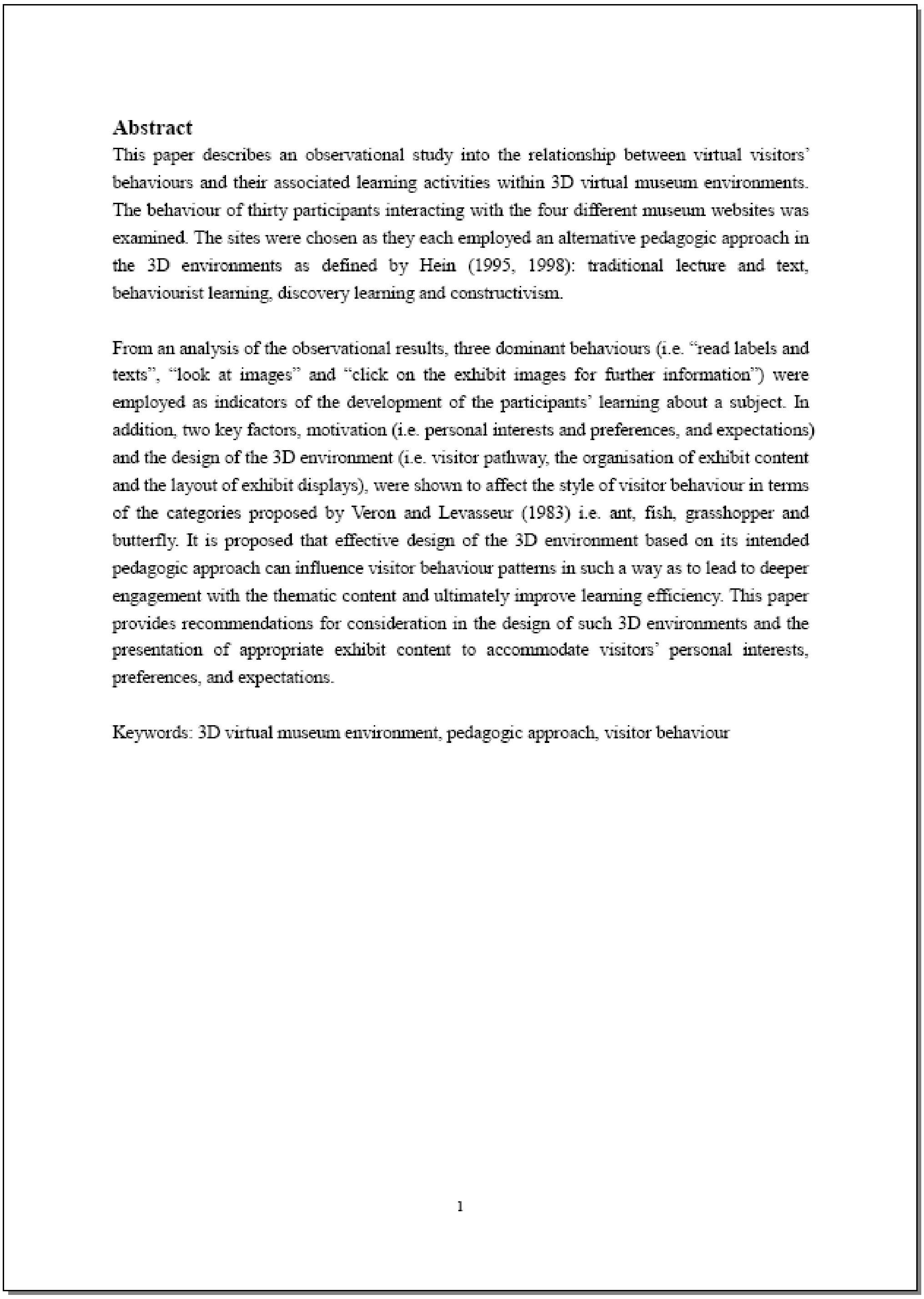
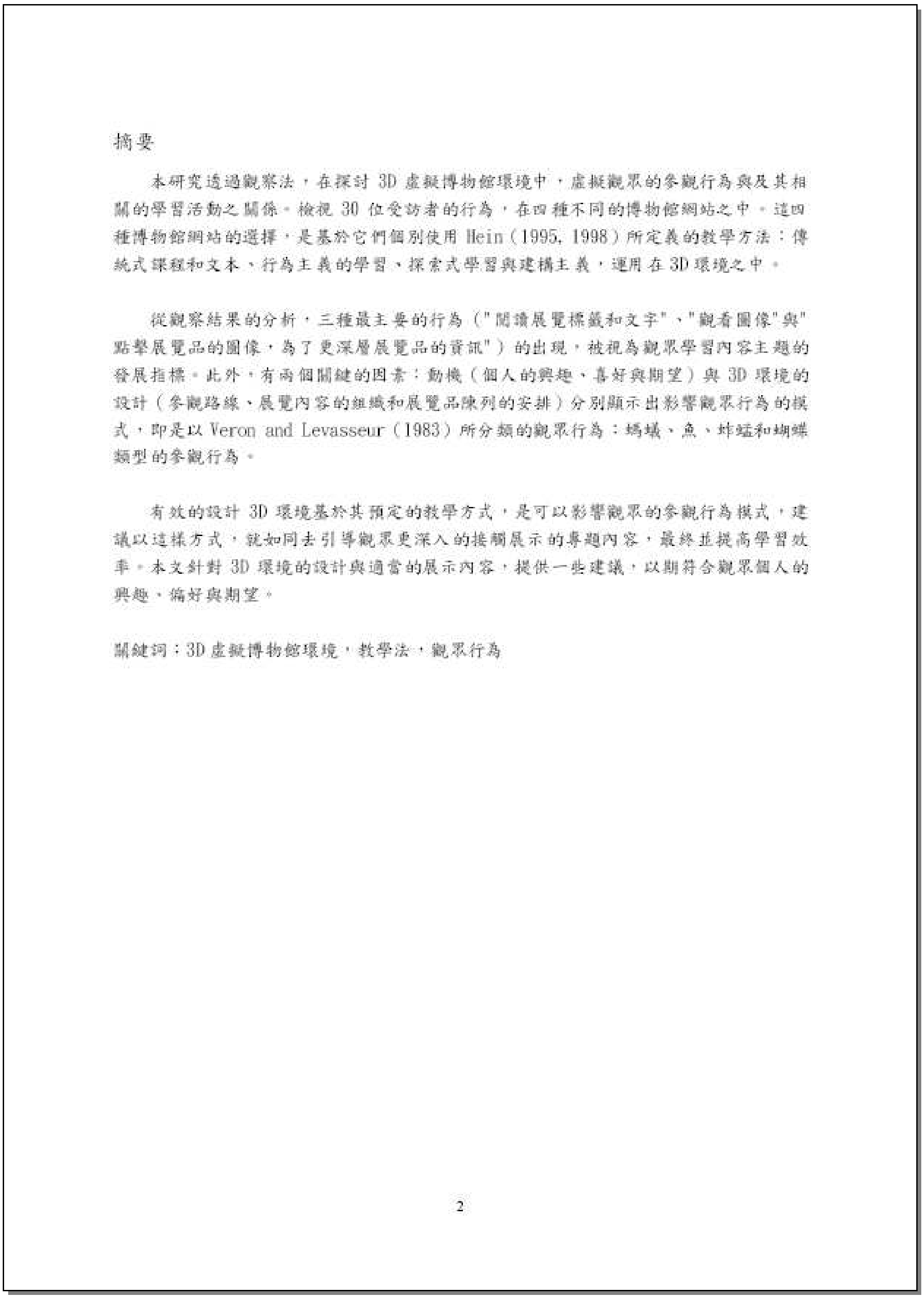


Abstract

This paper describes an observational study into the relationship between virtual visitors' behaviours and their associated learning activities within 3D virtual museum environments. The behaviour of thirty participants interacting with the four different museum websites was examined. The sites were chosen as they each employed an alternative pedagogic approach in the 3D environments as defined by Hein (1995, 1998): traditional lecture and text, behaviourist learning, discovery learning and constructivism.

From an analysis of the observational results, three dominant behaviours (i.e. "read labels and texts", "look at images" and "click on the exhibit images for further information") were employed as indicators of the development of the participants' learning about a subject. In addition, two key factors, motivation (i.e. personal interests and preferences, and expectations) and the design of the 3D environment (i.e. visitor pathway, the organisation of exhibit content and the layout of exhibit displays), were shown to affect the style of visitor behaviour in terms of the categories proposed by Veron and Levasseur (1983) i.e. ant, fish, grasshopper and butterfly. It is proposed that effective design of the 3D environment based on its intended pedagogic approach can influence visitor behaviour patterns in such a way as to lead to deeper engagement with the thematic content and ultimately improve learning efficiency. This paper provides recommendations for consideration in the design of such 3D environments and the presentation of appropriate exhibit content to accommodate visitors' personal interests, preferences, and expectations.

Keywords: 3D virtual museum environment, pedagogic approach, visitor behaviour



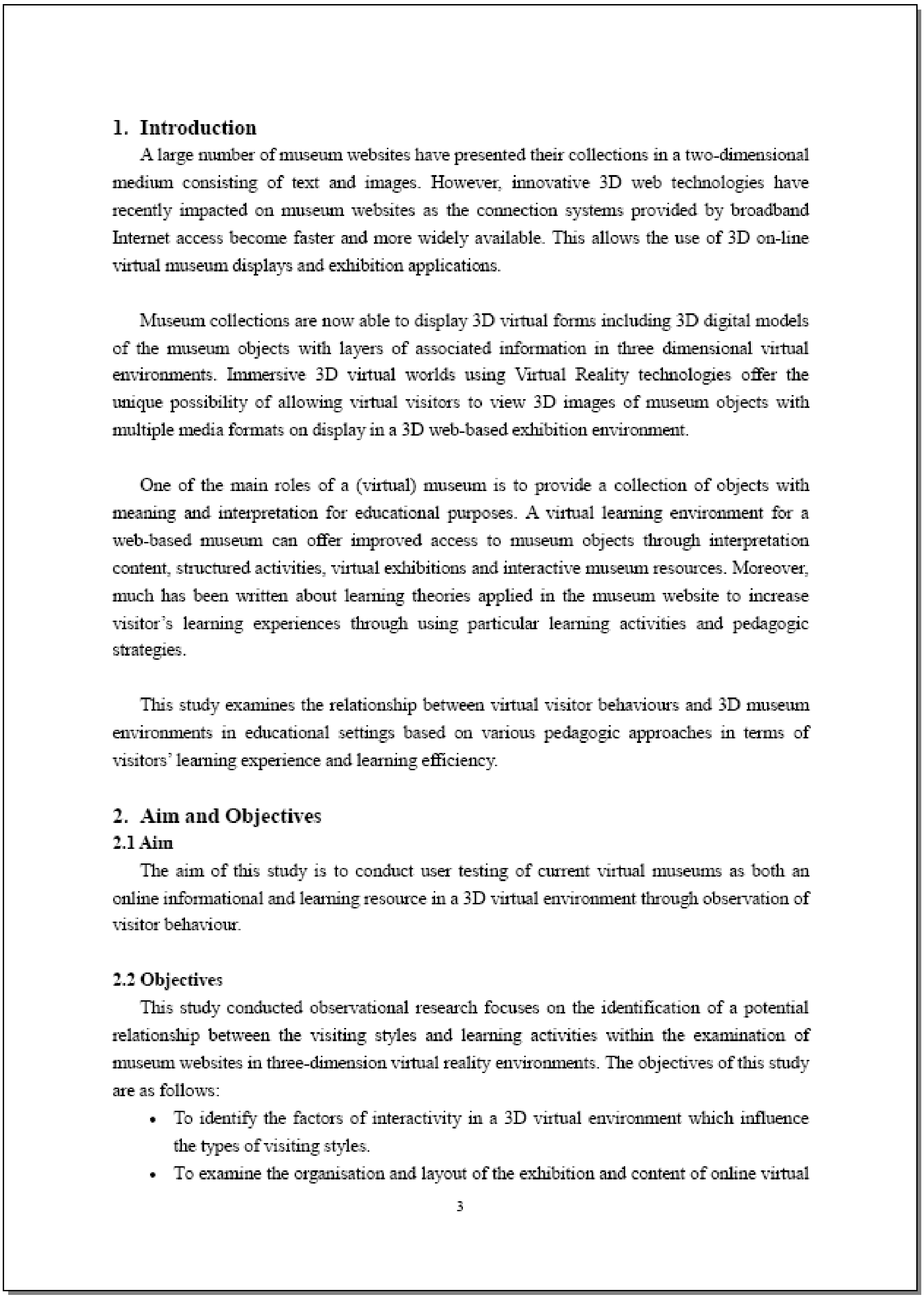
摘要

本研究透過觀察法，在探討 3D 虛擬博物館環境中，虛擬觀眾的參觀行為與及其相關的學習活動之關係。檢視 30 位受訪者的行為，在四種不同的博物館網站之中。這四種博物館網站的選擇，是基於它們個別使用 Hein（1995, 1998）所定義的教學方法：傳統式課程和文本、行為主義的學習、探索式學習與建構主義，運用在 3D 環境之中。

從觀察結果的分析，三種最主要的行為（"閱讀展覽標籤和文字"、"觀看圖像"與"點擊展覽品的圖像，為了更深層展覽品的資訊"）的出現，被視為觀眾學習內容主題的發展指標。此外，有兩個關鍵的因素：動機（個人的興趣、喜好與期望）與 3D 環境的設計（參觀路線、展覽內容的組織和展覽品陳列的安排）分別顯示出影響觀眾行為的模式，即是以 Veron and Levasseur（1983）所分類的觀眾行為：螞蟻、魚、蚱蜢和蝴蝶類型的參觀行為。

有效的設計 3D 環境基於其預定的教學方式，是可以影響觀眾的參觀行為模式，建議以這樣方式，就如同去引導觀眾更深入的接觸展示的專題內容，最終並提高學習效率。本文針對 3D 環境的設計與適當的展示內容，提供一些建議，以期符合觀眾個人的興趣、偏好與期望。

關鍵詞：3D 虛擬博物館環境，教學法，觀眾行為



1. Introduction

A large number of museum websites have presented their collections in a two-dimensional medium consisting of text and images. However, innovative 3D web technologies have recently impacted on museum websites as the connection systems provided by broadband Internet access become faster and more widely available. This allows the use of 3D on-line virtual museum displays and exhibition applications.

Museum collections are now able to display 3D virtual forms including 3D digital models of the museum objects with layers of associated information in three dimensional virtual environments. Immersive 3D virtual worlds using Virtual Reality technologies offer the unique possibility of allowing virtual visitors to view 3D images of museum objects with multiple media formats on display in a 3D web-based exhibition environment.

One of the main roles of a (virtual) museum is to provide a collection of objects with meaning and interpretation for educational purposes. A virtual learning environment for a web-based museum can offer improved access to museum objects through interpretation content, structured activities, virtual exhibitions and interactive museum resources. Moreover, much has been written about learning theories applied in the museum website to increase visitor's learning experiences through using particular learning activities and pedagogic strategies.

This study examines the relationship between virtual visitor behaviours and 3D museum environments in educational settings based on various pedagogic approaches in terms of visitors' learning experience and learning efficiency.

2. Aim and Objectives

2.1 Aim

The aim of this study is to conduct user testing of current virtual museums as both an online informational and learning resource in a 3D virtual environment through observation of visitor behaviour.

2.2 Objectives

This study conducted observational research focuses on the identification of a potential relationship between the visiting styles and learning activities within the examination of museum websites in three-dimension virtual reality environments. The objectives of this study are as follows:

- To identify the factors of interactivity in a 3D virtual environment which influence the types of visiting styles.
- To examine the organisation and layout of the exhibition and content of online virtual

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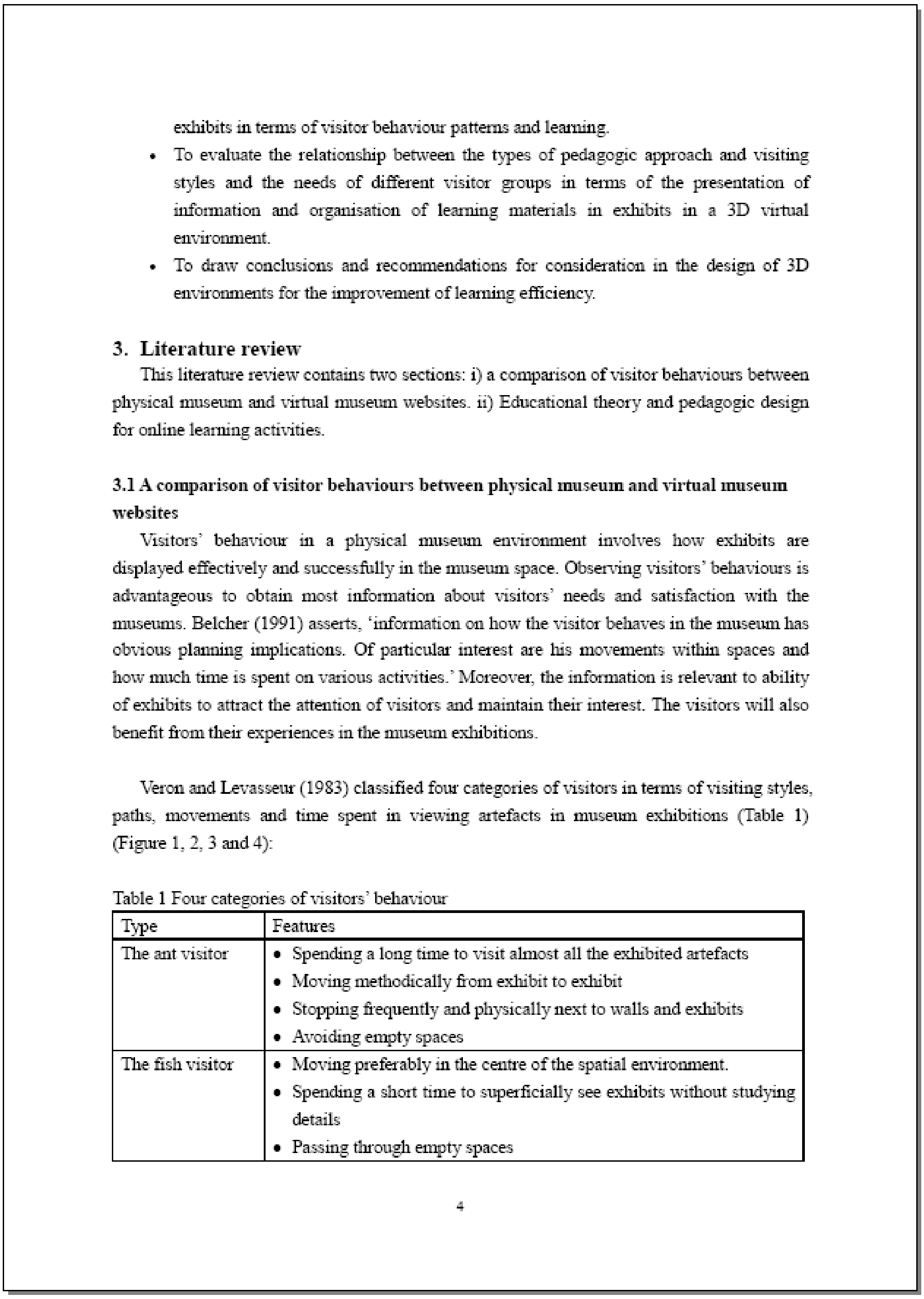


exhibits in terms of visitor behaviour patterns and learning.

- To evaluate the relationship between the types of pedagogic approach and visiting styles and the needs of different visitor groups in terms of the presentation of information and organisation of learning materials in exhibits in a 3D virtual environment.
- To draw conclusions and recommendations for consideration in the design of 3D environments for the improvement of learning efficiency.

3. Literature review

This literature review contains two sections: i) a comparison of visitor behaviours between physical museum and virtual museum websites. ii) Educational theory and pedagogic design for online learning activities.

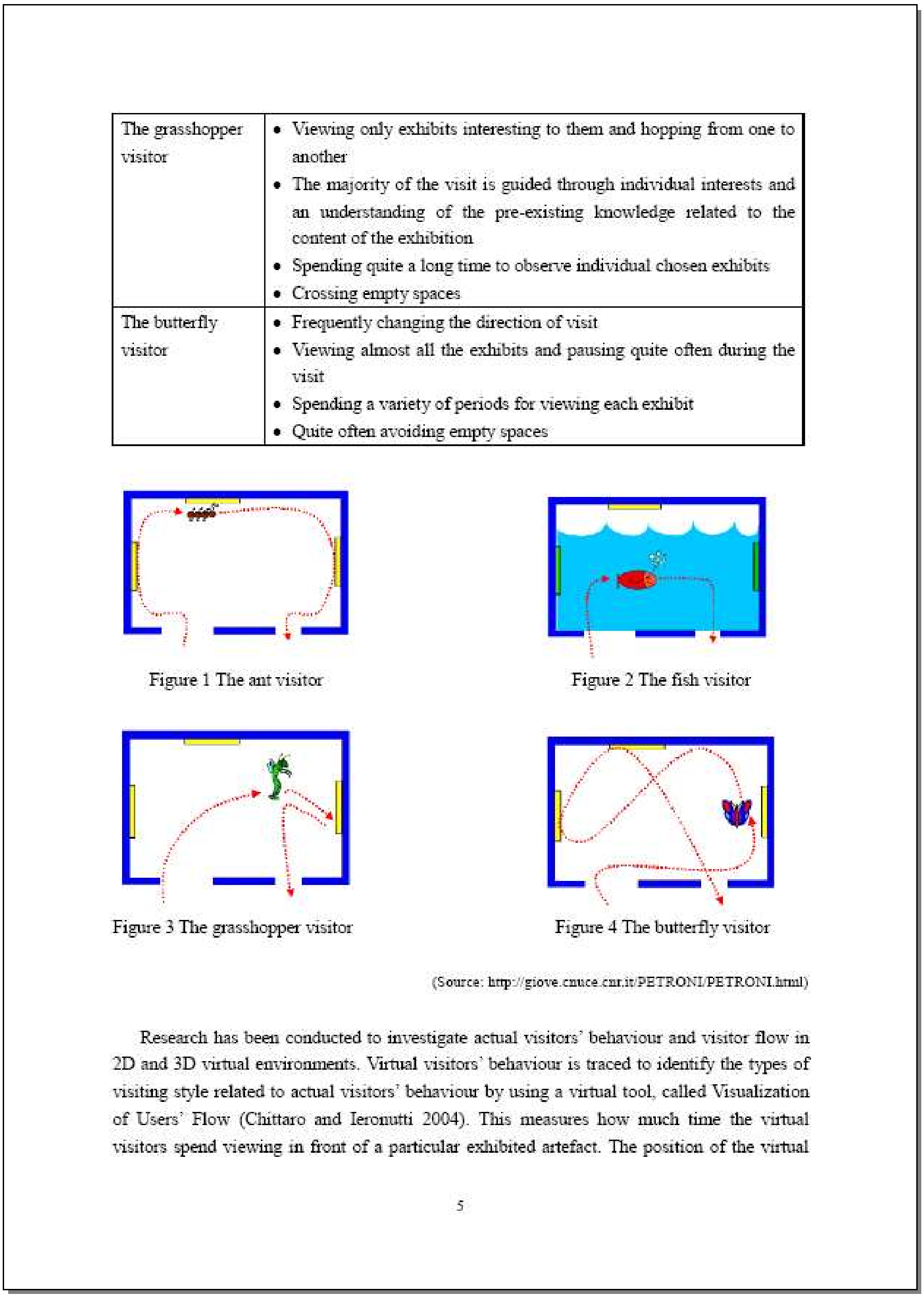
3.1 A comparison of visitor behaviours between physical museum and virtual museum websites

Visitors' behaviour in a physical museum environment involves how exhibits are displayed effectively and successfully in the museum space. Observing visitors' behaviours is advantageous to obtain most information about visitors' needs and satisfaction with the museums. Belcher (1991) asserts, 'information on how the visitor behaves in the museum has obvious planning implications. Of particular interest are his movements within spaces and how much time is spent on various activities.' Moreover, the information is relevant to ability of exhibits to attract the attention of visitors and maintain their interest. The visitors will also benefit from their experiences in the museum exhibitions.

Veron and Levasseur (1983) classified four categories of visitors in terms of visiting styles, paths, movements and time spent in viewing artefacts in museum exhibitions (Table 1) (Figure 1, 2, 3 and 4):

Table 1 Four categories of visitors' behaviour

Type	Features
The ant visitor	• Spending a long time to visit almost all the exhibited artefacts • Moving methodically from exhibit to exhibit • Stopping frequently and physically next to walls and exhibits • Avoiding empty spaces
The fish visitor	• Moving preferably in the centre of the spatial environment. • Spending a short time to superficially see exhibits without studying details • Passing through empty spaces



The grasshopper visitor	• Viewing only exhibits interesting to them and hopping from one to another • The majority of the visit is guided through individual interests and an understanding of the pre-existing knowledge related to the content of the exhibition • Spending quite a long time to observe individual chosen exhibits • Crossing empty spaces
The butterfly visitor	• Frequently changing the direction of visit • Viewing almost all the exhibits and pausing quite often during the visit • Spending a variety of periods for viewing each exhibit • Quite often avoiding empty spaces

Figure 1 The ant visitor

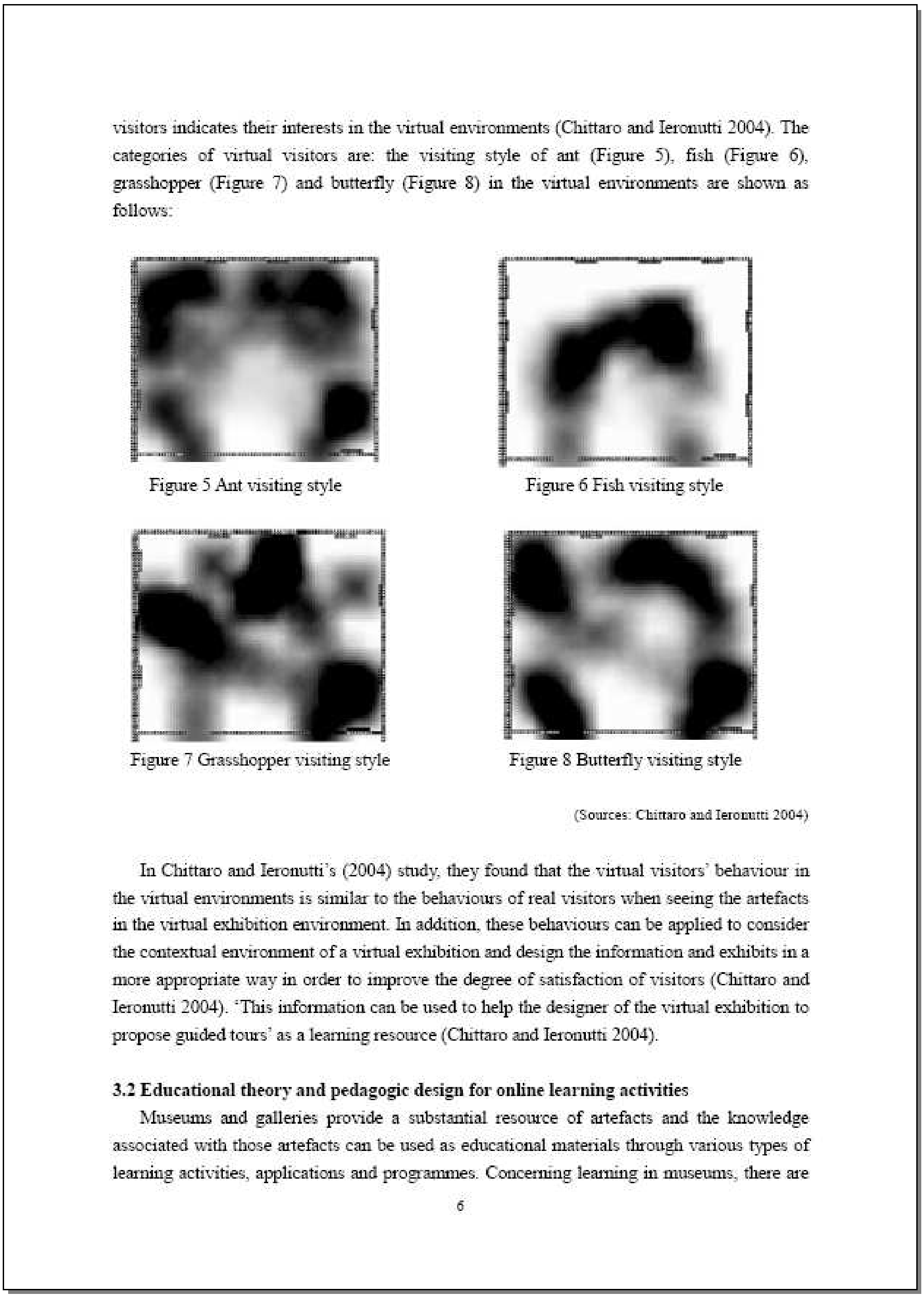
Figure 2 The fish visitor

Figure 3 The grasshopper visitor

Figure 4 The butterfly visitor

(Source: http://giove.cnuce.cnr.it/PETRONI/PETRONI.html)

Research has been conducted to investigate actual visitors' behaviour and visitor flow in 2D and 3D virtual environments. Virtual visitors' behaviour is traced to identify the types of visiting style related to actual visitors' behaviour by using a virtual tool, called Visualization of Users' Flow (Chittaro and Ieronutti 2004). This measures how much time the virtual visitors spend viewing in front of a particular exhibited artefact. The position of the virtual



visitors indicates their interests in the virtual environments (Chittaro and Ieronutti 2004). The categories of virtual visitors are: the visiting style of ant (Figure 5), fish (Figure 6), grasshopper (Figure 7) and butterfly (Figure 8) in the virtual environments are shown as follows:

Figure 5 Ant visiting style

Figure 6 Fish visiting style

Figure 7 Grasshopper visiting style

Figure 8 Butterfly visiting style

(Sources: Chittaro and Ieronutti 2004)

In Chittaro and Ieronutti's (2004) study, they found that the virtual visitors' behaviour in the virtual environments is similar to the behaviours of real visitors when seeing the artefacts in the virtual exhibition environment. In addition, these behaviours can be applied to consider the contextual environment of a virtual exhibition and design the information and exhibits in a more appropriate way in order to improve the degree of satisfaction of visitors (Chittaro and Ieronutti 2004). 'This information can be used to help the designer of the virtual exhibition to propose guided tours' as a learning resource (Chittaro and Ieronutti 2004).

3.2 Educational theory and pedagogic design for online learning activities

Museums and galleries provide a substantial resource of artefacts and the knowledge associated with those artefacts can be used as educational materials through various types of learning activities, applications and programmes. Concerning learning in museums, there are two issues related to educational theory underpinning the educational practices of museums: the different perceptions of knowledge and what type of learning theory is involved underlying the museum learning context (Hein 1995, 1998).

For similar reasons, the success of the museum online learning activity or programme should comprise of an educational theory through a coherent pedagogic strategy to meet the learning requirements of virtual visitors and enhance the learning experience. Before addressing how to apply an educational theory to learning activities and programmes in the learning contexts of web museums, it is useful to shed some light on the nature and elements of Hein's educational theories and considerations of the learning context of traditional museums.

Hein (1995, 1998) proposed educational theories that consist of two continua of theories crossing each other. Each educational theory places an emphasis on both theory of knowledge (epistemology) and on learning theory, as illustrated in Figure 9 and Table 2 (Hein 1995, 1998):

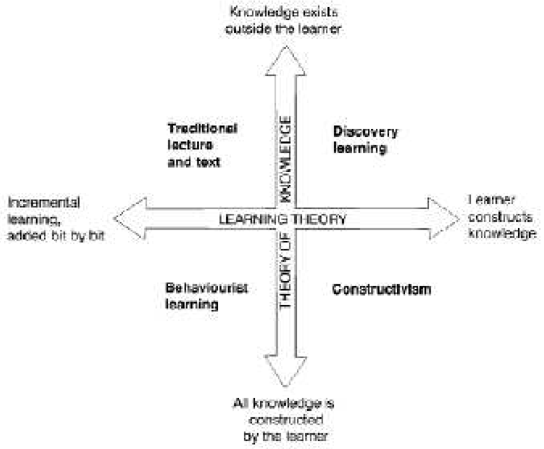


Figure 9 Educational theories

(Source: Hein 1995)

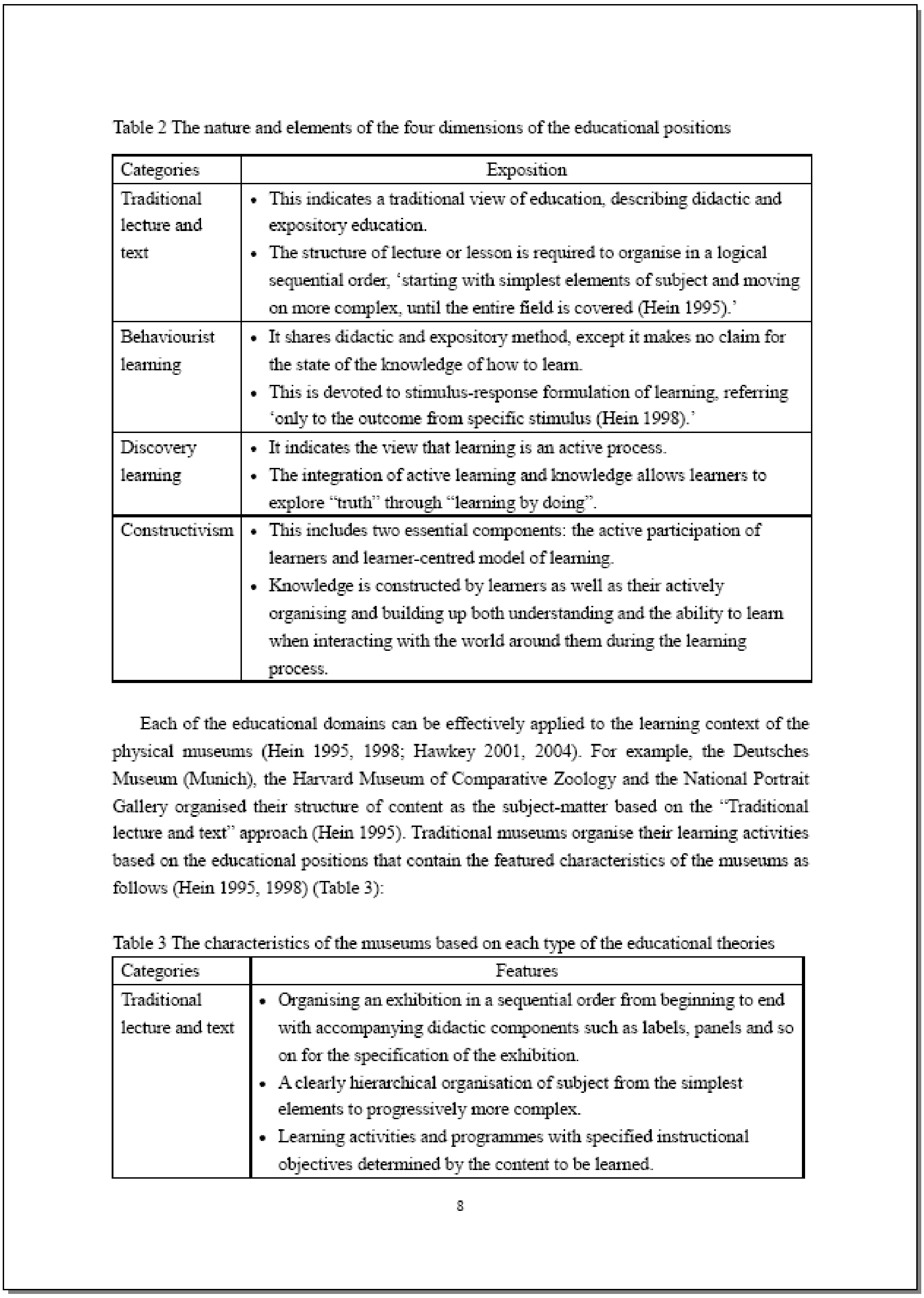


Table 2 The nature and elements of the four dimensions of the educational positions

Categories	Exposition
Traditional lecture and text	• This indicates a traditional view of education, describing didactic and expository education. • The structure of lecture or lesson is required to organise in a logical sequential order, 'starting with simplest elements of subject and moving on more complex, until the entire field is covered (Hein 1995).'
Behaviourist learning	• It shares didactic and expository method, except it makes no claim for the state of the knowledge of how to learn. • This is devoted to stimulus-response formulation of learning, referring 'only to the outcome from specific stimulus (Hein 1998).'
Discovery learning	• It indicates the view that learning is an active process. • The integration of active learning and knowledge allows learners to explore "truth" through "learning by doing".
Constructivism	• This includes two essential components: the active participation of learners and learner-centred model of learning. • Knowledge is constructed by learners as well as their actively organising and building up both understanding and the ability to learn when interacting with the world around them during the learning process.

Each of the educational domains can be effectively applied to the learning context of the physical museums (Hein 1995, 1998; Hawkey 2001, 2004). For example, the Deutsches Museum (Munich), the Harvard Museum of Comparative Zoology and the National Portrait Gallery organised their structure of content as the subject-matter based on the "Traditional lecture and text" approach (Hein 1995). Traditional museums organise their learning activities based on the educational positions that contain the featured characteristics of the museums as follows (Hein 1995, 1998) (Table 3):

Table 3 The characteristics of the museums based on each type of the educational theories

Categories	Features
Traditional lecture and text	• Organising an exhibition in a sequential order from beginning to end with accompanying didactic components such as labels, panels and so on for the specification of the exhibition. • A clearly hierarchical organisation of subject from the simplest elements to progressively more complex. • Learning activities and programmes with specified instructional objectives determined by the content to be learned.

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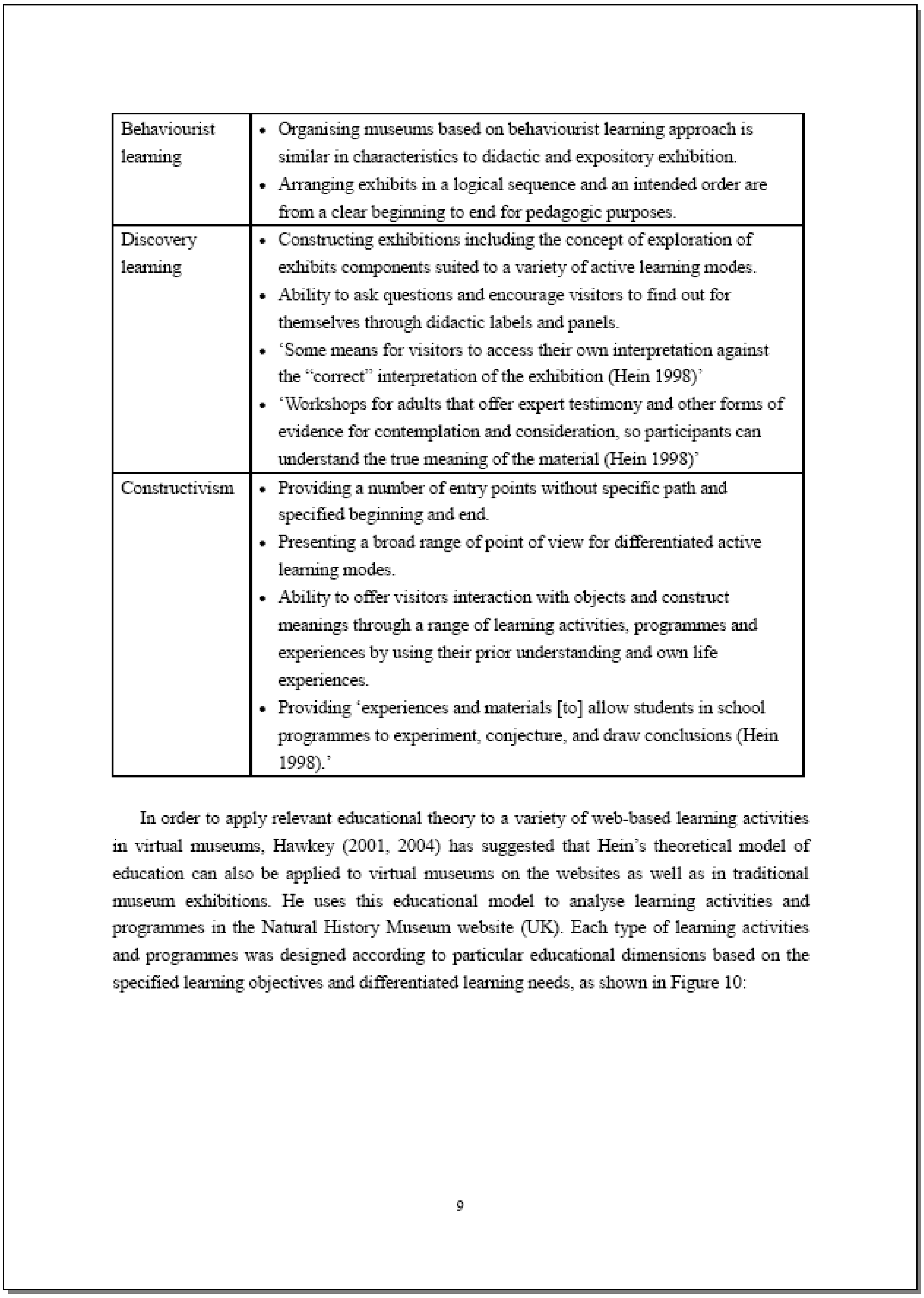


Behaviourist learning	• Organising museums based on behaviourist learning approach is similar in characteristics to didactic and expository exhibition. • Arranging exhibits in a logical sequence and an intended order are from a clear beginning to end for pedagogic purposes.
Discovery learning	• Constructing exhibitions including the concept of exploration of exhibits components suited to a variety of active learning modes. • Ability to ask questions and encourage visitors to find out for themselves through didactic labels and panels. • 'Some means for visitors to access their own interpretation against the "correct" interpretation of the exhibition (Hein 1998)' • 'Workshops for adults that offer expert testimony and other forms of evidence for contemplation and consideration, so participants can understand the true meaning of the material (Hein 1998)'
Constructivism	• Providing a number of entry points without specific path and specified beginning and end. • Presenting a broad range of point of view for differentiated active learning modes. • Ability to offer visitors interaction with objects and construct meanings through a range of learning activities, programmes and experiences by using their prior understanding and own life experiences. • Providing 'experiences and materials [to] allow students in school programmes to experiment, conjecture, and draw conclusions (Hein 1998).'

In order to apply relevant educational theory to a variety of web-based learning activities in virtual museums, Hawkey (2001, 2004) has suggested that Hein's theoretical model of education can also be applied to virtual museums on the websites as well as in traditional museum exhibitions. He uses this educational model to analyse learning activities and programmes in the Natural History Museum website (UK). Each type of learning activities and programmes was designed according to particular educational dimensions based on the specified learning objectives and differentiated learning needs, as shown in Figure 10:

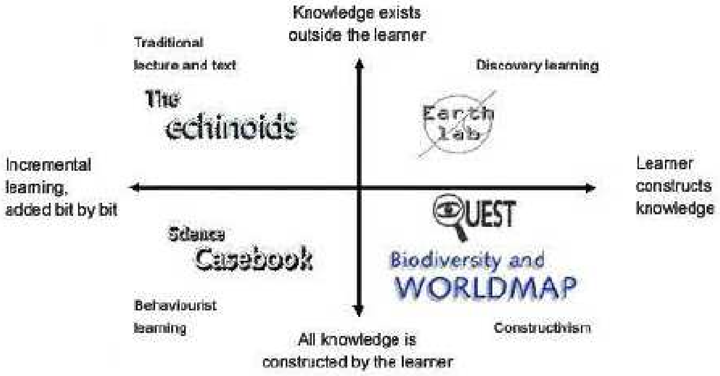


Figure 10 Hein's educational theory applied to the Natural History Museum website

(Source: adapted from Hawkey 2001)

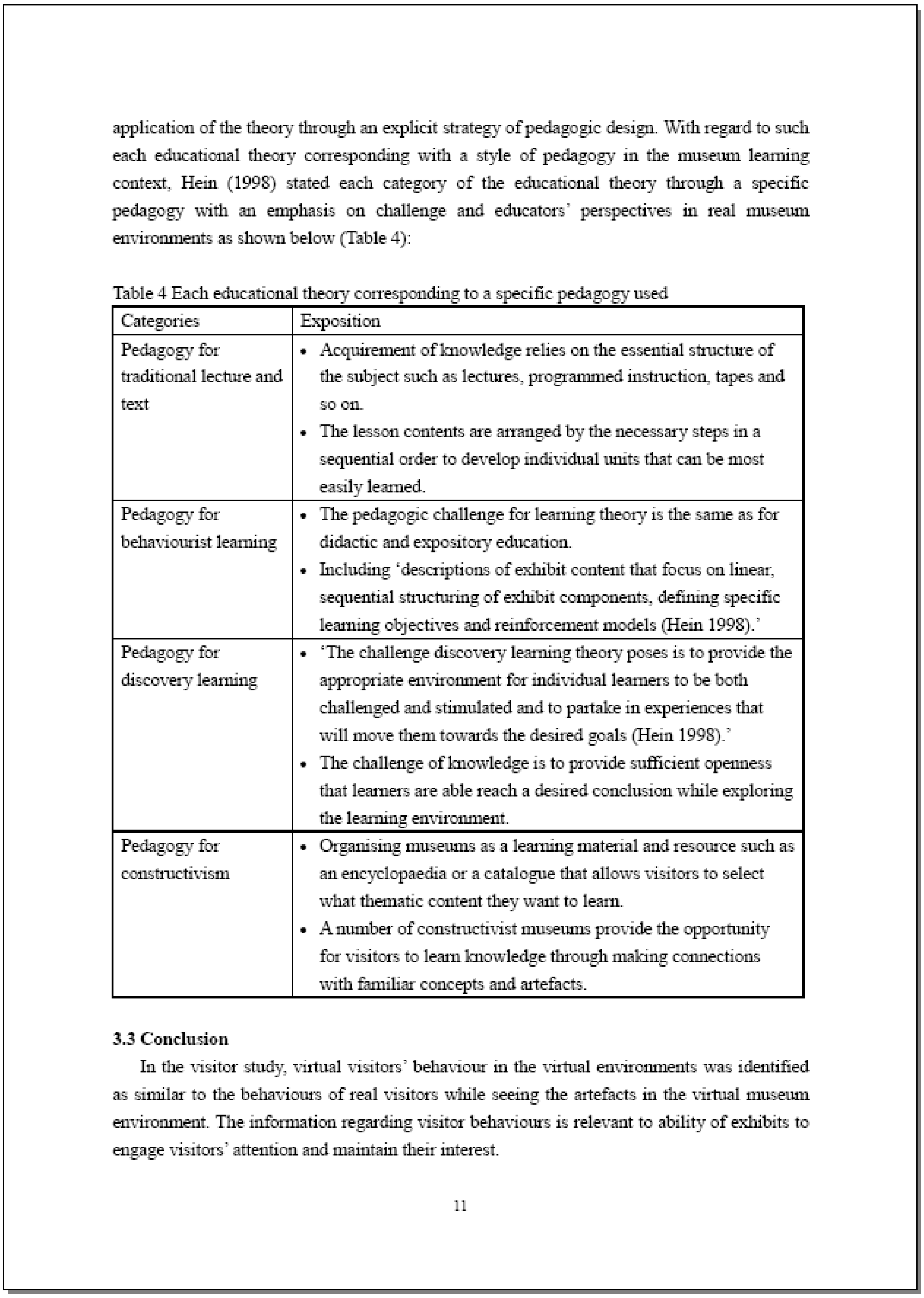
- The echinoids (traditional lecture and text): learning resources and information about echinoids in this programme are organised by the necessary steps in a sequential order for visitors to learn thematic content in a systematic matter from simple to complex.

- Earth lab (discovery learning): this learning activity provides resources regarding specimens, rocks, minerals and fossils through the concept of exploration of exhibits components. Visitors are allowed to learn knowledge of museum artefacts through their individual discoveries to actively select categories from the database.

- Science casebook (behaviourist learning): this programme presents a number of science cases for visitors to learn how the scientists work in the Natural History Museum. One of the cases, "The Beast of Bodmin Moor", investigates the skull of Beast of Bodmin Moor with large fangs as learning content in a logical sequence from beginning to end for its intended pedagogic purposes.

- QUEST (constructivism): this programme allows visitors to learn their own exploration and investigation of selected virtual objects in terms of size, mass, age, material and so on through using a variety of interaction learning activity. 'It is active learning predicated on discovery rather than merely passive (Hawkey 2004).'

A complete educational programme not only includes a theory, but also contains



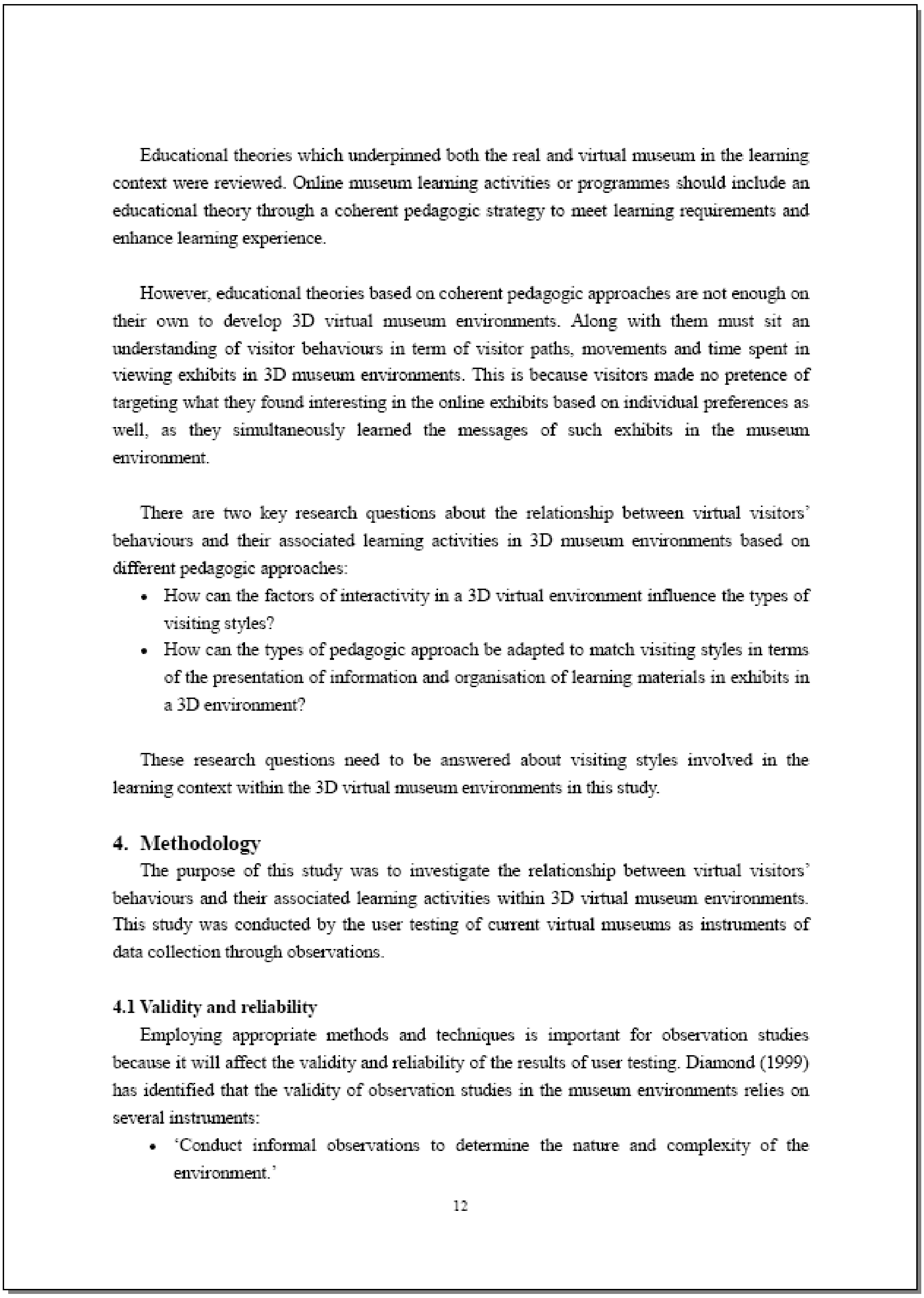
application of the theory through an explicit strategy of pedagogic design. With regard to such each educational theory corresponding with a style of pedagogy in the museum learning context, Hein (1998) stated each category of the educational theory through a specific pedagogy with an emphasis on challenge and educators' perspectives in real museum environments as shown below (Table 4):

Table 4 Each educational theory corresponding to a specific pedagogy used

Categories	Exposition
Pedagogy for traditional lecture and text	• Acquirement of knowledge relies on the essential structure of the subject such as lectures, programmed instruction, tapes and so on. • The lesson contents are arranged by the necessary steps in a sequential order to develop individual units that can be most easily learned.
Pedagogy for behaviourist learning	• The pedagogic challenge for learning theory is the same as for didactic and expository education. • Including 'descriptions of exhibit content that focus on linear, sequential structuring of exhibit components, defining specific learning objectives and reinforcement models (Hein 1998).'
Pedagogy for discovery learning	• 'The challenge discovery learning theory poses is to provide the appropriate environment for individual learners to be both challenged and stimulated and to partake in experiences that will move them towards the desired goals (Hein 1998).' • The challenge of knowledge is to provide sufficient openness that learners are able reach a desired conclusion while exploring the learning environment.
Pedagogy for constructivism	• Organising museums as a learning material and resource such as an encyclopaedia or a catalogue that allows visitors to select what thematic content they want to learn. • A number of constructivist museums provide the opportunity for visitors to learn knowledge through making connections with familiar concepts and artefacts.

3.3 Conclusion

In the visitor study, virtual visitors' behaviour in the virtual environments was identified as similar to the behaviours of real visitors while seeing the artefacts in the virtual museum environment. The information regarding visitor behaviours is relevant to ability of exhibits to engage visitors' attention and maintain their interest.



Educational theories which underpinned both the real and virtual museum in the learning context were reviewed. Online museum learning activities or programmes should include an educational theory through a coherent pedagogic strategy to meet learning requirements and enhance learning experience.

However, educational theories based on coherent pedagogic approaches are not enough on their own to develop 3D virtual museum environments. Along with them must sit an understanding of visitor behaviours in term of visitor paths, movements and time spent in viewing exhibits in 3D museum environments. This is because visitors made no pretence of targeting what they found interesting in the online exhibits based on individual preferences as well, as they simultaneously learned the messages of such exhibits in the museum environment.

There are two key research questions about the relationship between virtual visitors' behaviours and their associated learning activities in 3D museum environments based on different pedagogic approaches:

- How can the factors of interactivity in a 3D virtual environment influence the types of visiting styles?
- How can the types of pedagogic approach be adapted to match visiting styles in terms of the presentation of information and organisation of learning materials in exhibits in a 3D environment?

These research questions need to be answered about visiting styles involved in the learning context within the 3D virtual museum environments in this study.

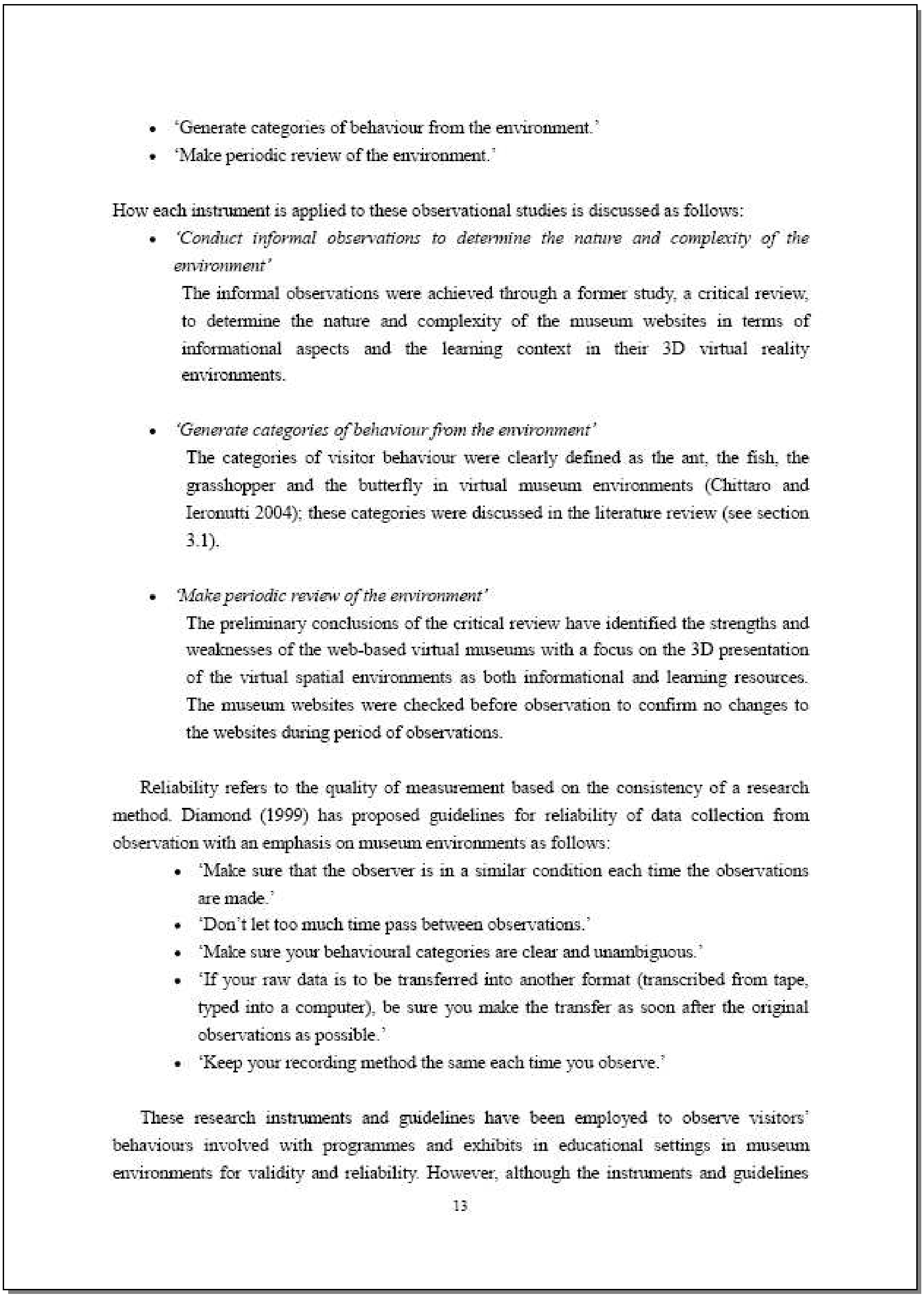
4. Methodology

The purpose of this study was to investigate the relationship between virtual visitors' behaviours and their associated learning activities within 3D virtual museum environments. This study was conducted by the user testing of current virtual museums as instruments of data collection through observations.

4.1 Validity and reliability

Employing appropriate methods and techniques is important for observation studies because it will affect the validity and reliability of the results of user testing. Diamond (1999) has identified that the validity of observation studies in the museum environments relies on several instruments:

- 'Conduct informal observations to determine the nature and complexity of the environment.'



- 'Generate categories of behaviour from the environment.'
- 'Make periodic review of the environment.'

How each instrument is applied to these observational studies is discussed as follows:

- *'Conduct informal observations to determine the nature and complexity of the environment'*

  The informal observations were achieved through a former study, a critical review, to determine the nature and complexity of the museum websites in terms of informational aspects and the learning context in their 3D virtual reality environments.

- *'Generate categories of behaviour from the environment'*

  The categories of visitor behaviour were clearly defined as the ant, the fish, the grasshopper and the butterfly in virtual museum environments (Chittaro and Ieronutti 2004); these categories were discussed in the literature review (see section 3.1).

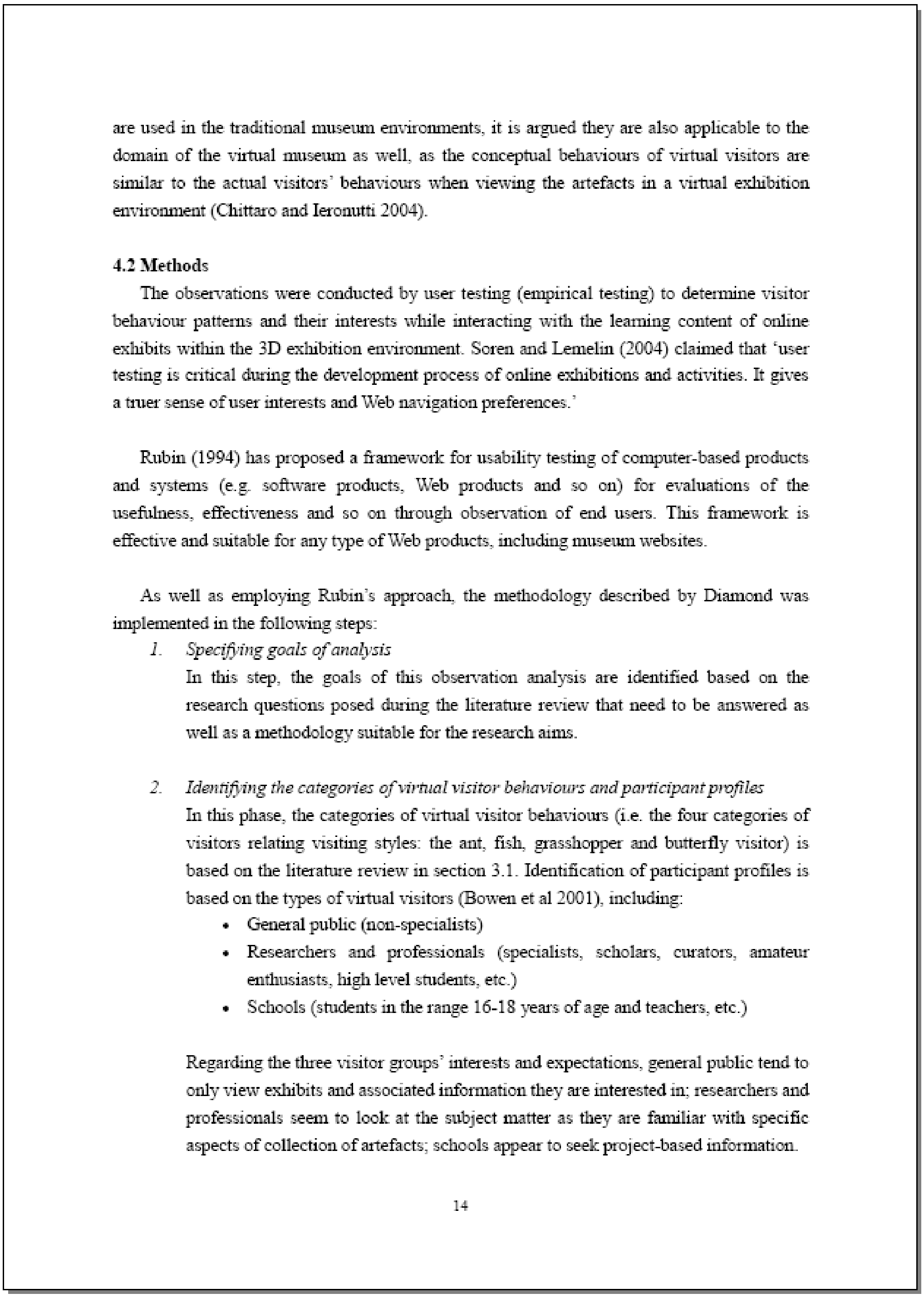
- *'Make periodic review of the environment'*

  The preliminary conclusions of the critical review have identified the strengths and weaknesses of the web-based virtual museums with a focus on the 3D presentation of the virtual spatial environments as both informational and learning resources. The museum websites were checked before observation to confirm no changes to the websites during period of observations.

Reliability refers to the quality of measurement based on the consistency of a research method. Diamond (1999) has proposed guidelines for reliability of data collection from observation with an emphasis on museum environments as follows:

- 'Make sure that the observer is in a similar condition each time the observations are made.'
- 'Don't let too much time pass between observations.'
- 'Make sure your behavioural categories are clear and unambiguous.'
- 'If your raw data is to be transferred into another format (transcribed from tape, typed into a computer), be sure you make the transfer as soon after the original observations as possible.'
- 'Keep your recording method the same each time you observe.'

These research instruments and guidelines have been employed to observe visitors' behaviours involved with programmes and exhibits in educational settings in museum environments for validity and reliability. However, although the instruments and guidelines



are used in the traditional museum environments, it is argued they are also applicable to the domain of the virtual museum as well, as the conceptual behaviours of virtual visitors are similar to the actual visitors' behaviours when viewing the artefacts in a virtual exhibition environment (Chittaro and Ieronutti 2004).

4.2 Methods

The observations were conducted by user testing (empirical testing) to determine visitor behaviour patterns and their interests while interacting with the learning content of online exhibits within the 3D exhibition environment. Soren and Lemelin (2004) claimed that 'user testing is critical during the development process of online exhibitions and activities. It gives a truer sense of user interests and Web navigation preferences.'

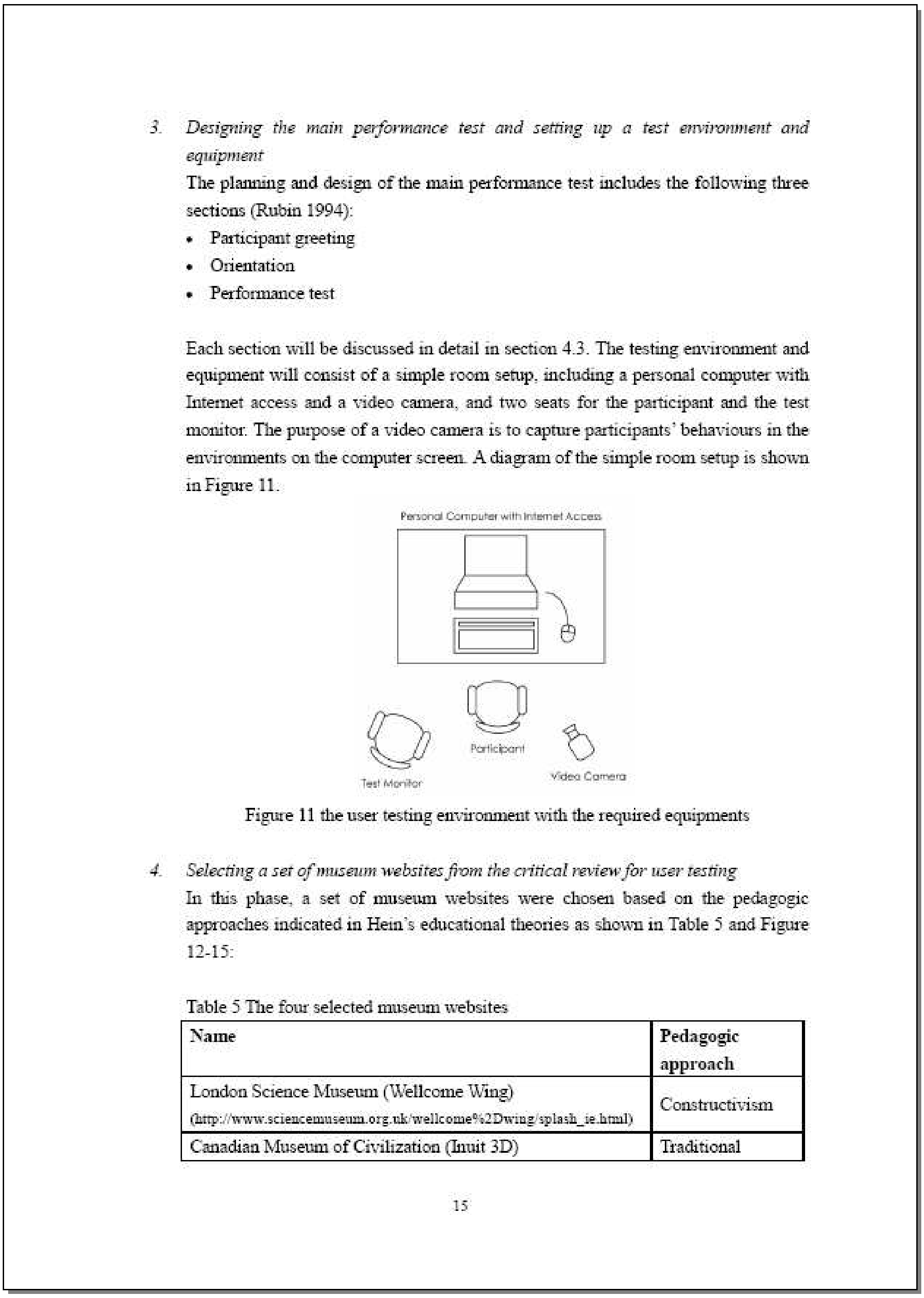
Rubin (1994) has proposed a framework for usability testing of computer-based products and systems (e.g. software products, Web products and so on) for evaluations of the usefulness, effectiveness and so on through observation of end users. This framework is effective and suitable for any type of Web products, including museum websites.

As well as employing Rubin's approach, the methodology described by Diamond was implemented in the following steps:

1. *Specifying goals of analysis*
   In this step, the goals of this observation analysis are identified based on the research questions posed during the literature review that need to be answered as well as a methodology suitable for the research aims.

2. *Identifying the categories of virtual visitor behaviours and participant profiles*
   In this phase, the categories of virtual visitor behaviours (i.e. the four categories of visitors relating visiting styles: the ant, fish, grasshopper and butterfly visitor) is based on the literature review in section 3.1. Identification of participant profiles is based on the types of virtual visitors (Bowen et al 2001), including:
   - General public (non-specialists)
   - Researchers and professionals (specialists, scholars, curators, amateur enthusiasts, high level students, etc.)
   - Schools (students in the range 16-18 years of age and teachers, etc.)

   Regarding the three visitor groups' interests and expectations, general public tend to only view exhibits and associated information they are interested in; researchers and professionals seem to look at the subject matter as they are familiar with specific aspects of collection of artefacts; schools appear to seek project-based information.



3. *Designing the main performance test and setting up a test environment and equipment*

   The planning and design of the main performance test includes the following three sections (Rubin 1994):

   - Participant greeting
   - Orientation
   - Performance test

   Each section will be discussed in detail in section 4.3. The testing environment and equipment will consist of a simple room setup, including a personal computer with Internet access and a video camera, and two seats for the participant and the test monitor. The purpose of a video camera is to capture participants' behaviours in the environments on the computer screen. A diagram of the simple room setup is shown in Figure 11.

Figure 11 the user testing environment with the required equipments

4. *Selecting a set of museum websites from the critical review for user testing*

   In this phase, a set of museum websites were chosen based on the pedagogic approaches indicated in Hein's educational theories as shown in Table 5 and Figure 12-15:

Table 5 The four selected museum websites

Name	**Pedagogic approach**
London Science Museum (Wellcome Wing) (http://www.sciencemuseum.org.uk/wellcome%2Dwing/splash_ie.html)	Constructivism
Canadian Museum of Civilization (Inuit 3D)	Traditional

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(http://www.civilization.ca/aborig/inuit3d/inuit_e.html)	lecture and text
Helsinki City Museum (Henrik Govinius' site) (http://www.virtualhelsinki.net/museum/english/index2.html)	Discovery learning
Philadelphia Museum of Art (Constantin Brancusi's Mademoiselle Pogany) (http://www.narrativerooms.com/pogany/vr/index_a.html)	Behaviourist learning

Figure 12 The Wellcome Wing

Figure 13 Inuit 3D

Figure 14 Henrik Govinius' site

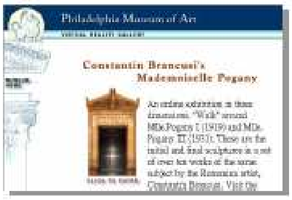
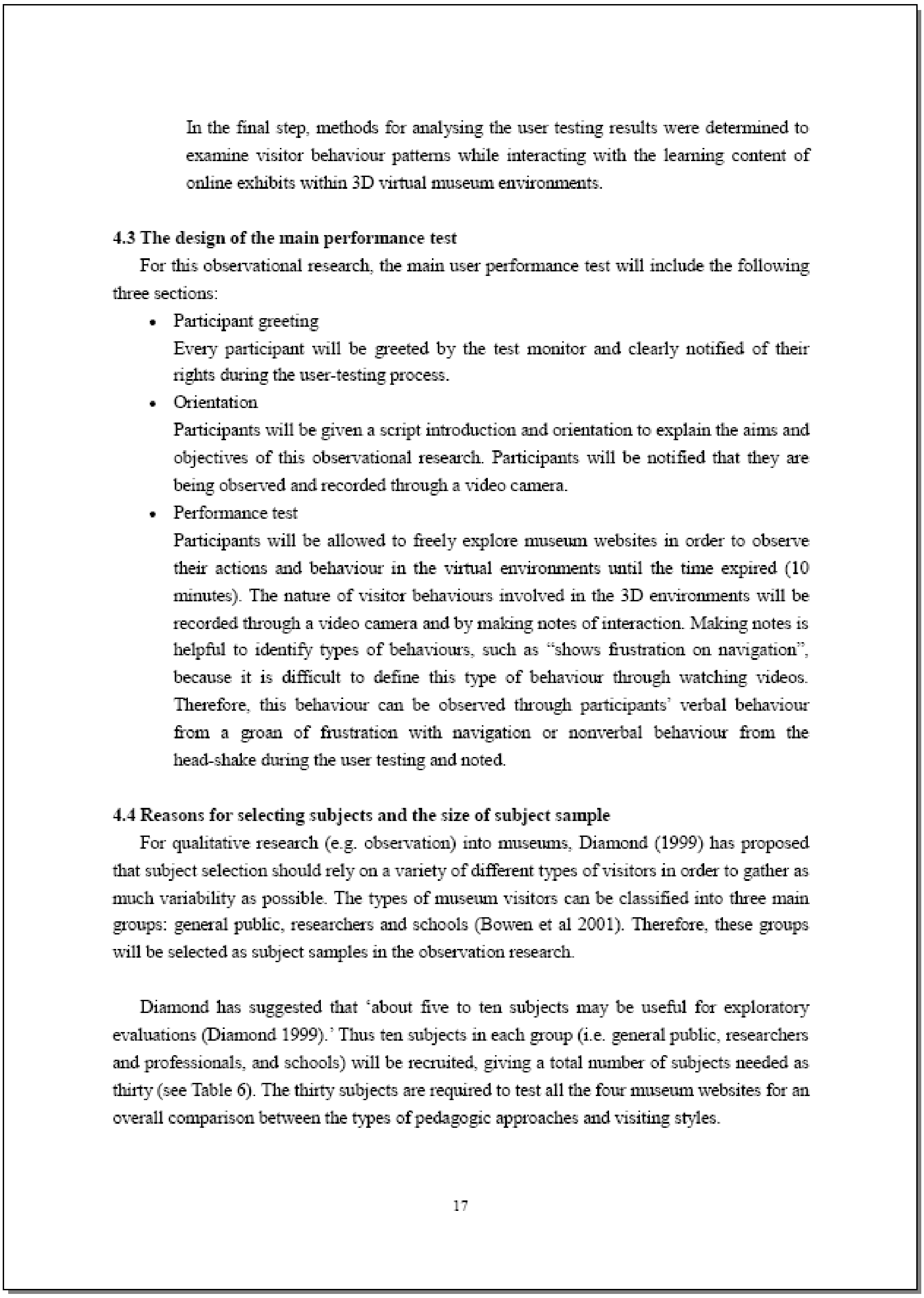


Figure 15 Constantin Brancusi's Mademoiselle Pogany

From the preliminary conclusions of the critical review, these four 3D museum environments on the websites were chosen based on the four different pedagogic approaches according to Hein's (1998) pedagogic categories in terms of structure of the subject, organisation of thematic content and arrangement of exhibit components. Moreover, the four selected museum websites were shown to effectively and clearly present their cultural materials content in 3D spatially architectural environments for the educational and interpretive requirements of the target audiences; thereby these museum websites can be used to determine the relationship between visiting styles and learning context within 3D virtual museum environments for different groups of virtual visitors through user testing.

5. *Determining methods for analysing the user-testing results*



In the final step, methods for analysing the user testing results were determined to examine visitor behaviour patterns while interacting with the learning content of online exhibits within 3D virtual museum environments.

4.3 The design of the main performance test

For this observational research, the main user performance test will include the following three sections:

- Participant greeting
  Every participant will be greeted by the test monitor and clearly notified of their rights during the user-testing process.
- Orientation
  Participants will be given a script introduction and orientation to explain the aims and objectives of this observational research. Participants will be notified that they are being observed and recorded through a video camera.
- Performance test
  Participants will be allowed to freely explore museum websites in order to observe their actions and behaviour in the virtual environments until the time expired (10 minutes). The nature of visitor behaviours involved in the 3D environments will be recorded through a video camera and by making notes of interaction. Making notes is helpful to identify types of behaviours, such as "shows frustration on navigation", because it is difficult to define this type of behaviour through watching videos. Therefore, this behaviour can be observed through participants' verbal behaviour from a groan of frustration with navigation or nonverbal behaviour from the head-shake during the user testing and noted.

4.4 Reasons for selecting subjects and the size of subject sample

For qualitative research (e.g. observation) into museums, Diamond (1999) has proposed that subject selection should rely on a variety of different types of visitors in order to gather as much variability as possible. The types of museum visitors can be classified into three main groups: general public, researchers and schools (Bowen et al 2001). Therefore, these groups will be selected as subject samples in the observation research.

Diamond has suggested that 'about five to ten subjects may be useful for exploratory evaluations (Diamond 1999).' Thus ten subjects in each group (i.e. general public, researchers and professionals, and schools) will be recruited, giving a total number of subjects needed as thirty (see Table 6). The thirty subjects are required to test all the four museum websites for an overall comparison between the types of pedagogic approaches and visiting styles.

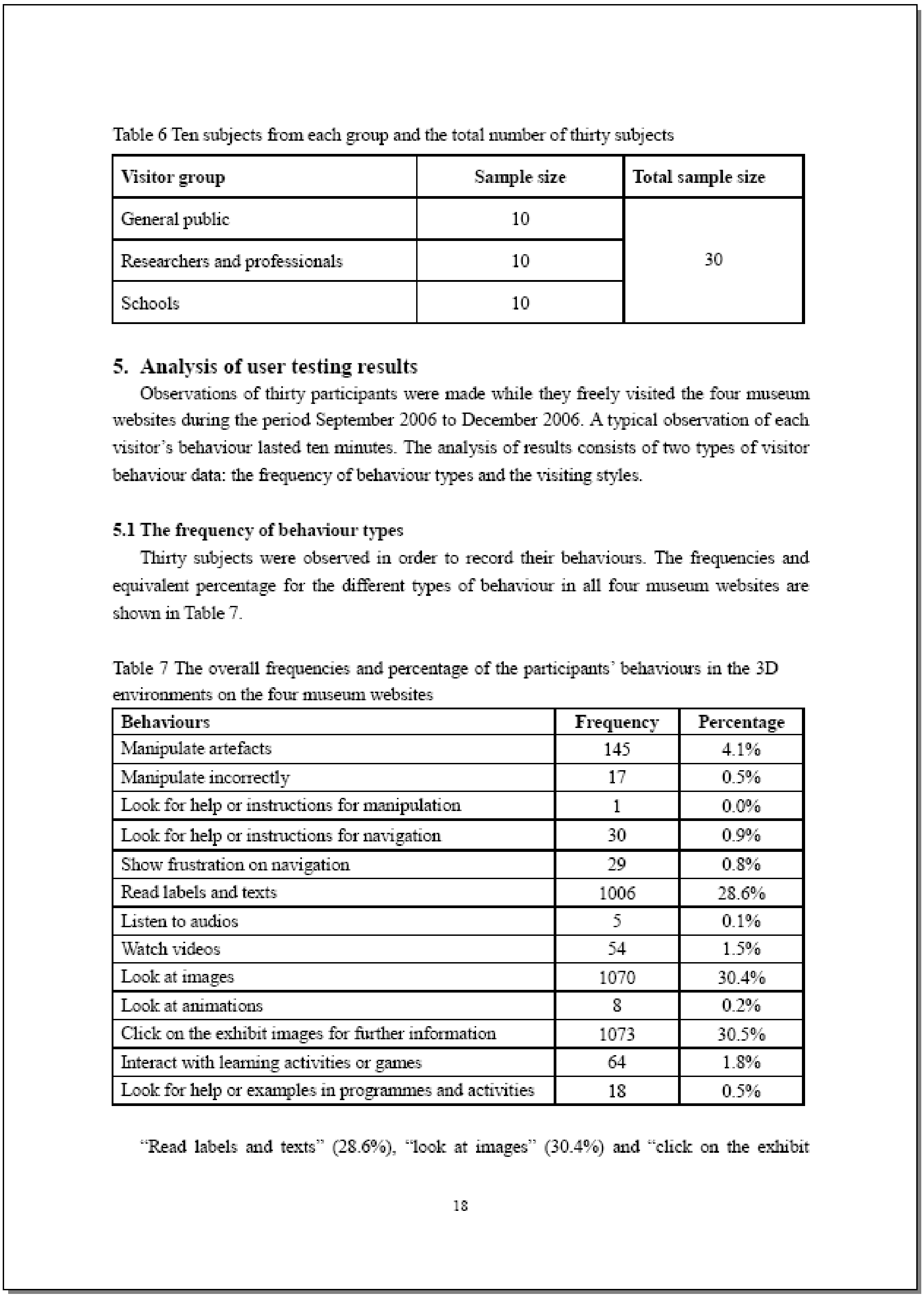


Table 6 Ten subjects from each group and the total number of thirty subjects

Visitor group	Sample size	Total sample size
General public	10	30
Researchers and professionals	10	
Schools	10	

5. Analysis of user testing results

Observations of thirty participants were made while they freely visited the four museum websites during the period September 2006 to December 2006. A typical observation of each visitor's behaviour lasted ten minutes. The analysis of results consists of two types of visitor behaviour data: the frequency of behaviour types and the visiting styles.

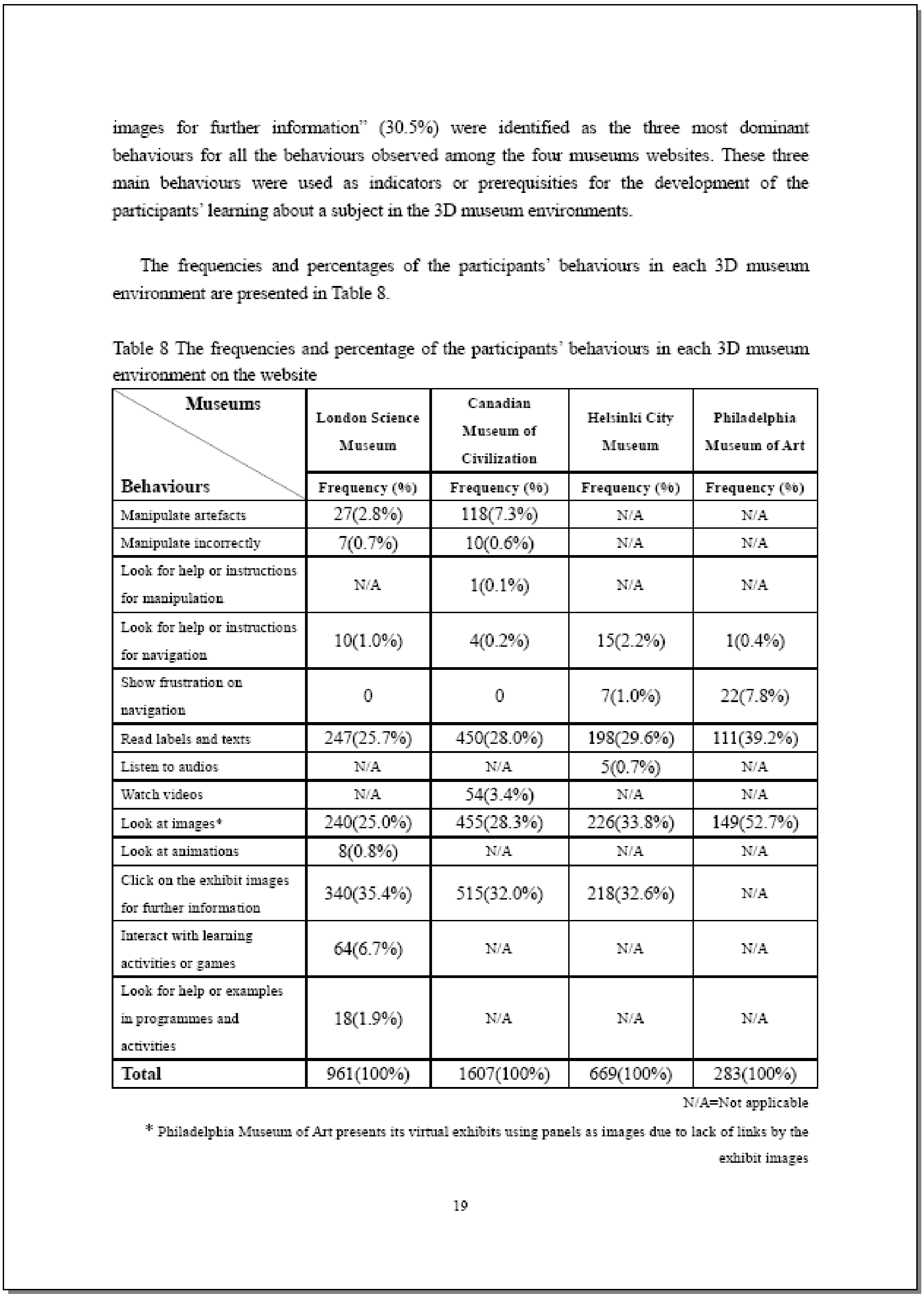
5.1 The frequency of behaviour types

Thirty subjects were observed in order to record their behaviours. The frequencies and equivalent percentage for the different types of behaviour in all four museum websites are shown in Table 7.

Table 7 The overall frequencies and percentage of the participants' behaviours in the 3D environments on the four museum websites

Behaviours	Frequency	Percentage
Manipulate artefacts	145	4.1%
Manipulate incorrectly	17	0.5%
Look for help or instructions for manipulation	1	0.0%
Look for help or instructions for navigation	30	0.9%
Show frustration on navigation	29	0.8%
Read labels and texts	1006	28.6%
Listen to audios	5	0.1%
Watch videos	54	1.5%
Look at images	1070	30.4%
Look at animations	8	0.2%
Click on the exhibit images for further information	1073	30.5%
Interact with learning activities or games	64	1.8%
Look for help or examples in programmes and activities	18	0.5%

"Read labels and texts" (28.6%), "look at images" (30.4%) and "click on the exhibit



images for further information" (30.5%) were identified as the three most dominant behaviours for all the behaviours observed among the four museums websites. These three main behaviours were used as indicators or prerequisities for the development of the participants' learning about a subject in the 3D museum environments.

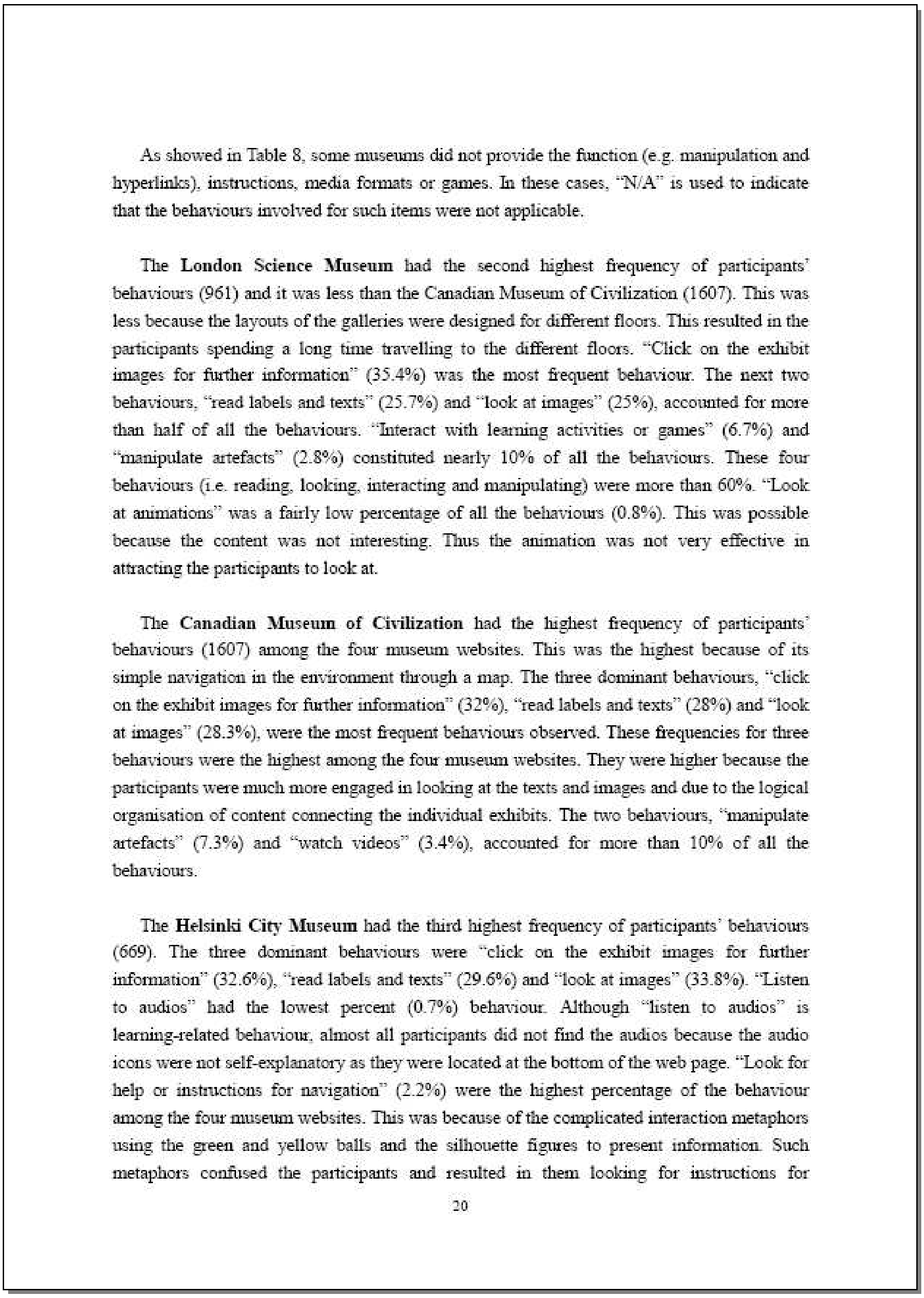
The frequencies and percentages of the participants' behaviours in each 3D museum environment are presented in Table 8.

Table 8 The frequencies and percentage of the participants' behaviours in each 3D museum environment on the website

Museums	**London Science Museum**	**Canadian Museum of Civilization**	**Helsinki City Museum**	**Philadelphia Museum of Art**
Behaviours	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**
Manipulate artefacts	27(2.8%)	118(7.3%)	N/A	N/A
Manipulate incorrectly	7(0.7%)	10(0.6%)	N/A	N/A
Look for help or instructions for manipulation	N/A	1(0.1%)	N/A	N/A
Look for help or instructions for navigation	10(1.0%)	4(0.2%)	15(2.2%)	1(0.4%)
Show frustration on navigation	0	0	7(1.0%)	22(7.8%)
Read labels and texts	247(25.7%)	450(28.0%)	198(29.6%)	111(39.2%)
Listen to audios	N/A	N/A	5(0.7%)	N/A
Watch videos	N/A	54(3.4%)	N/A	N/A
Look at images*	240(25.0%)	455(28.3%)	226(33.8%)	149(52.7%)
Look at animations	8(0.8%)	N/A	N/A	N/A
Click on the exhibit images for further information	340(35.4%)	515(32.0%)	218(32.6%)	N/A
Interact with learning activities or games	64(6.7%)	N/A	N/A	N/A
Look for help or examples in programmes and activities	18(1.9%)	N/A	N/A	N/A
Total	961(100%)	1607(100%)	669(100%)	283(100%)

N/A=Not applicable

* Philadelphia Museum of Art presents its virtual exhibits using panels as images due to lack of links by the exhibit images

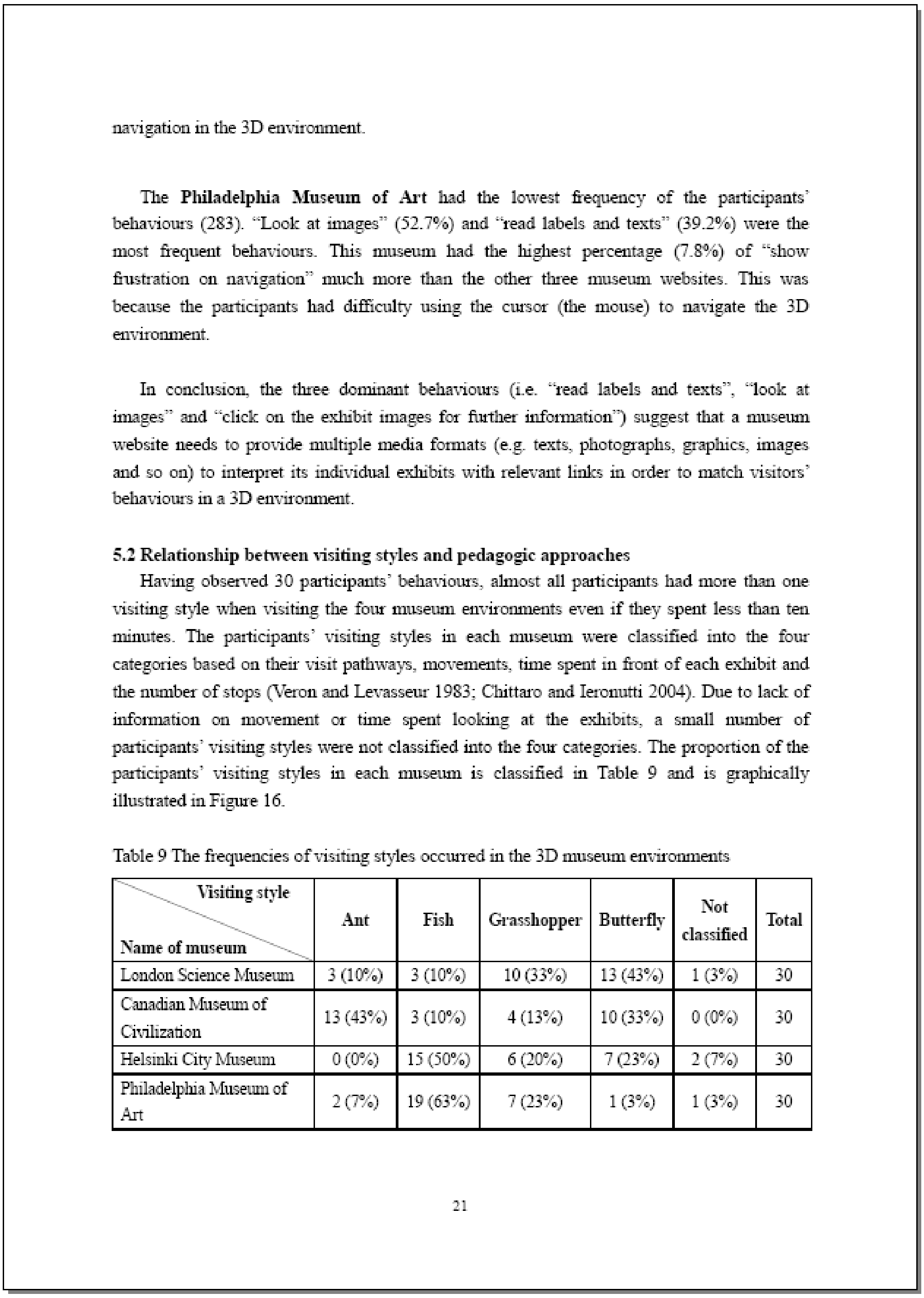


As showed in Table 8, some museums did not provide the function (e.g. manipulation and hyperlinks), instructions, media formats or games. In these cases, "N/A" is used to indicate that the behaviours involved for such items were not applicable.

The **London Science Museum** had the second highest frequency of participants' behaviours (961) and it was less than the Canadian Museum of Civilization (1607). This was less because the layouts of the galleries were designed for different floors. This resulted in the participants spending a long time travelling to the different floors. "Click on the exhibit images for further information" (35.4%) was the most frequent behaviour. The next two behaviours, "read labels and texts" (25.7%) and "look at images" (25%), accounted for more than half of all the behaviours. "Interact with learning activities or games" (6.7%) and "manipulate artefacts" (2.8%) constituted nearly 10% of all the behaviours. These four behaviours (i.e. reading, looking, interacting and manipulating) were more than 60%. "Look at animations" was a fairly low percentage of all the behaviours (0.8%). This was possible because the content was not interesting. Thus the animation was not very effective in attracting the participants to look at.

The **Canadian Museum of Civilization** had the highest frequency of participants' behaviours (1607) among the four museum websites. This was the highest because of its simple navigation in the environment through a map. The three dominant behaviours, "click on the exhibit images for further information" (32%), "read labels and texts" (28%) and "look at images" (28.3%), were the most frequent behaviours observed. These frequencies for three behaviours were the highest among the four museum websites. They were higher because the participants were much more engaged in looking at the texts and images and due to the logical organisation of content connecting the individual exhibits. The two behaviours, "manipulate artefacts" (7.3%) and "watch videos" (3.4%), accounted for more than 10% of all the behaviours.

The **Helsinki City Museum** had the third highest frequency of participants' behaviours (669). The three dominant behaviours were "click on the exhibit images for further information" (32.6%), "read labels and texts" (29.6%) and "look at images" (33.8%). "Listen to audios" had the lowest percent (0.7%) behaviour. Although "listen to audios" is learning-related behaviour, almost all participants did not find the audios because the audio icons were not self-explanatory as they were located at the bottom of the web page. "Look for help or instructions for navigation" (2.2%) were the highest percentage of the behaviour among the four museum websites. This was because of the complicated interaction metaphors using the green and yellow balls and the silhouette figures to present information. Such metaphors confused the participants and resulted in them looking for instructions for



navigation in the 3D environment.

The **Philadelphia Museum of Art** had the lowest frequency of the participants' behaviours (283). "Look at images" (52.7%) and "read labels and texts" (39.2%) were the most frequent behaviours. This museum had the highest percentage (7.8%) of "show frustration on navigation" much more than the other three museum websites. This was because the participants had difficulty using the cursor (the mouse) to navigate the 3D environment.

In conclusion, the three dominant behaviours (i.e. "read labels and texts", "look at images" and "click on the exhibit images for further information") suggest that a museum website needs to provide multiple media formats (e.g. texts, photographs, graphics, images and so on) to interpret its individual exhibits with relevant links in order to match visitors' behaviours in a 3D environment.

5.2 Relationship between visiting styles and pedagogic approaches

Having observed 30 participants' behaviours, almost all participants had more than one visiting style when visiting the four museum environments even if they spent less than ten minutes. The participants' visiting styles in each museum were classified into the four categories based on their visit pathways, movements, time spent in front of each exhibit and the number of stops (Veron and Levasseur 1983; Chittaro and Ieronutti 2004). Due to lack of information on movement or time spent looking at the exhibits, a small number of participants' visiting styles were not classified into the four categories. The proportion of the participants' visiting styles in each museum is classified in Table 9 and is graphically illustrated in Figure 16.

Table 9 The frequencies of visiting styles occurred in the 3D museum environments

Visiting style / **Name of museum**	**Ant**	**Fish**	**Grasshopper**	**Butterfly**	**Not classified**	**Total**
London Science Museum	3 (10%)	3 (10%)	10 (33%)	13 (43%)	1 (3%)	30
Canadian Museum of Civilization	13 (43%)	3 (10%)	4 (13%)	10 (33%)	0 (0%)	30
Helsinki City Museum	0 (0%)	15 (50%)	6 (20%)	7 (23%)	2 (7%)	30
Philadelphia Museum of Art	2 (7%)	19 (63%)	7 (23%)	1 (3%)	1 (3%)	30

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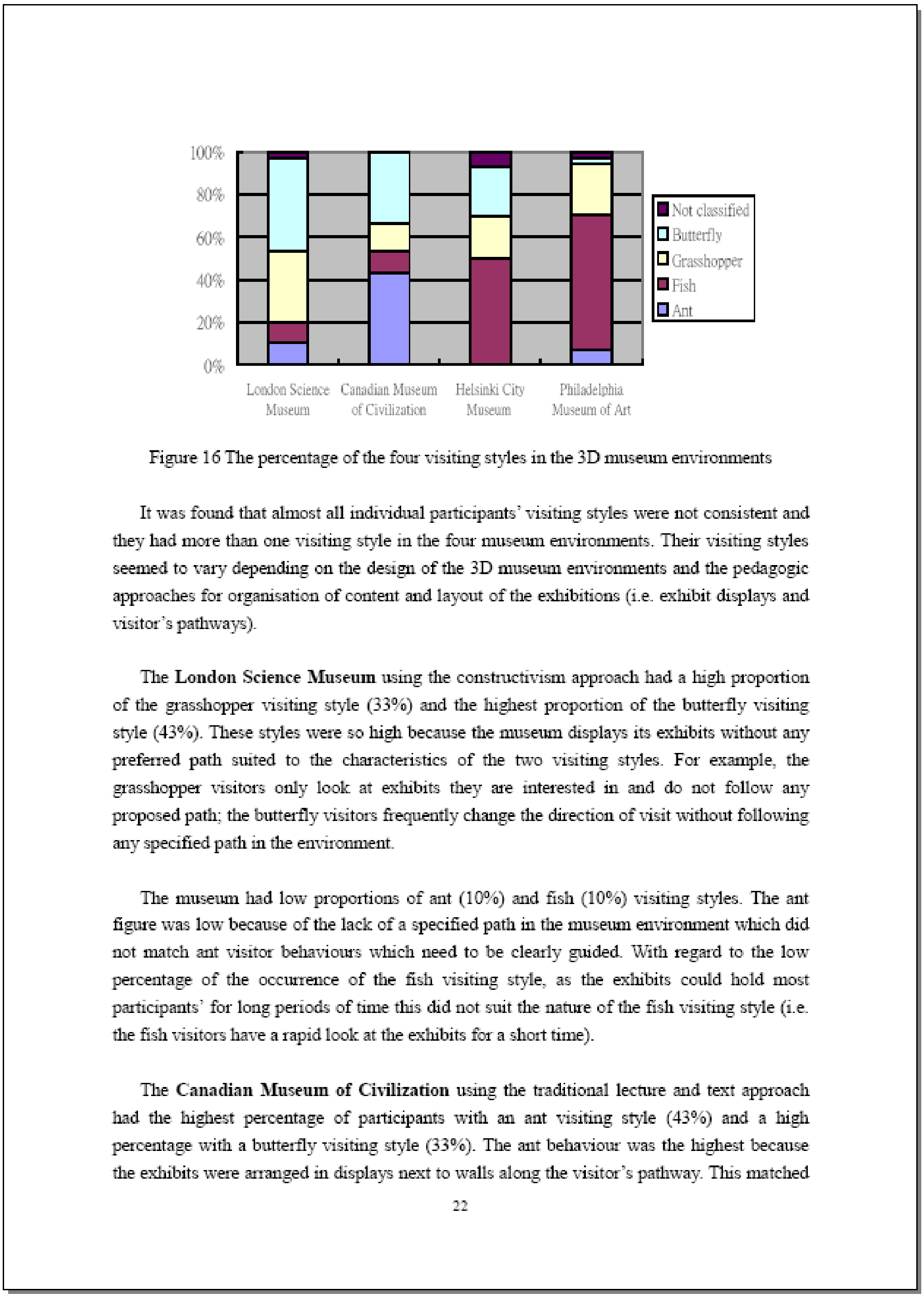


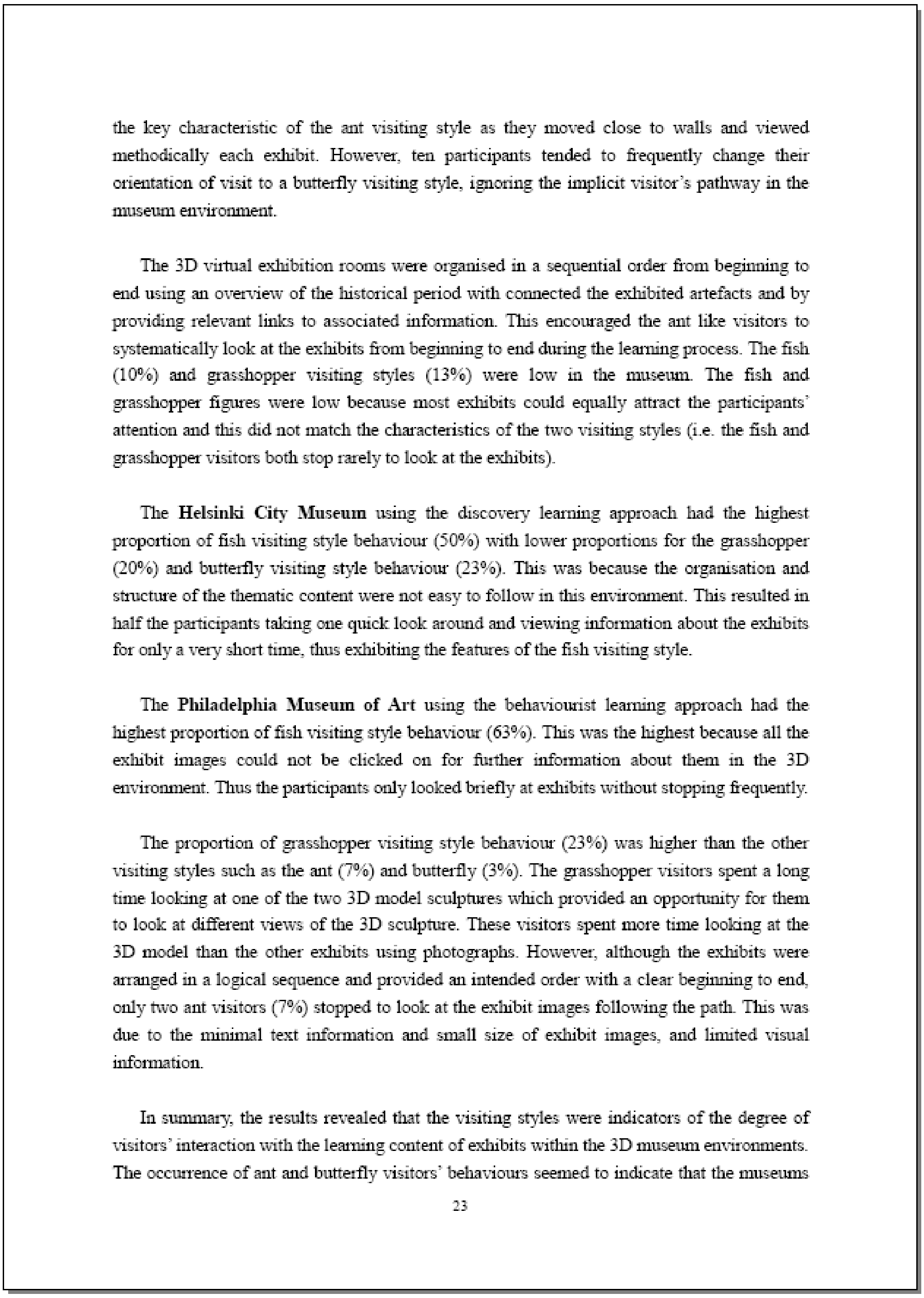
Figure 16 The percentage of the four visiting styles in the 3D museum environments

It was found that almost all individual participants' visiting styles were not consistent and they had more than one visiting style in the four museum environments. Their visiting styles seemed to vary depending on the design of the 3D museum environments and the pedagogic approaches for organisation of content and layout of the exhibitions (i.e. exhibit displays and visitor's pathways).

The **London Science Museum** using the constructivism approach had a high proportion of the grasshopper visiting style (33%) and the highest proportion of the butterfly visiting style (43%). These styles were so high because the museum displays its exhibits without any preferred path suited to the characteristics of the two visiting styles. For example, the grasshopper visitors only look at exhibits they are interested in and do not follow any proposed path; the butterfly visitors frequently change the direction of visit without following any specified path in the environment.

The museum had low proportions of ant (10%) and fish (10%) visiting styles. The ant figure was low because of the lack of a specified path in the museum environment which did not match ant visitor behaviours which need to be clearly guided. With regard to the low percentage of the occurrence of the fish visiting style, as the exhibits could hold most participants' for long periods of time this did not suit the nature of the fish visiting style (i.e. the fish visitors have a rapid look at the exhibits for a short time).

The **Canadian Museum of Civilization** using the traditional lecture and text approach had the highest percentage of participants with an ant visiting style (43%) and a high percentage with a butterfly visiting style (33%). The ant behaviour was the highest because the exhibits were arranged in displays next to walls along the visitor's pathway. This matched



the key characteristic of the ant visiting style as they moved close to walls and viewed methodically each exhibit. However, ten participants tended to frequently change their orientation of visit to a butterfly visiting style, ignoring the implicit visitor's pathway in the museum environment.

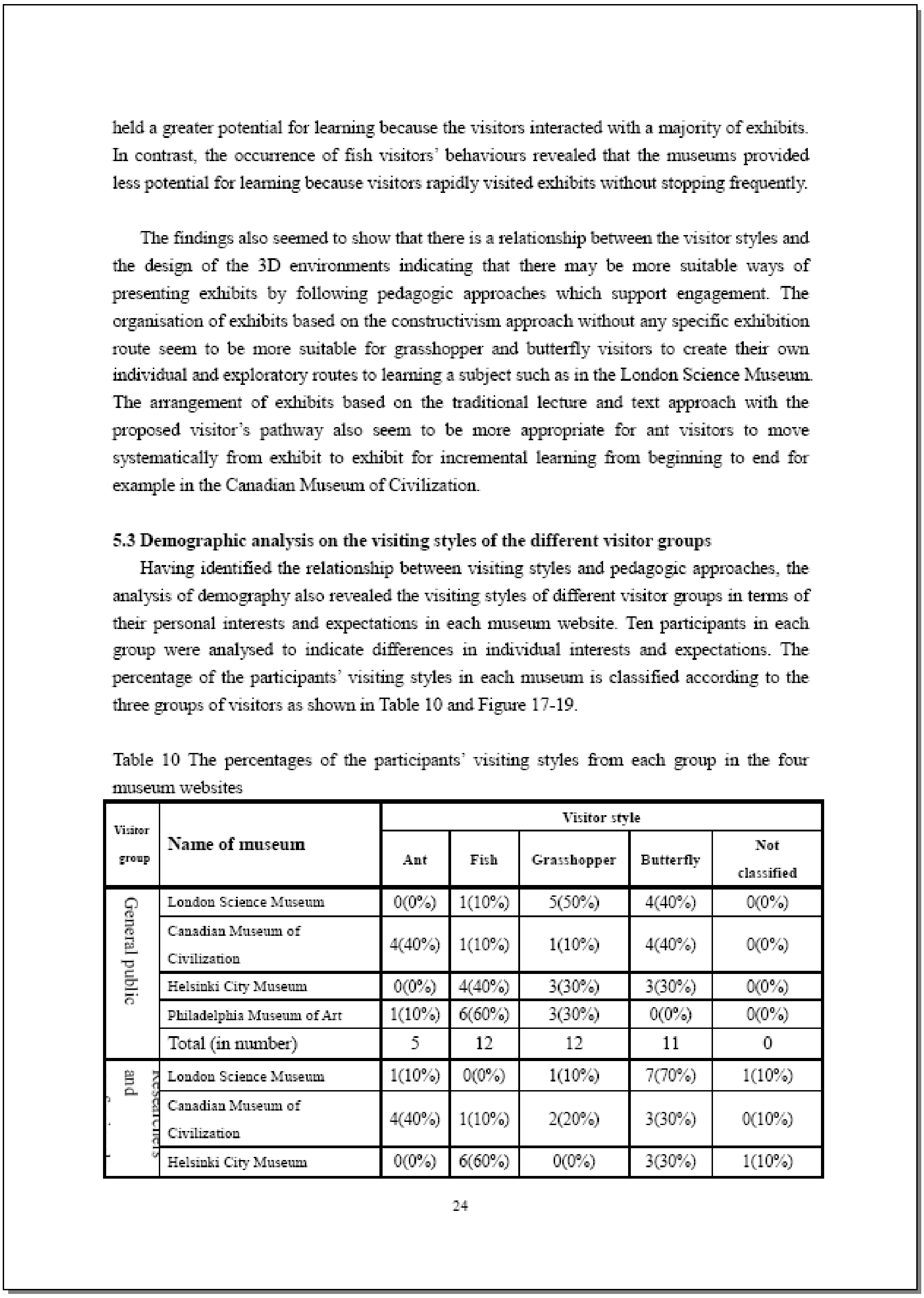
The 3D virtual exhibition rooms were organised in a sequential order from beginning to end using an overview of the historical period with connected the exhibited artefacts and by providing relevant links to associated information. This encouraged the ant like visitors to systematically look at the exhibits from beginning to end during the learning process. The fish (10%) and grasshopper visiting styles (13%) were low in the museum. The fish and grasshopper figures were low because most exhibits could equally attract the participants' attention and this did not match the characteristics of the two visiting styles (i.e. the fish and grasshopper visitors both stop rarely to look at the exhibits).

The **Helsinki City Museum** using the discovery learning approach had the highest proportion of fish visiting style behaviour (50%) with lower proportions for the grasshopper (20%) and butterfly visiting style behaviour (23%). This was because the organisation and structure of the thematic content were not easy to follow in this environment. This resulted in half the participants taking one quick look around and viewing information about the exhibits for only a very short time, thus exhibiting the features of the fish visiting style.

The **Philadelphia Museum of Art** using the behaviourist learning approach had the highest proportion of fish visiting style behaviour (63%). This was the highest because all the exhibit images could not be clicked on for further information about them in the 3D environment. Thus the participants only looked briefly at exhibits without stopping frequently.

The proportion of grasshopper visiting style behaviour (23%) was higher than the other visiting styles such as the ant (7%) and butterfly (3%). The grasshopper visitors spent a long time looking at one of the two 3D model sculptures which provided an opportunity for them to look at different views of the 3D sculpture. These visitors spent more time looking at the 3D model than the other exhibits using photographs. However, although the exhibits were arranged in a logical sequence and provided an intended order with a clear beginning to end, only two ant visitors (7%) stopped to look at the exhibit images following the path. This was due to the minimal text information and small size of exhibit images, and limited visual information.

In summary, the results revealed that the visiting styles were indicators of the degree of visitors' interaction with the learning content of exhibits within the 3D museum environments. The occurrence of ant and butterfly visitors' behaviours seemed to indicate that the museums



held a greater potential for learning because the visitors interacted with a majority of exhibits. In contrast, the occurrence of fish visitors' behaviours revealed that the museums provided less potential for learning because visitors rapidly visited exhibits without stopping frequently.

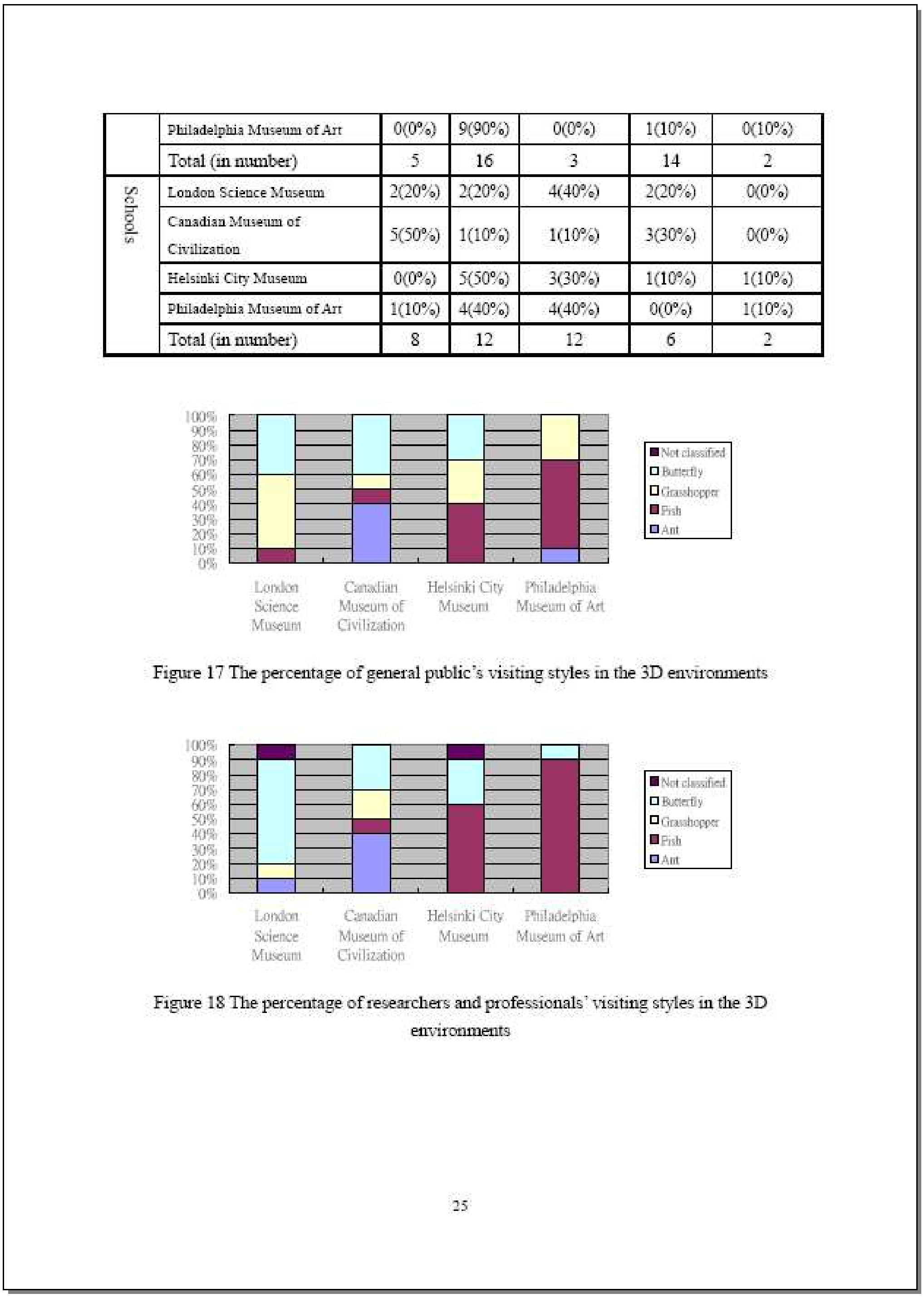
The findings also seemed to show that there is a relationship between the visitor styles and the design of the 3D environments indicating that there may be more suitable ways of presenting exhibits by following pedagogic approaches which support engagement. The organisation of exhibits based on the constructivism approach without any specific exhibition route seem to be more suitable for grasshopper and butterfly visitors to create their own individual and exploratory routes to learning a subject such as in the London Science Museum. The arrangement of exhibits based on the traditional lecture and text approach with the proposed visitor's pathway also seem to be more appropriate for ant visitors to move systematically from exhibit to exhibit for incremental learning from beginning to end for example in the Canadian Museum of Civilization.

5.3 Demographic analysis on the visiting styles of the different visitor groups

Having identified the relationship between visiting styles and pedagogic approaches, the analysis of demography also revealed the visiting styles of different visitor groups in terms of their personal interests and expectations in each museum website. Ten participants in each group were analysed to indicate differences in individual interests and expectations. The percentage of the participants' visiting styles in each museum is classified according to the three groups of visitors as shown in Table 10 and Figure 17-19.

Table 10 The percentages of the participants' visiting styles from each group in the four museum websites

Visitor group	Name of museum	Visitor style				
		Ant	Fish	Grasshopper	Butterfly	Not classified
General public	London Science Museum	0(0%)	1(10%)	5(50%)	4(40%)	0(0%)
	Canadian Museum of Civilization	4(40%)	1(10%)	1(10%)	4(40%)	0(0%)
	Helsinki City Museum	0(0%)	4(40%)	3(30%)	3(30%)	0(0%)
	Philadelphia Museum of Art	1(10%)	6(60%)	3(30%)	0(0%)	0(0%)
	Total (in number)	5	12	12	11	0
and Researchers	London Science Museum	1(10%)	0(0%)	1(10%)	7(70%)	1(10%)
	Canadian Museum of Civilization	4(40%)	1(10%)	2(20%)	3(30%)	0(10%)
	Helsinki City Museum	0(0%)	6(60%)	0(0%)	3(30%)	1(10%)



	Philadelphia Museum of Art	0(0%)	9(90%)	0(0%)	1(10%)	0(10%)
	Total (in number)	5	16	3	14	2
Schools	London Science Museum	2(20%)	2(20%)	4(40%)	2(20%)	0(0%)
	Canadian Museum of Civilization	5(50%)	1(10%)	1(10%)	3(30%)	0(0%)
	Helsinki City Museum	0(0%)	5(50%)	3(30%)	1(10%)	1(10%)
	Philadelphia Museum of Art	1(10%)	4(40%)	4(40%)	0(0%)	1(10%)
	Total (in number)	8	12	12	6	2

Figure 17 The percentage of general public's visiting styles in the 3D environments

Figure 18 The percentage of researchers and professionals' visiting styles in the 3D environments

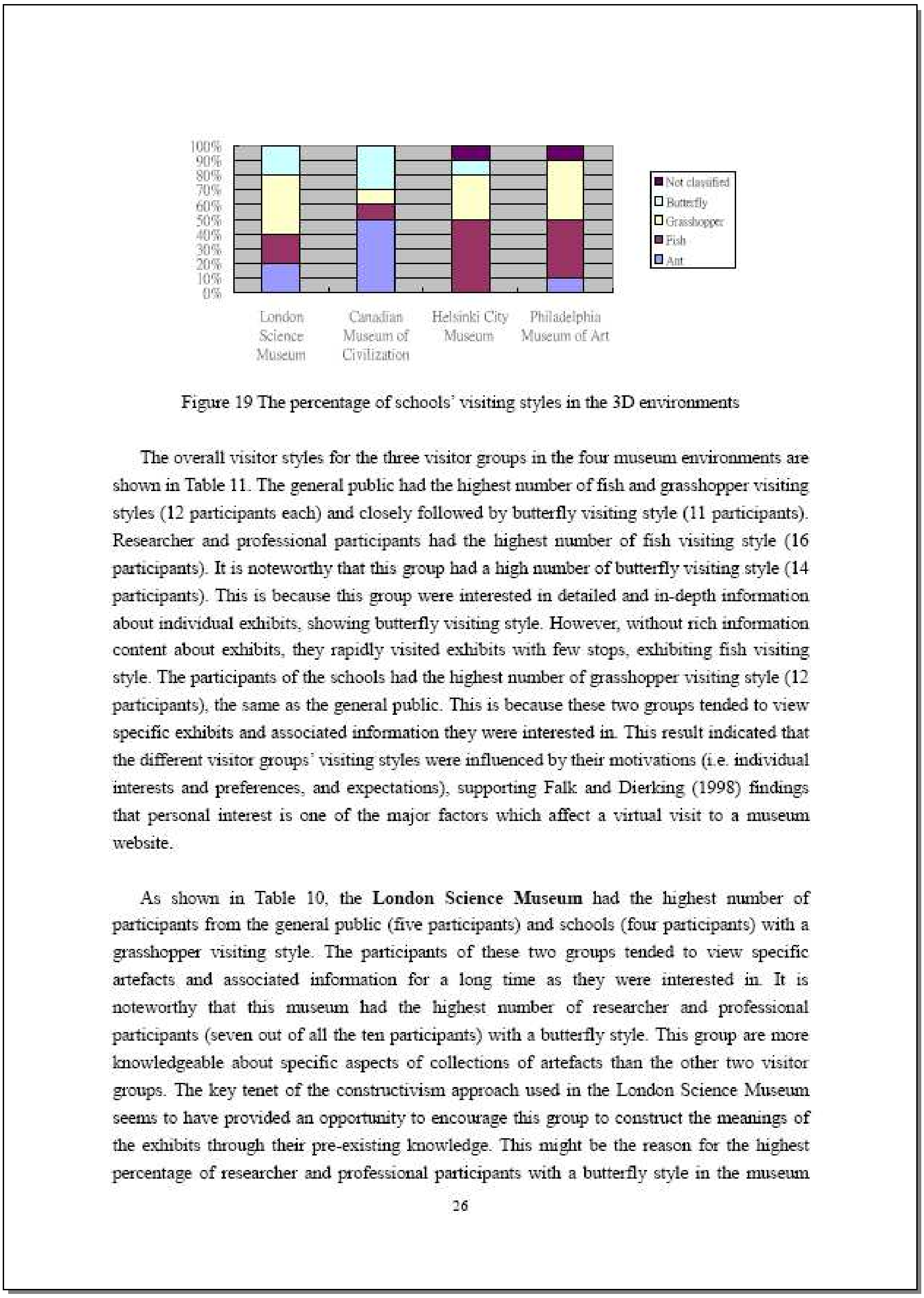
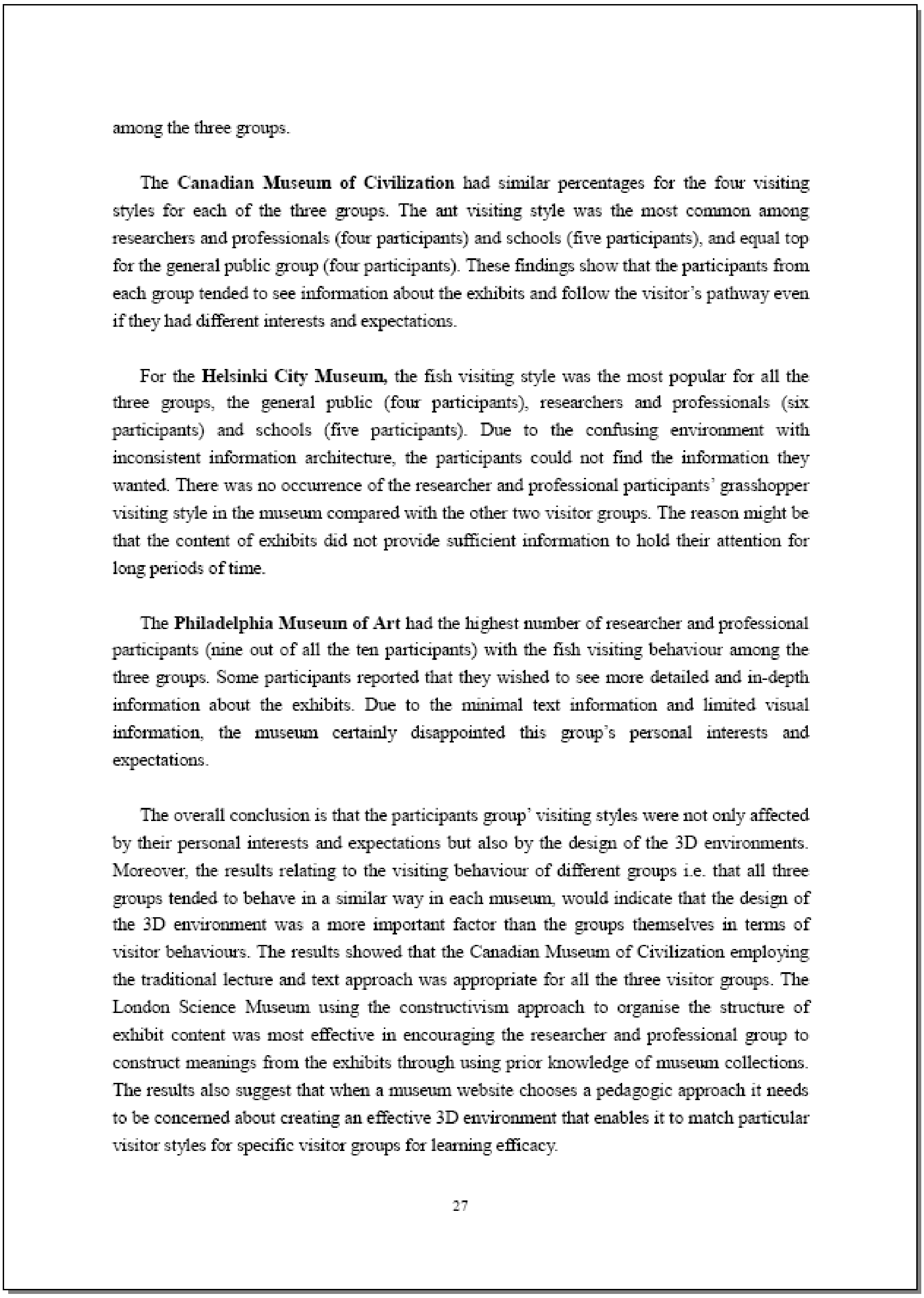


Figure 19 The percentage of schools' visiting styles in the 3D environments

The overall visitor styles for the three visitor groups in the four museum environments are shown in Table 11. The general public had the highest number of fish and grasshopper visiting styles (12 participants each) and closely followed by butterfly visiting style (11 participants). Researcher and professional participants had the highest number of fish visiting style (16 participants). It is noteworthy that this group had a high number of butterfly visiting style (14 participants). This is because this group were interested in detailed and in-depth information about individual exhibits, showing butterfly visiting style. However, without rich information content about exhibits, they rapidly visited exhibits with few stops, exhibiting fish visiting style. The participants of the schools had the highest number of grasshopper visiting style (12 participants), the same as the general public. This is because these two groups tended to view specific exhibits and associated information they were interested in. This result indicated that the different visitor groups' visiting styles were influenced by their motivations (i.e. individual interests and preferences, and expectations), supporting Falk and Dierking (1998) findings that personal interest is one of the major factors which affect a virtual visit to a museum website.

As shown in Table 10, the **London Science Museum** had the highest number of participants from the general public (five participants) and schools (four participants) with a grasshopper visiting style. The participants of these two groups tended to view specific artefacts and associated information for a long time as they were interested in. It is noteworthy that this museum had the highest number of researcher and professional participants (seven out of all the ten participants) with a butterfly style. This group are more knowledgeable about specific aspects of collections of artefacts than the other two visitor groups. The key tenet of the constructivism approach used in the London Science Museum seems to have provided an opportunity to encourage this group to construct the meanings of the exhibits through their pre-existing knowledge. This might be the reason for the highest percentage of researcher and professional participants with a butterfly style in the museum



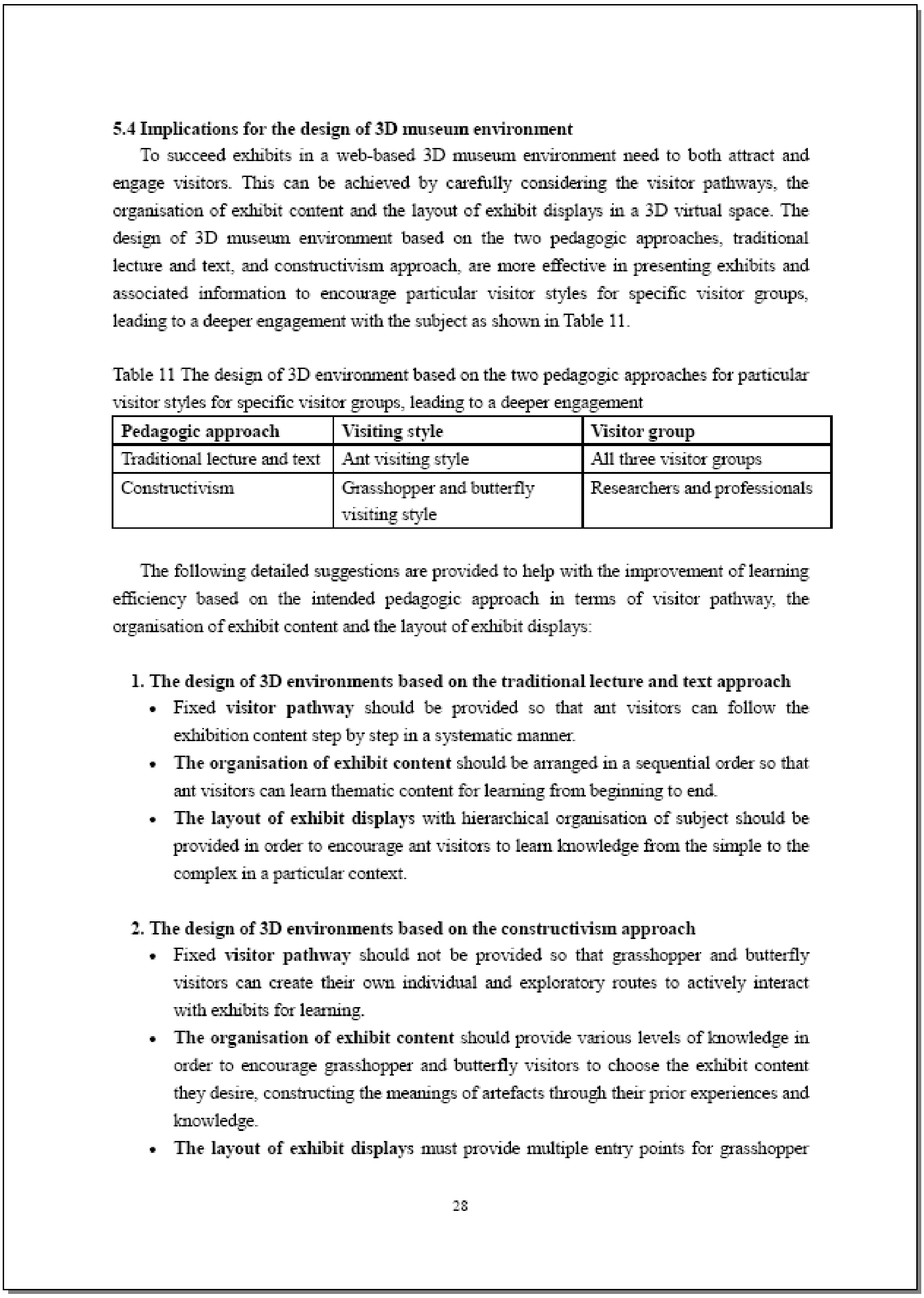
among the three groups.

The **Canadian Museum of Civilization** had similar percentages for the four visiting styles for each of the three groups. The ant visiting style was the most common among researchers and professionals (four participants) and schools (five participants), and equal top for the general public group (four participants). These findings show that the participants from each group tended to see information about the exhibits and follow the visitor's pathway even if they had different interests and expectations.

For the **Helsinki City Museum,** the fish visiting style was the most popular for all the three groups, the general public (four participants), researchers and professionals (six participants) and schools (five participants). Due to the confusing environment with inconsistent information architecture, the participants could not find the information they wanted. There was no occurrence of the researcher and professional participants' grasshopper visiting style in the museum compared with the other two visitor groups. The reason might be that the content of exhibits did not provide sufficient information to hold their attention for long periods of time.

The **Philadelphia Museum of Art** had the highest number of researcher and professional participants (nine out of all the ten participants) with the fish visiting behaviour among the three groups. Some participants reported that they wished to see more detailed and in-depth information about the exhibits. Due to the minimal text information and limited visual information, the museum certainly disappointed this group's personal interests and expectations.

The overall conclusion is that the participants group' visiting styles were not only affected by their personal interests and expectations but also by the design of the 3D environments. Moreover, the results relating to the visiting behaviour of different groups i.e. that all three groups tended to behave in a similar way in each museum, would indicate that the design of the 3D environment was a more important factor than the groups themselves in terms of visitor behaviours. The results showed that the Canadian Museum of Civilization employing the traditional lecture and text approach was appropriate for all the three visitor groups. The London Science Museum using the constructivism approach to organise the structure of exhibit content was most effective in encouraging the researcher and professional group to construct meanings from the exhibits through using prior knowledge of museum collections. The results also suggest that when a museum website chooses a pedagogic approach it needs to be concerned about creating an effective 3D environment that enables it to match particular visitor styles for specific visitor groups for learning efficacy.



5.4 Implications for the design of 3D museum environment

To succeed exhibits in a web-based 3D museum environment need to both attract and engage visitors. This can be achieved by carefully considering the visitor pathways, the organisation of exhibit content and the layout of exhibit displays in a 3D virtual space. The design of 3D museum environment based on the two pedagogic approaches, traditional lecture and text, and constructivism approach, are more effective in presenting exhibits and associated information to encourage particular visitor styles for specific visitor groups, leading to a deeper engagement with the subject as shown in Table 11.

Table 11 The design of 3D environment based on the two pedagogic approaches for particular visitor styles for specific visitor groups, leading to a deeper engagement

Pedagogic approach	**Visiting style**	**Visitor group**
Traditional lecture and text	Ant visiting style	All three visitor groups
Constructivism	Grasshopper and butterfly visiting style	Researchers and professionals

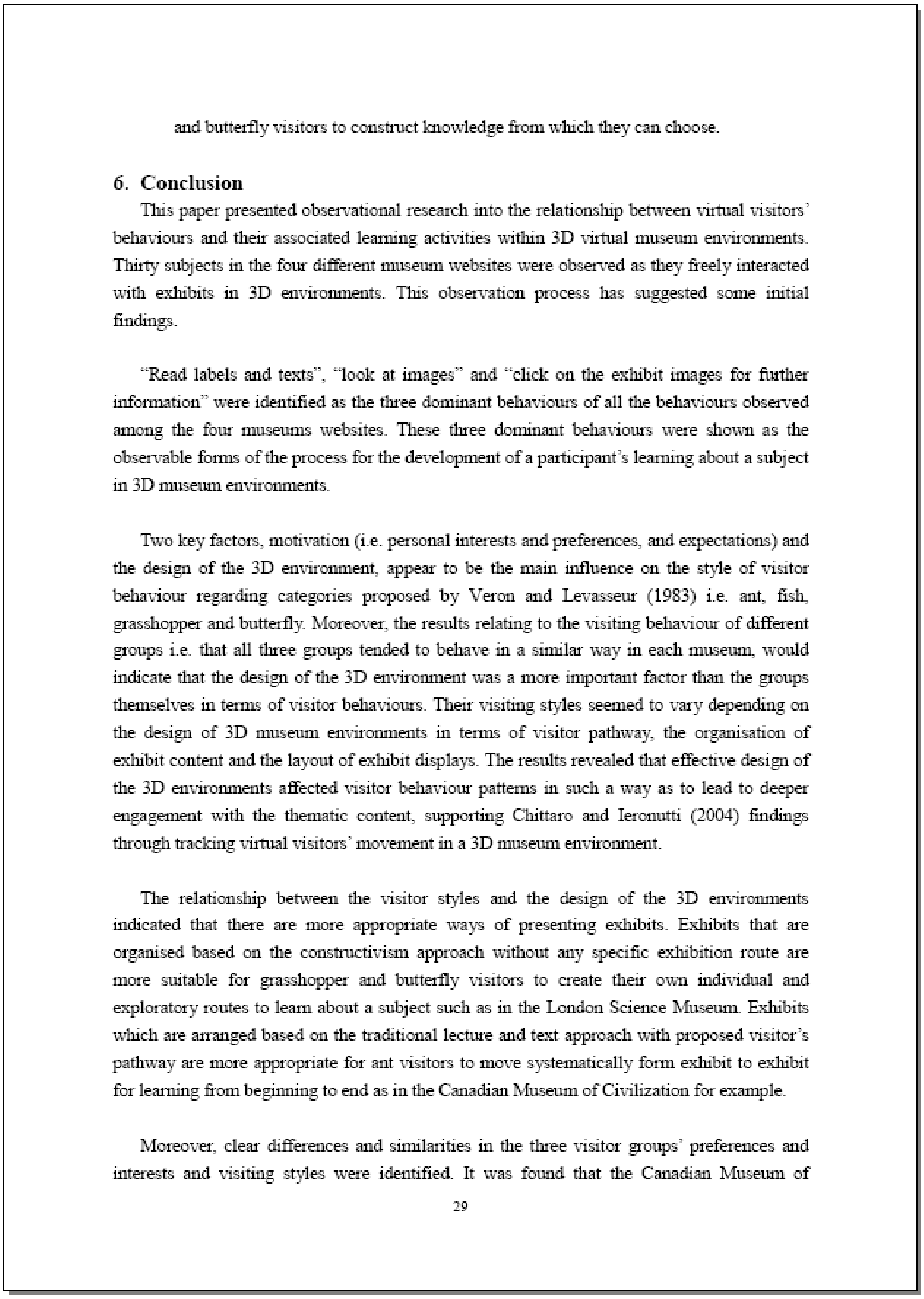
The following detailed suggestions are provided to help with the improvement of learning efficiency based on the intended pedagogic approach in terms of visitor pathway, the organisation of exhibit content and the layout of exhibit displays:

1. The design of 3D environments based on the traditional lecture and text approach

- Fixed **visitor pathway** should be provided so that ant visitors can follow the exhibition content step by step in a systematic manner.
- **The organisation of exhibit content** should be arranged in a sequential order so that ant visitors can learn thematic content for learning from beginning to end.
- **The layout of exhibit displays** with hierarchical organisation of subject should be provided in order to encourage ant visitors to learn knowledge from the simple to the complex in a particular context.

2. The design of 3D environments based on the constructivism approach

- Fixed **visitor pathway** should not be provided so that grasshopper and butterfly visitors can create their own individual and exploratory routes to actively interact with exhibits for learning.
- **The organisation of exhibit content** should provide various levels of knowledge in order to encourage grasshopper and butterfly visitors to choose the exhibit content they desire, constructing the meanings of artefacts through their prior experiences and knowledge.
- **The layout of exhibit displays** must provide multiple entry points for grasshopper



and butterfly visitors to construct knowledge from which they can choose.

6. Conclusion

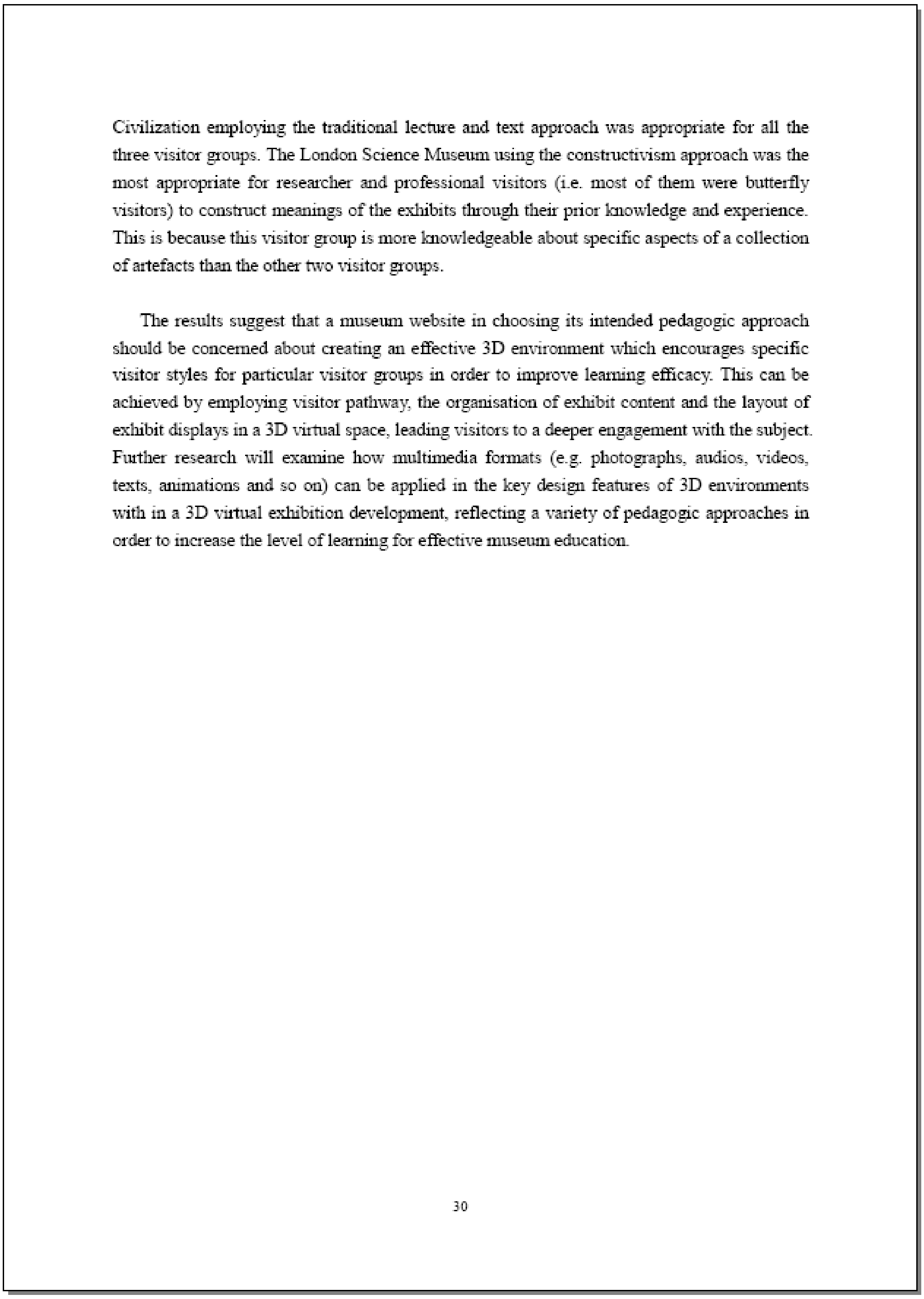
This paper presented observational research into the relationship between virtual visitors' behaviours and their associated learning activities within 3D virtual museum environments. Thirty subjects in the four different museum websites were observed as they freely interacted with exhibits in 3D environments. This observation process has suggested some initial findings.

"Read labels and texts", "look at images" and "click on the exhibit images for further information" were identified as the three dominant behaviours of all the behaviours observed among the four museums websites. These three dominant behaviours were shown as the observable forms of the process for the development of a participant's learning about a subject in 3D museum environments.

Two key factors, motivation (i.e. personal interests and preferences, and expectations) and the design of the 3D environment, appear to be the main influence on the style of visitor behaviour regarding categories proposed by Veron and Levasseur (1983) i.e. ant, fish, grasshopper and butterfly. Moreover, the results relating to the visiting behaviour of different groups i.e. that all three groups tended to behave in a similar way in each museum, would indicate that the design of the 3D environment was a more important factor than the groups themselves in terms of visitor behaviours. Their visiting styles seemed to vary depending on the design of 3D museum environments in terms of visitor pathway, the organisation of exhibit content and the layout of exhibit displays. The results revealed that effective design of the 3D environments affected visitor behaviour patterns in such a way as to lead to deeper engagement with the thematic content, supporting Chittaro and Ieronutti (2004) findings through tracking virtual visitors' movement in a 3D museum environment.

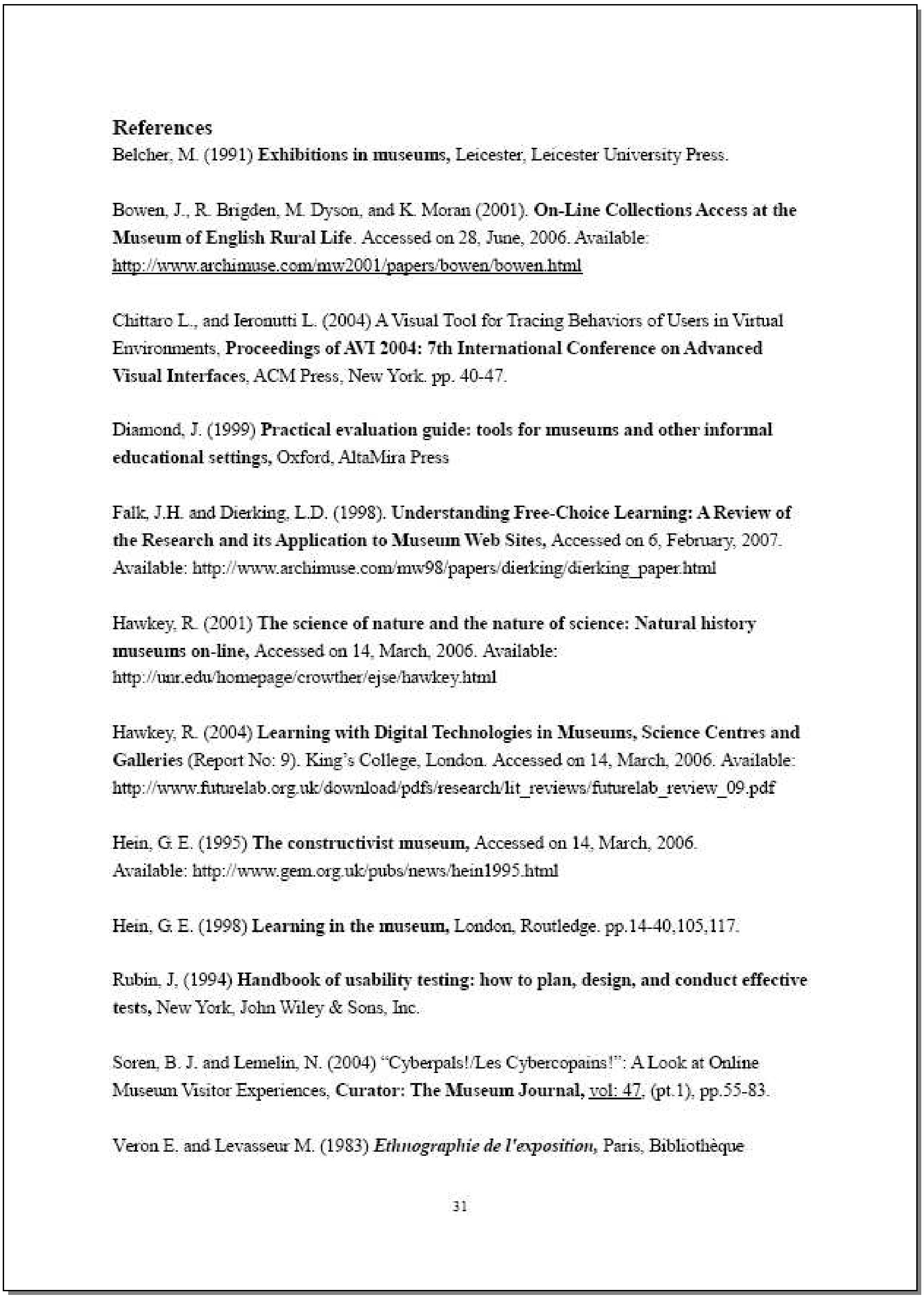
The relationship between the visitor styles and the design of the 3D environments indicated that there are more appropriate ways of presenting exhibits. Exhibits that are organised based on the constructivism approach without any specific exhibition route are more suitable for grasshopper and butterfly visitors to create their own individual and exploratory routes to learn about a subject such as in the London Science Museum. Exhibits which are arranged based on the traditional lecture and text approach with proposed visitor's pathway are more appropriate for ant visitors to move systematically form exhibit to exhibit for learning from beginning to end as in the Canadian Museum of Civilization for example.

Moreover, clear differences and similarities in the three visitor groups' preferences and interests and visiting styles were identified. It was found that the Canadian Museum of



Civilization employing the traditional lecture and text approach was appropriate for all the three visitor groups. The London Science Museum using the constructivism approach was the most appropriate for researcher and professional visitors (i.e. most of them were butterfly visitors) to construct meanings of the exhibits through their prior knowledge and experience. This is because this visitor group is more knowledgeable about specific aspects of a collection of artefacts than the other two visitor groups.

The results suggest that a museum website in choosing its intended pedagogic approach should be concerned about creating an effective 3D environment which encourages specific visitor styles for particular visitor groups in order to improve learning efficacy. This can be achieved by employing visitor pathway, the organisation of exhibit content and the layout of exhibit displays in a 3D virtual space, leading visitors to a deeper engagement with the subject. Further research will examine how multimedia formats (e.g. photographs, audios, videos, texts, animations and so on) can be applied in the key design features of 3D environments with in a 3D virtual exhibition development, reflecting a variety of pedagogic approaches in order to increase the level of learning for effective museum education.



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London 2008 CREATE Design Showcase

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A 3D online virtual environment to improve access to a museum as both a learning and information resource

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Objectives

To propose a theoretical design reference model with emphasis on facilitating the relationship between attraction and holding power of exhibits, visiting styles and the design of the 3D museum environment for learning efficacy.

About the project

This research addresses the relationship between attraction and holding power of the exhibits, visiting styles and the design of 3D museum environments based on pedagogic approaches for learning efficacy.

This model was developed based on the two research findings:

- Attraction levels were highest for the exhibits which employed multiple media formats or 3D model artefacts combined with in-depth interpretive content and information; holding power was highest for the exhibits which used games or videos with high interaction.
- The design of the 3D museum environment (i.e. three key design factors: visitor pathways, the organisation of exhibit content and the layout of exhibit displays) based on the two pedagogic approaches (i.e. traditional lecture and text and constructivism) encourage the related visiting style(s), leading to a deeper engagement (e.g. manipulates exhibits, looks at images, reads labels and texts, etc.) with the thematic content.

The Ergonomics Society
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