Immersive Virtual Environments as Unique Learning Spaces in Museum Education

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ABSTRACT

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Recently there has been a focus on the value and utility of the use of digital technologies in both museums and museum education. Much of this focus has surrounded the use of web-sites and the Internet. However, there is a need to also consider the use of digital technologies on-site within museum walls. Immersive virtual environments are one branch of digital technologies being explored in museums. Therefore their implications for museum education need to be considered, especially in light of the constant change and development of these types of technology. In addition, there needs to be a consideration of possible new approaches to museum education that these technologies allow.

This thesis focuses on an exploration of immersive virtual environments (IVEs) from the perspective of museum education. First, is an exploration of the definitions of IVEs, and a short history of how they developed. Next is an exploration of the defining attributes of IVEs and learning theories that are compatible with and embrace IVEs. Finally, there is a focus on how IVEs offer unique learning spaces in museums and how this relates to meaning making for visitors. This thesis is based on the literature, reviews and original studies of other authors, educators and researchers. What is found is that there are some surprising overlaps in the thus far separate developments of IVEs, museum education and the personal interpretations of museum visitors, which may have significance for further research.

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DEDICATION

For Peking.

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1.0 **INTRODUCTION**

Virtual environments and immersed spaces are changing the way we view our relationship and ourselves to our environments. This in turn will influence the way we interpret our world and how we learn in certain contexts. Technology is in a constant state of flux. The consequence of this flux means that we can't entirely foresee the implications of the use of technology in both museum and educational contexts. One way to guide this is to explore both the meaning of technology in museums and how it is being used in order to change our perceptions of its possibilities. My intention is to explore this, and ideally, to look at museums as a catalyst for including new technology as a pertinent educational and social tool that involves both positive and challenging experiences for the visitor. Also important is engaging the imagination and inspiring an exploration of museum exhibits and technology to facilitate personal learning for the museum visitor.

Many writers state that there is a failure to recognize that new media in museums and other contexts do more than simulate traditional artistic and museum practices (Giaccardi, 2004; Grau, 2004). Digital technologies are a medium in their own right, a new reality for which a new critical and aesthetic language is being developed. There is an inherent difference between what can be called traditional approaches to museum exhibition/education and those that are including the use of new media, particularly immersive environments. To accept this difference as unproblematic and without inquiry would serve to make educators and the museum community at large critically unaware of contemporary issues affecting both museums and museum visitors.

The definition of "new media" includes but is not limited to terms such as virtual reality, interactive media and immersive spaces. In fact, the very term "new media" suggests growing and developing technologies. For the purposes of this study, I will be focusing on the term "immersive virtual environments" to include both virtual reality and interactive media, under the ever-changing umbrella of new media, also referred to as digital technologies. Although definitions are an important part of understanding a phenomenon, there are greater questions to be addressed, some fundamental questions about what new media or digital technologies mean to people, how they will be used, built upon, dispersed to the public, and, how they will enhance education in the museum realm.

These queries are very broad and generalized to be sure, and can be studied from many different disciplines and research approaches. The focus of this investigation, however, centers on the realm of museum education and digital technologies, and more particularly to the point, the use of digital technologies in museum exhibitions. On-line museums and exhibitions are beyond the scope of this thesis.

According to Roy Hawkey, art educator and researcher at Futurelab, a museum research centre in the UK, there is significant debate over the value and utility of digital resources in museums. In consideration of this, he states, "museums are a heterogeneous set of institutions whose original twin functions of scholarship and education, once inseparable, but subsequently divorced, are being reunited by digital technologies" (Hawkey, 2004, pg.

2). This means that the use of digital technologies, in all its forms, offers new approaches to learning "by different audiences and for different purposes" (Hawkey, 2004, pg. 2), in order to re-unite scholarship and museum education.

In light of this, I propose a thesis that considers an overview of the use of digital resources, specifically immersive virtual environments, in theory and in practice. This will be done in order to point towards how museum educators can unite digital technology and education in museums comprehensively and meaningfully for the visitor.

Thus, questions I am exploring in this thesis are "What are the elements of immersive virtual environments? How are they unique learning spaces? What are the possible applications to museum education and to visitors' meaning making in museums?" These questions address and connect the three way interface between digital technology, education and on-site museums, as there has been little to no research or writings that accomplish this.

1.1 Scope of this thesis

This thesis considers the aspects of learning provided by museums and galleries through the use of immersive virtual environments (IVEs) on-site. It does not consider the use of digital technologies in other areas of the museum sector or other types of digital resources for education such as audio guides, web-sites, podcasts, etc. In addition, the focus of this thesis is on the unique aspects of IVEs that can be used in on-site museum education, but does not focus on a particular type of museum, nor a particular age group.

In addition, there are many important factors in museum education such as visitor population and access to museums, visitor research and evaluation, educator training and so forth. However, as important as these aspects are, this thesis is very specifically focused on the relationship between IVEs and museum education and learning as there is very little research that explores these intersections.

Definitions of "museum" and "gallery" in this thesis are broad and generalized. Hawkey (2004) recognizes that "the museum is not a single, homogeneous entity, but a diverse range of institutions" (pg. 8).

The differences between theories of learning and theories of knowledge are acknowledged, but the focus is on the application of learning theories within IVEs and museums. As for a definition of learning, I espouse this:

> Learning is a process of active engagement with experience. It is what people do when they want to make sense of the world. It may involve the development or deepening of skills, knowledge, understanding, awareness, values, ideas and feelings, or an increase in the capacity to reflect. Effective learning leads to change, development and the desire to learn more. (CLMG 2000).

In addition, although theories in technological education have a grounded history with many nuances that are not covered here, I have used some of these theories as a guide in informing the use of IVEs in a museum education setting. As much of the research that I

have found in this area comes from scientific dialogue and researchers, there is an unavoidable bias inherent in the source literature.

This thesis is divided into several categories. First, is an exploration of the definitions of IVEs, and a short history of how they developed. Next is an exploration of the defining attributes of IVEs and learning theories that are compatible with and embrace IVEs. Finally, there is a focus on how IVEs are unique learning spaces in museums and how this relates to meaning making for visitors.

1.2 Discussion

My interest in this topic originated with my interest in museums and education within these museums. This interest grew out of personal experience with museum exhibitions as a visitor and as a museum educator, in addition to the observation of others when dealing with digital technologies in museum settings. Often I felt that these technologies offered some novelty and amusement, but wondered how this could become something more- experientially, and more to the point- educationally.

Museum scholar, educator and researcher, George Hein, has also touched upon this point in *Learning in Museums* (1998). To paraphrase, he discusses how, museums, offering experience and quite often novelty for the visitor, are bound to contain educational potential. When using digital technologies, there is an additional novelty that can draw the visitor into the exhibition, yet the educational potential derived from this attraction is based on the personal meanings visitors attach to the experience. What this experience

means to each visitor is as diverse and individual as the visitors themselves (Hooper-Greenhill, 2003; Hein, 1998). In addition, the novelty of the museum experience (Hein, 1998) can easily translate into an engagement with the exploration and adventure of museum exhibits. With the addition of the novelty of digital technologies in museum exhibitions, it is the responsibility of the educators who work there to use this novelty to offer avenues for different types of experiences for the visitor. The use of digital technologies and immersive environments broadens these avenues of experience considerably.

In addition to the increasing use of digital technologies, currently many museums across North America and Europe use a constructivist approach in their educational mandate (Hawkey, 2004; Hooper-Greenhill, 1995; Hein, 1994, 1995, 1998). What a constructivist approach means is that learning is actively constructed and assimilated into existing structures by the learner rather than passively absorbed..... that is, knowledge is not independent of the learner but rather constructed by the learner using his/her ideas and experiences (Hawkey, 2004; Hein, 1995, 1998). Therefore, from a constructivist viewpoint, museums as learning institutions can serve as interpreters of culture by critically examining how their exhibitions and programs are contextualized and presented to the public (Hein, 1998). This is done in order to offer visitors a range of experiences from which to build personal meaning and knowledge. Ideally, this will result in challenging experiences that engage visitor's imaginations and inspire an exploration of exhibitions. To summarize both these points, novelty draws the visitor into an experience, and from a constructivist viewpoint, education and experience are inextricably linked.

When we combine constructivism, the critical examination of the museum as an institution, and visitor experience with the expansive growth in the use of digital technologies both on-site (i.e. the museum), and off-site (i.e. the world wide web), this provide(s):

> a number of challenges for educators and curators at the heart of which is the question of what is distinctive about learning in museums and how this might change or evolve through the increasing use of digital technologies (Hawkey, 2004, pg. 1).

One branch of the many forms of digital technologies that contribute to the evolution of learning in museums is known as immersive virtual environments.

2.0 WHAT ARE IMMERSIVE VIRTUAL ENVIRONMENTS?

These types of environments are a set of emerging electronic technologies, with applications in a wide range of fields (McLellan 2004; Hawkey, 2004). Often, researchers use the terms Virtual Reality (VR), Virtual Environment (VE) and Immersive Virtual Reality (IVE) interchangeably. The term "reality" can be misleading, and so the term Immersive Virtual Environment (IVE) will be used in this thesis. Virtual Environment researcher, Benjamin C. Lok (2004), states that "Immersive Virtual Environments are broadly defined as systems that allow participants to experience interactive computer generated worlds from a first person perspective as opposed to pre-rendered videos, movies, or animations" (pg. 49). McLellan, (2004) uses this definition:

> A class of computer controlled multi-sensory communication technologies that allow more intuitive interactions with data and involve human senses in new ways. Virtual reality can also be defined as an environment created by the computer in which the user feels present. This technology was devised to enable people to deal with information more easily (pg. 461).

According to Oliver Grau (2004), art-historical scholar and researcher, these are environments that use "simulated stereophonic sound, tactile and/or haptic impressions, thermo-receptive and/or kinesthetic sensations, [which] combine to convey to the observer the illusion of being in a complex structure space, producing the most intensive feeling of immersion possible" (pg. 16). McLellan (2004) breaks down tactile and haptic senses of touch thus, "tactile feedback [is] passive touch, feeling surfaces and textures,

and haptic feedback [is] active touch, where there is a sense of force feedback, pressure or resistance" (pg. 462).

A sense of locomotion is another important attribute of immersive virtual environments (IVEs). In an IVE, the participant has the sense of free movement and multiple points of view, and this natural locomotion changes the point of view rather than relying solely on interface devices such as a mouse or keyboard (Lok, 2004; McLellan, 2004).

It must be remembered that as computer-generated environments, IVEs are essentially in their infancy, but are rapidly evolving. However, the use of immersive spaces has a long precedent in history, well before the introduction of computer generated media.

2.1 *Historical Background*

Although VR and IVEs seem to be a very recent phenomenon, they actually have a long-standing historical grounding (Grau, 2004) and have only recently engaged the use of digital media. For example, in *Virtual Art: from Illusion to Immersion,* Grau (2004) reviews the history and development of illusion and immersion to point out how illusionary visual space can be traced back to antiquity. Examples of historic immersive/illusionary environments include the larger than life murals of Pompeii, where frescoes "address the observer from all sides in a unity of time and place, enclosing him or her hermetically. This creates an illusion of "being *in the picture* (his emphasis), inside an image space and its illusionary events" (Grau, 2004, pg. 25). He illustrates this by an example of The Great Frieze of the Villa dei Misteri at Pompeii (60 B.C.). This frieze

depicts images related to the cult of Dionysius in which highly realistic, life size figures on the four walls surrounding the chamber almost entirely fill the observer's field of vision. "The overall effect is to break down barriers between the observer and what is happening in the images on the walls" (Grau, 2004, pg. 25).

Another example given by Grau is that of the panorama, a process developed by Irishman Robert Barker in 1787. These were large circular views in correct perspective, and when viewed from a central and elevated platform "appeared to be true and undistorted" (pg. 56). In a panorama, the observer is "installed *in* the picture", (pg. 57) and this pictorial space is concerned with the representation of nature in the service of an illusion. The purpose is to create the effect of being in a real landscape through a 360 degree illusion space, an innovation that revolutionized the image in the 18th century and beyond (Grau, 2004).

The first example, the Great Frieze at Pompeii, was intended, according to Grau (2004) to "bring gods and humans together on the same pictorial level" (pg. 25). The second example, the panorama, develops the use of panoramic rotundas, particularly in light of military occupation and propaganda. These examples show a critical examination of why illusory/immersive environments are used. In present day, it is not only what makes the addition of the use of digital technologies in immersive environments unique, but the purpose behind this use (Grau, 2004). There is the question of why, today, these illusionary spaces are being created, and for the sake of this study, what purpose or meaning they have in museum education.

More recently, "the technology that has led up to virtual reality technology- computer graphics, simulation, human computer interfaces, etc.- has been developing and coalescing for over three decades" (McLellan, 2004, pg. 462). Head mounted displays (HMDs) and mechanical virtual reality devices, that included 3-D visuals, movement, and even smells (McLellan, 2004) were being developed in the 1960's. Although not commercial successes, McLellan states that these beginning attempts showed great vision.

However, because of the confines of the computer and media technologies at the time, virtual reality had a start-stop process in its evolution over the decades between the 1960's to the 1980's. NASA, in the mid-1980's, developed a breakthrough project using both a HMD and a wired glove that developed ways in which astronauts could simulate "the environments and the procedures [that] would be engaged in during space flights" (McLellan, 2004, pg. 462). Great excitement about the technology became widespread in the 1980's and 90's, but because of the expense and technical problems, interest dwindled as the World Wide Web developed, which met broader, and less expensive, expectations (McLellan, 2004).

In the end, it was medical, military and engineering needs that drove new advances in the technology (McLellan, 2004). This was based mostly on the need for remote access to other computer generated environments, also known as "telepresence", which simply put, is the ability for the participant to feel and act as though they are somewhere else (Grau, 2004; McLellan, 2004). According to McLellan (2004), "the 1990's saw a paradigm shift to projective displays that keep viewers in their natural environment" (pg. 462).

2.2 Different kinds of IVEs:

Thurman and Mattoon (1994) present a model for differentiating between different types of VR. Their model helps to identify different types of virtual reality "based on how closely the application corresponds to physical reality" (pg. 57).

The two end points of the spectrum, what they refer to as the "verity dimension"- physical and abstract- describe the degree that a VR and entities within the virtual environment have the characteristics of reality, between real world counterparts and completely novel environments that may not resemble the real world at all (Thurman, Matoon, 1994).

Physical: _____ Abstract:

Correspondence to Physical Laws	Telepresence	Alternative Realities	Novel Environments

(Verity Scale adapted from Thomas and Matoon, 1994)

Although there have been many classification schemes put forth by VE researchers (McLellan, 2004), I have found there to be, broadly, three types of immersive virtual environments. They include:

2.3 *Completely Virtual:*

As previously outlined by Grau (2004), Lok (2004) and McLellan (2004) the type of IVE that is most commonly conceived of is one that is completely "virtual". Everything in the environment is computer generated, from objects to sensory stimuli. McLellan (2004) defines this type of IVE as "immersive first-person... where the viewer is placed inside the image; the generated image is assigned properties which make it look and act real in terms of visual perception and in some cases aural and tactile perception"(pg. 464).

Computer interface devices commonly associated with this type of IVE are "head-mounted display (HMD), fiber-optic wired gloves, position tracking devices, and audio systems providing 3-D (bin-aural) sound" (McLellan, 2004, pg. 464). However, as previously stated, there is rapid growth and evolution with this type of technology, as different software and interfaces are developed, many of these interfaces will be replaced by less cumbersome devices.

2.4 *Augmented Reality:*

Augmented reality is a type of IVE that "supplements reality rather than completely replacing it. Virtual and real objects co-exist in the same space" (Azuma, 1997). Basically, this is a type of technology where virtual objects are superimposed over the real world by using interfaces that allow the viewer to see both the virtual objects and the real-world surroundings using, for example, special goggles or hand-held devices (Azuma, 1997, 1999; Lok, 2004; McLellan, 2004). This is done in order to "highlight certain features and enhance understanding. Augmented reality is about augmentation of

human perception: supplying information not ordinarily detectable by human senses" (Azuma, 1999).

This type of immersive virtual environment (IVE) is used mostly as a training tool, for example, highlighting the controls needed to land an airplane, or superimposing information over the human body in medical operations in order for the doctor to more clearly see the site of the operation more effectively (McLellan, 2004).

2.5 *Mixed-Reality or Hybrid IVEs:*

Although, somewhat confusingly, closely related to Augmented Reality, Mixed-Reality or Hybrid Immersive Virtual spaces include some real objects for manipulation into a mostly virtual environment, as opposed to superimposing virtual elements onto real environments (Lok, 2004). In this way, they are like the two sides of a coin, but meet specifically different needs. In Augmented Reality, the goal is to heighten human senses or awareness in a real environment, in Hybrid IVEs, the goal is to allow more dynamic interaction with objects in Virtual Environments. This is accomplished by the VE program using tracking devices on real world objects, and implementing them into a virtual environment in real time (Lok, 2004). This is to avoid the issue of having to track and elucidate every possible action or use of a real world object and make it virtual, by creating programs that recognize the real world object as it is actually used. Again, this is used mostly for training purposes, such as estimating the space needed for difficult NASA procedures (Lok, 2004), using real objects that are incorporated into a virtual shuttle cockpit. Lok, (2004), explains it thus, "A hybrid environment system that merges dynamic real objects with virtual objects would improve VE interactivity and effectiveness. It

would also allow participants to see themselves, along with tools and parts, incorporated into the VE" (pg. 52).

To clarify further, in a real world operation, the surgeon may need the superimposition of neurological mapping onto a human brain during the operation, rather than exploring the mapping in a computer generated environment before the operation. This is Augmented Reality. In Hybrid or Mixed Reality design, an astronaut may need the use of real tools (wrenches, screwdrivers) in a virtual environment (i.e. virtual cockpit) to get a better sense of possible scenarios in the actual shuttle mission. This allows for better design of the cockpit before the launch. Augmented reality is tied to "as it happens" and Hybrid reality, "as it may happen".

3.0 **DEFINING ELEMENTS OF IVEs**

Although it is important to have a general understanding of the development and history of IVEs, and the various forms they can take, *it is important to recognize that the current technologies in IVEs are time-bound.* That is, as research by various disciplines continues, the specific discussion of interface types, such as HMDs, become less important (in applicable, real situation contexts), and the underlying principles of IVEs become more important, particularly in learning contexts.

As these technologies continue to develop, and are implemented in daily life, (the WII, Home Décor programs, etc.), the ever changing hardware, software and interface devices take a back seat to how these technologies actually affect people and their perception of the world around them.

As has been pointed out previously by such authors and researchers as Azuma (1997, 1999), Grau (2004), Lok (2004), and McLellan (2004), the core attributes of IVEs, whether stated implicitly or explicitly, are presence, immersion, and interaction.

IVEs typically seek to elicit a sense of presence, or "being there". According to Lok (2004), this is accomplished "By physically immersing participants, approximating the sensory information of their real world experience and relying on their own direct experience" (pg. 50).

McLellan (2004) continues, stating that "The sense of presence or immersion is a critical feature distinguishing virtual reality from other types of computer applications" (pg. 463).

All of these definitions state some type of presence, immersion, and interaction. Most closely linked are the ideas of presence and immersion, the feelings of "being there" and able to react "there", yet, as I surmise, this would not be functionally capable if one could not also "interact there". That is, the IVE, much like its real world counterpart, needs to react to the user's input.

3.1 *Presence:*

Grau's description of presence in immersive environments is that these environments address "as many senses as possible to the highest possible degree with illusionary information via a "natural", "intuitive", and "physically intimate" interface" (Grau, 2004, pg.15) and further, "it is to give the viewer the strongest impression possible of being at the location where the images are. This requires the most exact adaptation of illusionary information to the physiological disposition of the human senses" (Grau, 2004, pg. 14). Cognitive researchers and psychologists Singer and Witmer (1998) define presence as the "subjective experience of being in one place or environment, even when one is physically situated in another, and applied to virtual environments, refers to experiencing the computer generated environment rather than the actual physical locale" (pg. 225).

The idea of presence is important to the ideas of immersive spaces because it focuses on the mental processes of attention and mental models of virtual space, and in essence informs how we perceive these environments. Singer and Witmer (1998) continue, stating that "presence is a normal awareness phenomenon that requires directed attention and is based in the interaction between sensory stimulation, environmental factors that

encourage involvement and enable immersion and internal tendencies to become involved" (pg. 225).

Also, they developed questionnaires in order to determine what aspects of a virtual environment (VE) contribute to the experience of presence. What they found was that interaction, or user control, affects immersion and is essential for a strong sense of presence. Thus, user control over an experience in a VE can help users to perceive themselves to be inside the computer generated world, and thus, they experience that world directly, making the experience more meaningful (Singer & Witmer, 1998). What can be learned from this study and from observations by Grau (2004) is that the feeling of presence can occur through a combination of poly-sensorality, immersion, and interaction.

These aspects of presence can aid museum educators in the use of immersive environments and other digital technologies by recognizing and using these elements and to aid in learning and user experience. In addition these elements are not isolated, but work in tandem. These differing elements will be discussed further after describing the concept of presence more completely.

Although presence is, basically, the feeling of "being there", there are many ways in which this can occur. Presence is not exclusive to computer mediated environments such as an immersive virtual environment. It can happen when you are watching a movie, reading an involving book, listening to a good story, or even getting lost in an absorbing art work. For presence to happen you must be allowed, or afforded, by the environment

and your imagination/inclination to feel immersed in what you are looking at, reading, hearing, feeling, touching etc. Presence is reliant on a multitude of important elements, most significantly, immersion and interaction. These are elements that work in tandem. For presence to occur in an IVE, all of these elements need to be present. An IVE allows all of these to happen together, but ultimately, it is up to the participant to provide the suspension of disbelief and at "some level, and to some degree [have] his/her perceptions overlook [the technology] [so] the environments are perceived as if the technology was not involved in the experience" (Lombard, 2000, Resources for the study of presence: Presence explication).

Presence is a normal awareness phenomenon that requires directed attention and is based in the interaction between sensory stimulation, environmental factors that encourage involvement, enable immersion and motivate a person's internal tendencies to become involved. Steuer (1992), states that presence is the central goal of virtual reality, perhaps the defining feature. According to a survey on presence conducted by Scheumie et al. (2001), presence is: subjective, social, experiential, first person, involved, exclusive, technologically mediated, ecological, embodied and interactive, amongst many other definitions.

Thus, we can say that there are many differing theories on presence. Mantovani and Riva (1999), psychology and IVE researchers, state that definitions of presence come from the ontological view of the researchers involved. They begin their argument by stating that the meaning of presence is closely linked to the concept that each researcher has of

reality, the researcher's own ontology. The most common approach that most VR/IVE researchers and developers take into account is what is known as *physical presence* which is concrete and object based. This is opposed to *subjective presence*, which is the personal perception of being located in the same physical space as a certain event, a certain process, or where a certain person stands. Thus, a "realistic" view of presence is that subjective experience is only verified next to objective criteria, that it involves concrete, objective interaction and is mainly dependent on successfully completing a specified task, not on the user's perceptions and experiences.

However, Mantovani and Riva (1999) have three major objections to the definition of presence presented above. First, is the assumption that experiencing presence is essentially physical (the user interacts with an object). Second, they ascertain that not all everyday realities are the same. In their view, these are mediated by the context in which they are inserted. This includes the use of how technology is used in any given situation because they feel that technology is an important expression of cultural mediation. Third, they state that this approach includes a model of objective interaction where the "Communication model is a passage of information from one person to another, and does not take into account a co-operative component where there is reciprocal responsibility for successful interaction" (Mantovani & Riva, 1999, pg. 4).

This is an important point, because it shows that in the realistic, objective view, knowledge is separated from communication. Knowledge is viewed as an object that exists independently of the participants.

Ultimately, Mantovani and Riva feel that virtual reality, (and in my terms, IVEs) may serve as an effective tool to promote cooperation and communication. In opposition to the "reality" or objective based view of what defines presence, these authors propose a concept of presence as a social construction. They state:

> Reality is not outside escaping social interchange and cultural mediation, it is continually negotiated and filtered by artifacts, by means of which we adapt the environment to our needs and at the same time adapt ourselves to the environment in order to exploit the affordances they offer us (Mantovani & Riva, 1999, pg. 4).

Briefly, affordances are the possibilities or opportunities that the environment offers or affords, i.e., a ground affords walking or standing, a door knob affords turning. We will return to affordances later. These authors then outline three ontological perspectives on presence which are arranged hierarchically. Each will be discussed in turn below. They are: 1) Ingenuous realism, 2) The ecological perspective, and 3) The social constructionism perspective.

1) Ingenuous realism: In this view, presence falls under the *rationalistic tradition*- reality is a set of objects located outside the mind, and has a set of well-defined characteristics. "Ingenuous realism contains an ontological position which states what reality is- meaning that in ingenuous realism, knowledge is limited to perceiving a pre-existing reality". Yet, these authors believe it would be "more suitable to avoid the idea that "real" objects exist

outside of social actors, and that "virtual" mediated objects are less real because they only exist in peoples heads" (Ibid, pg.7).

2) Ecological perspective: The ecological approach relies heavily on the research of psychologist J. Gibson (1986). Mostly concerned with bio-evolution, Gibson explores the circular relationship between organisms and the environment, "namely that the environment has provided conditions that are commensurate with the organisms evolution" (Zahoric & Jenison, 1998, pg. 83). In Gibson's view, valid perception is that which allows affordances, which may differ from one organism to another. Mantovani and Riva (1999) point out "valid perception for every specific individual-environmental relation is what makes possible successful action in the environment (within the context of the relation)" (pg. 8) which differs from ingenuous realism.

This relates to presence, because in this view, presence is equivalent to successfully supported action in the environment. Scheumie et al (2001) also speak of affordances, which are the possibilities that the environment offers. Also citing the research of Gibson, these authors speak of "perception-action" coupling, which means that an organism perceives its environment in terms of its affordances, making perception dependent on possible action, thus, the coupling. How this is clearly related to presence is that through affordance, tools become "ready to hand", the user is no longer aware of the tool itself, but only the action of the tool in whatever task is performed. In an IVE, this happens through the perception the user has of the VE equipment and what can be done with it- the mediating technology itself will eventually become "ready to hand" and the user is

less aware of it. Thus, as these authors state, "Successfully supported actions in an environment will lead one to perceive oneself as existing in that environment to a sense of presence" (Scheumie et al., pg. 186).

Mantovani and Riva (1999) point out that the ecological approach shifts focus away from producing the faithfulness of "reality" through primarily visual means, to other possible interactions that VR environments allow. They state that the sensation of presence depends on the level of interaction/interactivity which users have in these environments, which also calls for a certain amount of freedom of movement. This allows the user to be able to adapt smoothly to the needs of the changing environment. "In this approach, the reality of experience is defined relative to functionality, rather than to appearances...it proposes a relational concept of presence..[with] the centrality of action."(Mantovini & Riva, pg. 10).

3) Social Constructionism: This centrality of action becomes the emergent principle in Mantovani and Riva's personal viewpoints on the ontology of presence. Contesting ingenuous realism, and building on the ecological perspective, they developed the "Presence of social construction: the cultural perspective" (Mantovani & Riva, 1999, pg. 11). In their view, action in everyday situations is not made up of movements from a single individual, but is part of social dynamics where certain goals are the aim of both the individual and the collective. These authors propose a definition of presence that develops the ecological approach but: a) recognizes the mediated character of every possible experience of presence, b) conceives experience as immersed in a social context;

c) emphasizes the component of ambiguity inherent in everyday situations; and d) highlights the function of clarification of which culture (artifacts and principles) plays. In these authors' view, there are only two elements which guarantee presence: a cultural framework, and the possibility of negotiation, of both actions and their meaning.

Mantovani and Riva (1999) conclude by stating that ingenuous realism, which tries to mimic the external reality outside of an IVE, hinders the potentials of these systems. Instead, the ecological approach is a liberating alternative to this, promoting a more productive vision of presence from the viewpoint of possible simulations. The authors' cultural perspective of presence takes this one step further, founding it on a vision of social constructionism, which rejects the duality of subjective vs. objective approaches to the definition of presence. Instead, the social constructionism view, rather than faithfully trying to mimic (objective) reality, is based instead on shared social meanings.

Riva, with other authors, Loreti, Lunghi, Vatalaro and Davide, developed the social constructionism view of presence further (Riva, et al., 2003). Although these authors' main concern is with the development of Ambient Intelligence, which is a more ubiquitous type of technology, their evolution of the concept of presence is equally applicable to IVEs.

What these authors point out is that a general definition of presence as "being there" is somewhat limited. They state:

> Presence is not simply a 'sense of being there' that might be assessed in a questionnaire, however long, complex and validated the questionnaire- it is the

> *total response* (italics in the original) to being in a place, and to being in a place with other people. To use it as a definition or a starting point is a category error: somewhat like defining humor in terms of a smile (Riva, et. al, 2003, pg. 61).

What these authors propose instead as a definition is "making sense there", a simple yet vital distinction from the definitions put forth by other researchers. This involves the study of presence by analyzing the "user/s interaction with and within the synthetic environment including all the different aspects: the social relationships established and the physical and symbolic resources exploited" (Riva, et. al, 2003, pg. 62).

This builds on the social constructionism point of view by including not only the social and cultural aspects of understanding and environment, but also what the environment affords the user; how the user can make sense of the environment. Riva et al. (2003) state that Information Technology (IT) is shifting away from focusing solely on the computer, to the user. In this way, IVEs are not simply reduced to a collection of hardware. Instead, IVEs are the leading edge of the "general evolution of present communication interfaces like telephone, television and computers" (Riva, et. al, 2003, pg. 77). They state that the ultimate objective of this evolution is the full immersion of the user's sensory channels into a vivid communication experience. Further, the possibility of experiencing presence is strongly related to the possibility of defining a context. This must provide orientive information as well as an account of the events that occurred. In particular, "the events must be embedded within an appropriate spatial temporal context." (Riva et. al, 2003, pg. 77).

In the terms of context, virtual reality and immersive virtual environments are a hybrid technology with two faces: a symbolic communication system and a simulation tool. Riva et al. (2003) state that the main characteristic of the sense of presence is its hybridity. This occurs through a careful balance of simulation and symbolic communication. Also, rather than making a distinction about a dualistic approach to the definition, subjective vs. objective, they state that there are very good reasons some virtual environments (IVEs) seek to emulate reality closely, such as military training. Other IVEs however, function very much as symbolic systems where "simulation is less important than the connotation of meaning" (Riva et. al, 2003, pg. 78) such as in virtual artworks or games. Symbol systems in IVEs will be explored further in the learning theories section.

Thus, Riva et al. state that it is clear that the sense of "being there" covers only the simulation side of a sense of presence:

> *To be "present" in the context offered by a symbolic system, the user has to be aware of its meaning* (italics in the original). Only "making sense there", the user really experiences a full sense of presence (2003, pg. 79).

To summarize, it is clear that the concept of presence is multifaceted. There are those that seek to define it in "objective" "rationalistic" terms, and others who prefer to use a more subjective approach. As stated by Manotvani and Riva (1999), these definitions are based on the ontological perspective of the researcher- what the researcher sees as being "real". For the purposes of this thesis, I will be advocating the ecological approach (Gibson,

1986; Mantovani & Riva; 1999; Scheumie et al. 2001), and most importantly, the "making sense there" definition (Riva et al., 2003) when I speak of presence. The reason for this is that these approaches consider the use of IVEs as experiential devices that aid in constructing knowledge, rather than solely as devices that can mimic reality with the sole aim of task completion and empirical research. This is important, as these ontological approaches converge with the theories of constructivist learning, which is the learning approach being explored in this thesis.

Even within the ecological and social construction theories of presence and "making sense there", there are some key underlying factors to how and why presence occurs. Both involvement/interaction and immersion are thought to be necessary for experiencing presence (Scheumie et al., 2001). Presence, immersion, and involvement are all considered psychological states (Witmer & Singer, 1998) that need to occur for the user to truly experience the environment. Beyond the overarching importance of these three elements, there are other elements and psychological states that play a role in the development of presence. They are outlined below.

3.2 *Other Factors in the development of presence*

While all of the previous definitions of presence, it must be noted, have specific applications to the aims of specific research groups in varying disciplines, there are some core attributes of presence that reside in each. They are: the level of attention to the environment, ambiguity, affordance by the environment, poly-sensorality, and ultimately, immersion and involvement/interaction, which will be dealt with in their own sections.

Attention:

Attention in a virtual environment (VE), like many attributes of presence, can be seen as a psychological state (Scheumie et al., 1998). These authors state it is presence as involvement; "a psychological state experienced as a consequence of focusing one's attention on a coherent set of stimuli or related activities and events" (pg. 185). Witmer and Singer (1998) speak about attention in presence as the need for broad focus. Focus is important to a sense of presence because this determines the extent to which users will become involved in the environment. According to Witmer and Singer, the novelty of the experience of being in an IVE is an important factor in developing focus and attention. "when experiencing a novel environment, people are typically more aroused and broadly focused on the tasks to be performed or the situation to be experienced" (1998, pg. 226). Broad focus, according to these authors, allows the user to be extensively focused on the environment and the task at hand. They continue, stating that novelty, immediacy, and uniqueness of a VE experience requires the broad focusing of attention on all aspects of the environment. Witmer and Singer make a very meaningful statement:

> Experience of presence is based in attention to continuities, connectedness, and coherence of the stimulus flow. The coherence of the VE characteristics and stimuli thus enables the focusing of attention, but does not force that on the experiencer. This concept of enabling without forcing distinguishes the experience of presence from the factors that typically support the experience. (Witmer & Singer 1998, pg. 226).

Thus, attention in a VE allows presence through a heightened awareness and focus that allows the user to become more involved in the environment. Novelty and uniqueness aid in the heightened awareness, but ultimately it is up to the user how much attention they are willing to give. It is important that the level of attention is not forced, but is the user's choice, that is, the environment enables the user to focus attention at his/her own discretion.

Ambiguity:

Mantovani and Riva (1999) state that an unavoidable feature of everyday situations is ambiguity. This ambiguity lies in the characteristics of an encounter between "the changing interests of the actor and the equally changing affordances offered by the environment" (Mantovani & Riva, 1999, pg. 12). This ambiguity also exists in virtual environments. From their social constructionism point of view, Mantovani and Riva state that culture (artifacts and principles) is the device which societies use to reduce ambiguity inherent in everyday situations. To communicate and cooperate more effectively, both within and without of virtual environments, there needs to be a frame of reference that exists among participants. This frame of reference is made up of artifacts

and principles from a shared culture or context. Their point is, that although "this ambiguity does not disappear,... it may be better managed by the social negotiation of the meaning of situations and accomplished acts" (Mantovani & Riva, 1999, pg. 13). That is, using shared meanings, social actors can navigate through uncertainty in different situations.

Riva et al., (2003) use a similar approach to their explanation of ambiguity, which they call uncertainty. They state when something doesn't fit in a given setting, this causes a meaning breakdown. "This requires a sense making process to turn the oddity into something familiar and manageable."(Riva et al., 2003, pg. 78). In their view, sense-making is a process where people, individually or in groups, and within a given symbolic system, negotiate the meaning of situations around them. They use the term "negotiate" to mean a process of progressive discovery, and like Mantovani and Riva (1999), the easiest way to do this is through a shared context of meaning.

Even assuming that most users of a particular virtual environment have shared social meanings, which will not always be likely, it is the process of discovering and making sense of the environment that allows the navigation of uncertainty. This is closely related to the concept of affordances, which is less concerned with shared social meaning, and more concerned with perception.

Affordance:

Although affordance has been addressed previously in its relation to presence within the ecological perspective, I believe it warrants its own section. As has been mentioned previously, affordance is the possibilities or opportunities that the environment offers or

affords. Affordance is based on perception. Perception in an IVE is dependent on the context of the environment, that is, what surrounds the user gives the user the cues needed to interact successfully in that environment. In addition, within the ontological view that presence is "making sense there", perception is an active, not a passive process. Perception systems (visual, audio, tactile, locomotion, etc.) enable us to navigate and handle the world. This is not just objective vs. subjective, but that the affordances in both non-computer mediated environments and computer-mediated environments allow users to perceive themselves and the context they are in, and the possible actions they can complete.

McLellan (2004), a librarian and VR researcher, citing Gibson (1986), explains that "Gibson hypothesized that by observing one's own capacity for visual, manipulative, and locomotor interaction with environments and objects, one perceives the meaning and utility of environments and objects, i.e., their affordances" (pg. 476). McLellan states that this is important to presence because the environment must afford exploration in order for people to make sense of it. Using the senses in tandem allows the user to perceive the objects and environment and, in this way, she states, we can begin to learn something important from the data retrieved. McLellan also points out that, virtual or not, this exploration is necessary in order to support perceptualization [sic] (McLellan, 2004) more fully. This is a fundamental advantage of virtual reality, that it facilitates active perception and exploration of the environment portrayed.

Poly-sensorality

Poly-sensorality involves the use of multiple senses in a VE environment. Witmer and Singer (1998) state that information presented through sensory factors such as, visual, audio, tactile etc. contributes to the experience of presence. The use of multiples senses in a computer-generated environment also involves environmental richness (Witmer & Singer, 1998). This is what these authors explain as "the greater the extent of sensory information transmitted to appropriate sensors of the observer, the stronger the sense of presence" (pg. 229).

Poly-sensorality can also be seen as multimodal presentation: the more completely and coherently all the senses are stimulated, the greater should be the capability for experiencing presence. This includes the consistency of information- all of the information being produced for the senses should follow logic (such as affordances and the ability for perception given by the environment) in order for the user to be able to make sense of the information they are receiving through the senses. If some of the senses in a virtual environment are incorporated unnaturally, i.e., they do not correlate with the users expectations of how to interact within an environment, the information becomes inconsistent and detracts from a feeling of presence. All of the avenues for sensing the environment should work together to limit the confusion the user may feel in the environment.

This may mean correlating to the outside or "real" environment in an IVE when this is appropriate, but it can also mean that through affordance, the user can perceive how to

act in an environment not specifically designed to mimic the real world. In both symbolic environments, and non-symbolic environments, the opportunity to use all of the senses should allow the user to make sense of where they are and act appropriately.

Immersion

While some researchers do not distinguish between immersion and presence, I am going to make the distinction between them: presence as "being there" and "making sense there", while immersion can be seen as "being enveloped there". Immersion is, according to Grau (2004): "a process, a change, a passage from one mental state to another. It is characterized by diminishing critical distance to what is shown and increasing emotional involvement in what is happening" (pg. 13). In addition, he states "Immersion describes a space of possibility, or impossibility formed by the illusionary addresses to the senses" (pg. 12). Witmer and Singer (1998) define immersion as the perception of being enveloped. Although immersion has been spoken of as "an objective description of aspects of the system such as the field of view and display resolution" (Slater & Wilbur, 1997, pg. 605), in keeping with the "making sense there" aspect of presence, I prefer the definition as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting within a VE" (Witmer & Singer, 1998, pg. 227). Witmer and Singer (1998) continue, stating that "A VE that produces a greater sense of immersion will produce higher levels of presence." (pg. 227).

Perception, again, is key to immersion. Edwina Bartlem, art historical theorist, scholar, and VR researcher, states that :

> The very term *immersion* implies that one is drawn into an intimate and embodied relationship with a virtual and physical architecture. It suggests that one is enclosed and embraced by the audio-visual space of the work, and transported into another realm or state of perception. (Reshaping spectatorship: Immersive and distributed aesthetics, n.d.)

In addition, she states that by the very act of immersion, one is affected by the surrounding environment. This occurs on the psychological, sensory, and emotional levels. Here again, perception is an active, not a passive relationship. Within this perception frame, the user experiences a fusion with the technologically mediated environment.

Bartlem continues:

> The user becomes deeply embedded in this illusory space and their faculties of perception—their senses and processes of cognition of space, time and motion—recognise this experience as being akin to an embodied form of perception. Consequently, the boundaries between the computer-generated stimuli of the VR system and the embodied space of the participant-viewer seem to collapse. (Reshaping spectatorship: Immersive and distributed aesthetics, n.d.)

When perception is active, and the environment responds, when the user affects and is affected by the environment, then a state of presence occurs. Through such aspects of presence as affordance, poly-sensorality, and natural movement within the IVE, immersion and presence work together to allow the user to "make sense there". It seems

very simple, although not explicitly stated by many VR/IVE researchers, that to act and react in an IVE, the user must feel both "there" and enveloped by the environment, which allows the perception or sense-making process to occur.

What makes virtual environments (VEs) unique from other types of media, such as desktop computer actions, television and even cinema, is the sense of acting directly, not indirectly, with the environment. Witmer and Singer (1998) explain that although immersion can occur while watching a movie or reading a book (as previously stated) VE is really the first computer mediated environment that allows full interaction, that is, a responding environment.

Part of this is due to control factors, that the environment reacts to the user in a predictable way which allows a continuity of affordances. According to Witmer and Singer (1998), "presence is greater when the manner in which one interacts with the environment is natural or well-practiced" (pg. 229). The greater the control the user has, the greater the sense of presence and immersion.

With all of the discussion about what allows presence and immersion, what does not allow these psychological states to occur, should also be mentioned. This would be "anything that causes the viewer to not be able to focus on the environment lessens the experience of presence including unnatural, clumsy interfaces, and the participant's ability or willingness to focus" (Witmer, Singer, 1998, pg. 230).

Constraints are another important aspect. Although affordances allow the user to know what they can do, constraints help the user to know what it is that they cannot do. This also aids in "making sense there". For example in a more "realistic" or symbolic environment, it may be important that the user does not fall through floors or fly through walls if this detracts from the goal of the application of the IVE (Witmer, Singer, 1998). Therefore, imbedded constraints help the user to understand the limits of the affordances.

Presence or immersion would also not occur without the user's involvement and interaction. The perception process described above requires that the computer generated environment must respond to the users actions, and that the greater the control of the user, the greater the sense of presence and immersion. Therefore interaction in the environment becomes very important.

Interaction

Although many researchers use the term "interaction" or "interactivity" frequently, many fail to define exactly what this means. As previously stated user control is a key factor in feeling present and immersed in a virtual environment (Witmer & Singer, 1998). A dictionary definition of what interaction means is a mutual or reciprocal action or influence by the user (Merriam-Webster Dictionary, 1996). Basically, interaction means that the user can influence, or control, the environment, and that the environment (should) respond in a way that makes sense to the user, or helps the user understand the environment.

What this means, is that the environment should afford, as previously discussed, the learner to make sense of where they are and what they are doing, and allow intuitive interaction and decision making as a result. As a learning tool, the virtual environment should respond to user action in order to produce a more direct sense of engagement, presence and immersion. Interaction is what allows an IVE to be an active, rather than passive, environment.

To summarize, interaction is an important learning element in an immersive virtual environment, although other learning environments can be interactive without the specific aid of digital technology. For any interactive and immersive environment, when an educational objective is employed, it allows user control through decision making and exploration, while giving the user the space and options to practice their own initiative and learning.

All of the elements discussed in this section combine to convey to the observer the illusion of being in a complex structural space of a natural world, producing the most intensive feeling of immersion possible (Grau, 2004). These concepts are strongly related to learning and the experience of an immersive environment in museum exhibitions.

4.0 IMMERSIVE VIRTUAL ENVIRONMENTS AS UNIQUE LEARNING SPACES

Before moving directly into how immersive virtual environments (IVEs) can be used in museum education, it is important to take a step back and consider learning theories that embrace this type of technology and in which IVEs can incorporate easily. This is in addition to what makes IVEs unique learning spaces to begin with. Although I will be concentrating in this section on theories of *learning*, it is important to note that this is different from theories of *knowledge* (Hein, 1998).

In a previous segment that explored the ontology of presence, the researcher's "view of reality", can also be explicitly linked to a theory of knowledge. As Hein (1998) states, theories of knowledge can be viewed in two ways. Knowledge can be seen as a pre-existing entity that we only receive a limited observation of by receiving facts through the act of transmission. As stated previously, in this view, knowledge is "out there", a separate entity from what we actually experience, which is evaluated by our ability to recite the facts we have received. On the other hand, knowledge can be seen as something constructed by the learner through personal experience, assimilation (building on experience and adding to or changing our knowledge), participation, and working within a social dynamic (responding to and engaging with others).

Hein (1998) points out that based on these contrasting views of knowledge, differing theories of learning have developed. Within many learning paradigms, including constructivism, both theories of knowledge and theories of learning must be considered.

Hawkey (2004) created a simple diagram of how the two intersect based on Hein's research (1995, 1998). In this diagram, basically, knowledge on the one hand is independent of people, and on the other, constructed by people. Within this paradigm, learning is either passive (knowledge is transmitted) or (both knowledge and learning) are constructed from ideas and experience (Hein, 1998), creating a four-way cross as to how differing theories of learning and knowledge intersect.

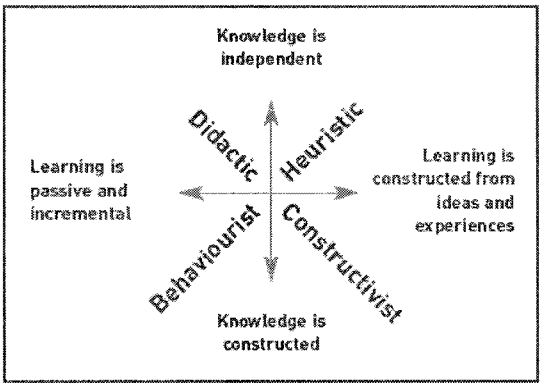

Fig. 1.0 model of knowledge and learning adapted from Hawkey (2004), and Hein (1995, 1998).

The learning theory adhered to in this thesis is that of constructivism, as defined earlier. In relation to the use of technology and constructivism in education, constructivism can be seen as an enveloping term that incorporates several learning theories which are outlined below. Constructivism can be seen as encompassing all of these theories because they grow out of research from educators that span back over a hundred years and that have been modulated, tested, and added to, most notably by Dewey, Vygotsky and Piaget. This variety allows educators to draw from these theories in order to create the most effective environment for learning.

Many researchers and educators that work from a constructivist perspective include the following learning theories in their discussions: contructivism, experiential learning,

sociolcultural learning theory, and co-operative learning (Gros, 2002; Hawkey; 2004, Hein; 1998, Roussos; 1997, Winn; 1993). In addition I will be outlining such learning elements as motivation and narrative, as well as offering a brief view of what cognitive science and symbol systems add to IVEs as unique learning spaces.

5.0 **LEARNING THEORIES**

5.1 *Constructivism*

Roussos (1997) states:

> The traditional approach to education reflects a transmission model, where learners accumulate pieces of information transmitted by the teacher. In many schools and universities, this approach to learning still dominates the curriculum. It is recognized in the field of education as instructional design. (pg. 5)

A word about instructional design; instructional design in the past has focused primarily on the transmission model. Duffy, (1992) states that instruction in general, particularly in the West, has emerged from an objectivist tradition. This view holds that "experience plays an insignificant role in the structuring of the world; meaning is something that exists in the world quite aside from experience" (pg. 2). The point here is that the goal is to strive for complete and correct understanding. This means that instruction can be described by set theoretic models, and that the goal of instructional delivery is to design an educational system that transmits content and skills in a clear, well structured, and efficient manner (Roussos, 1997). From the objectivist point of view, the focus is on the "correct" assimilation of knowledge and that there are specific sets of knowledge that the learner must "know". In addition, the "mastery" of this knowledge means that everyone has acquired the same information and now has it available to use.

More recently however, both Duffy (1992) and Roussos (1997) point out that an alternative epistemological basis to this objectivist tradition is constructivism. According to Roussos, this view "argues that the goal of education is to help students construct their

own understandings" (Roussos, 1997, pg. 5). Constructivism is concerned with the learner's creation of meaning and linking of new ideas to existing knowledge, and therefore involves a large degree of student autonomy and initiative. Duffy (1992) states that constructivism is an educational theory in which "the learner is building an internal representation of knowledge, a personal interpretation of experience" (pg. 21). He continues by stating that these representations and interpretations are open to change and the structure of which allows a foundation for which new knowledge structures can be added. "Learning is an active process in which meaning is developed on the basis of experience" (Duffy, 1992, pg. 21). The emphasis is on facilitating environments, rather than instructional goals.

The roots of constructivism are not new. In fact, the ideas of constructivism have been around for almost a century. However, the objectivist viewpoint still dominates many of the studies and research to date when dealing with Immersive Virtual Environments. Context and learning environments are an important key to constructivism (Duffy, 1992; Gros, 2002). This is explained as "meaning is seen as rooted in, and indexed by experience; the experience in which an idea is embedded is critical to the individual's understanding of and ability to use that idea." (Duffy, 1992, pg. 4). According to Gros (2002), this is opposed to a traditional transmissive approach where the learning goals, outcomes, contexts, and strategies are pre-determined by instructors and instructional design. Constructivism takes a more open approach, where the goals and outcomes are more flexible and are learner, not instructor based. Therefore, context is defined here as the inter-related conditions that allow experience and understanding.

Rousoss (1997) states that Piaget, "famous for his research on the psychological development of the child, believed that children have to go through stages in which they accept ideas they may later see as wrong" (pg. 3). In this view, understanding is gradually built up step by step through active involvement, not memorization. The teacher's role becomes one of a guiding mentor stimulating initiative, play, experimentation, reasoning and social collaboration. Dewey argues that education depends on action, and that children must actively construct knowledge by drawing it out of experiences that have meaning and importance to them (Dewey, 1966).

According to Vygotsky, effective instruction takes place in the "zone of proximal development". He defines this as the discrepancy between the child's actual development as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). This is also known as scaffolding. Concerning differences in approaches to learning by Piaget and Vygotsky, Gros (2002) states that the two are often compared, but instead, their theories should be seen as complementary. Piaget concentrated on the relationship between a person and his/her environment. Although not unique to constructivist theories of learning, Piaget focused on the connection between prior experiences and new knowledge (Gros, 2002). This means that new knowledge is incorporated into the learners' previous knowledge, and is either rejected, or assimilated to create new understanding. This process is also known as appropriation (Gros, 2002), which is an important element in Vygotsky's approach to learning. However, for Vygotsky, appropriation also included the

appropriation of tools, symbols, and instruments in the society in which the learner is immersed. A more complete discussion of symbol systems will take place further in this segment.

Roussos states "Constructivism has emerged in the last two decades as an alternate pedagogy closely related to the advances in educational technology" (1997, pg. 4). As Duffy (1992) sees it, "Learning always takes place in a context and the context forms an inexorable link with the knowledge embedded in it" (pg. 26). Therefore, an abstract, simplified environment such as school learning is both quantitatively and qualitatively different to the real world environment. Immersive virtual environments have the ability to "maintain the complexity of the environment and help the student to understand the concept embedded in the multiple complex environments in which it is found" (Duffy, 1992, pg. 26). In his view, this allows the transfer of ideas to other areas of the learner's life.

Of course, there are many educational researchers that view the constructivist learning approach from a more negative viewpoint, and these concerns should not be glossed over. There are extreme implementations of constructivism, which have provoked negative reactions (Roussos, 1997; Black, 2005). For example, Duffy states that some researchers have described constructivism as "a label for fuzzy, unscientific thinking" (Duffy, 1992). Roussos points out that "the application of constructivism in some contexts has led some researchers to believe that it supports spontaneous, uncontrolled learning in contrast to the systematic, organized instruction of knowledge employed by the objectivist tradition"

(1997, pg. 4).

In relation to this, constructivist learning environments can be difficult for an entry level learner because of the possible lack of guidance. In addition to solving or creating problems, it is necessary to have a good command of content. According to Gros (2002), at times, the constructivist perspective seems to underestimate or neglect these aspects. Gros also challenges the assumption that learning in context improves transfer of learning. She states that this is not an easy assumption to prove. This leads to concerns about the evaluation of learning, and as both Duffy (1992) and Roussos (1997) mention, this has been a critique of constructivist learning environments, as the evaluation methods and reliability are questioned against those of a more objectivist position.

Despite these critiques, there has been a turn to more flexible, open-ended, adaptive and multi-dimensional instructional techniques as well as more qualitative, observation-based methods of evaluation. As a result, constructivism is embraced by many educational technologists and "as such, it makes an ideal basis for building a theory of learning for open, informal, and virtual learning environments" (Roussos, 1997, pg. 4). This last point shows that constructivism as a learning theory is an appropriate choice for museum education.

5.2 *Experiential, Situated and Problem Based Learning*

Direct experience is considered to be a major principle in recent pedagogy. The roots of experiential learning lie with John Dewey. Furness, Winn and Yu (1998) state that

students need to experience the concepts and principles contained in the content as much and as directly as possible. Learning experiences, within this context, champion ownership, engagement and social context.

There are many principles that are involved in experiential learning. According to Furness et al. (1998), these include; complete mental and physical engagement, appropriate amounts of challenge and a cohesive narrative framework for the learning experience, a multi-sensory and challenging environment, and a learning environment that is cohesive.

Learning experiences must be valid within a social context established by group interaction. These experiences involve more than just one person directly or indirectly, and the activities must make sense to the group within which the student learns (Furness et al., 1998). The final outcomes of the learning must be valid within the broader community within which they will be applied. Furness et al. state that "The judgment of the learning experience's validity, within these concepts, is determined socially" (1998, pg. 11).

Because direct personal experience is a key element of constructivist learning principles, it is related to both situated and problem based learning environments. Although many theories of learning that are related to and have built upon constructivism are outlined below, these are two types of learning environments succinctly related to direct experience. The main objective of these approaches is to "facilitate the transferal [sic] of

learning, and the importance of the students learning not only to identify and solve problems, but also to generate new ones is emphasized" (Gros, 2002, pg. 331). The problem must be presented in a way that encourages the learner to solve it and include both the relevant and superfluous information that usually surrounds a real problem (Gros, 2002).

Situated learning is another key approach, and this approach can be viewed from either individual or social perspectives (Gros, 2002). Key principles of situated learning include: learning must be provided in context, the learner must be an active, not passive participant, knowledge is developed in action, artifacts and mediating objects are used, and it promotes a learning community (Gros, 2002, pp. 332-333). Problem based and situated learning approaches are important to constructivist learning environments because they put problem solving techniques into practice and context, removing the transmissive approach to learning which focuses on memorization and the acquisition of knowledge in an isolated manner.

However, it is here that I would like to make a point of distinction. As has been seen throughout this thesis, not all constructivists, educators, educational technologists, or/and VR/IVE researchers have come to a point of agreement concerning what "authentic tasks" (in a contextualized educational framework) mean, nor what "transfer of learning" into real world problems means. Some state that a VR/IVE must mimic the real world as closely as possible in order for transferal of learning to truly occur. Others, as has been described in terms of affordance and perception, and as will be further developed in the

section on cognitive learning and symbols, state that it is what the environment allows the learner in terms of actions and perception that is important. This is still a grey area in VR/IVE research which needs much consideration. Thus, IVE developers must be clear about their specific ontology, and educators must be careful not to use IVEs when other appropriate learning contexts and tools are more relevant. For this thesis, the "making sense there" ontology is adhered to, and this means that the IVE does not need to mimic real world reality. Instead, it should afford the user natural movements and interaction in order to understand what can and cannot be accomplished in the IVE. With this stated, it is still important to have a basic understanding of problem based environments as outlined by previous researchers, as described above.

5.3 *Sociocultural Theories and Cooperative Learning*

Various sociocultural theories have emerged in recent years, which expand upon the learning theory of constructivism and experiential learning. This approach consists of conceiving reality as a series of socially mediated activities. Based on the theories of Leontiev, this includes both individual and collective activity (Gros, 2002). Through appropriation, we take from our experiences, the tools, instruments and symbols in our society, and incorporate them into our existing knowledge and preferred learning style. This is a result of our cultural immersion, which is a social dynamic. Newer communication technologies, including IVEs, are mediums that provide opportunities for joint communication and knowledge construction, including the ability to span space and time. For example, there can be multiple physical locations of joined IVEs that allow people from all over the world to interact with each other simultaneously. Time-wise,

learners can interact on a direct personal level within an IVE that recreates historic places or events.

Cooperative learning has strong ties to both experiential and sociocultural approaches to learning. Rather than considering the importance of individual learning, it focuses on the importance of learning in a group. Like other learning approaches tied to constructivism, it emphasizes learning as an active process, best facilitated by interaction with peers, teachers and other learning resources. In cooperative learning, learners work together as a group, discussing what they are doing and finding, as well as sharing responsibility for learning (Roussos, 1997).

Advantages of this more social approach include possible higher performance in a group based on shared cognitive resources, the co-construction of knowledge, facilitation of learning by more capable peers, verbalization of multiple viewpoints, conflict and learning conflict resolution, observation, increased motivation, and increased self-esteem (Roussos, 1997). However, this approach doesn't necessarily ensure that everyone will achieve the same level or type of mastery, collaborate, or have uniform participation and effort and this can induce competition (Roussos, 1997).

Yet, a goal of all constructivist related learning theories is to prepare students for complex tasks in other areas of life. A unique attribute of IVEs is that they allow collaboration which adds to the complexity of the learning experience and environment. By experiencing a complex environment, students will eventually grow from novices to

experts. This is done with the help of capable peers, adult/expert guidance, and in an IVE these can also be combined with feedback from the computer generated environment.

5.4 *Other Elements in Constructivist Learning: Motivation, Narrative and Symbol Systems*

Other important elements in constructivist learning environments that are brought up by every researcher dealing with technology and education quoted thus far are motivation, narrative and novelty, and thus deserve consideration here. Motivation is an important element in any approach to learning and education. There are two broad categories of motivation, intrinsic and extrinsic. According to educational technology researcher Mei-Jen Kuo (2007):

1) Intrinsic motivation- is an innate need founded on competence and self determination, to explore one's environment- activities are stimulated through challenge and incongruity to play and explore for its own sake or internal interest, rather than for some external reward.

2) Extrinsic motivation- originates from external factors, such as tangible rewards, deadlines, school grades, or punishments.

To provide opportunities for learning, educators must first motivate and engage the learner in the activity. Roussos (1997) states that motivation concerns whether a student is willing to learn, not whether the student is able to learn. Therefore, the learning

environment should provide the learner opportunities in which to become engaged through self-initiated interest, and a complex enough environment to hold that interest. Intrinsic motivation is increased if the learner has "ownership" of experience and control over personal involvement in the experience. One way to achieve this is through novelty. Many educators have noticed that computer based games and programs intrinsically motivate students to show interest, and are drawn into the educational activity. An important contribution of immersive virtual environments is exactly this novelty; people are drawn to the 'magical' quality of virtual reality (McLellan, 2004).

Virtual environment researchers Furness, et al. (1998) point out that students' who can construct their own ideas directly from the experience, without the mediation of a third party are more interested and excited in what they learn. Motivation becomes largely intrinsic, interest is higher and retention longer than learning from a book or teacher.

5.5 *Narrative*

Narrative is another important learning element. People relate to narrative because it is a framing device for an experience. Narrative is important to constructivist learning theory because it is a defining feature of most experiences, and even a special kind of experience itself (McLellan, 2004). As McLellan explains, most experiences have a beginning, middle, and an end. "These boundaries help us differentiate meaning, pacing, and completion" (2004, pg. 481).

Much like a story, experiences need an attraction, engagement, and conclusion. Attraction is necessary to initiate experience, engagement is the experience itself. This must hold the attention of the learner in order for the experience to be relevant enough to continue, and "conclusions can come in many ways, but they must include resolution, through story, or context, or activity to make an otherwise enjoyable experience satisfactory—and memorable" (McLellan, 2004, pg. 481). It does not guarantee that the experience ends with the story, but it helps the learner to add this story to their personal experience and use it as a tool for constructing personal knowledge. Shedroff refers to this factor that endures in memory as the *takeaway*. Shedroff (2001) explains that takeaways help us to derive meaning from what we experience.

However, as Shedroff (2002) reports;

> Most technological experiences—including digital and, especially, online experiences—have paled in comparison to real-world experiences and they have been relatively unsuccessful as a result. What these solutions require is developers that understand what makes a good experience first and then to translate these principles, as much as possible, into the desired medium without the technology dictating the form of the experience.

To break down Shedroff's (2002) statement, digital and online experiences pale in comparison to real world experiences because many lack in engagement, narrative, environmental richness, and affordances by the environment. He is making the statement that digital environments are not being designed with the users' experience in mind. Therefore, to make educational technology and virtual environments in particular, more

compatible with meaningful experience, narrative or story can and should be used as a principal tool. As a framing device for experience, narrative is a natural element that can be used in the creation of an IVE.

Of course, when narrative is used in any educational context, the story line must be coherent, even when the learner is constructing the story him/herself, the options for coherency must be evident. This goes back to the idea of framing mentioned earlier, but it also means that when a person is engaged mentally and physically, they should be able to actualize an evident goal in their activity(ies) in order to be able to reflect on and assimilate the experience into their personal knowledge structure.

5.6 *Symbol Systems, Cognitive Learning Theory and Constructivism*

As technology changes, so too do the symbol systems incorporated by them. Thus, it is important to have a basic understanding of symbol systems that tie in with constructivist learning principles. There are two types of symbol systems people interact with: abstract and concrete. According to many cognitive scientists, humans think symbolically (Mclellan, 2004). Some studies have shown that humans process concrete symbols better than abstract ones, which is likely due to the way our brains have evolved, for example, recognizing the stripe pattern on a tiger in order to survive (McLellan, 2004).

Virtual Reality researcher William Winn (1993) links concrete and abstract symbols to types of experience. He states that we know the world in two ways- direct personal experience, which is subjective, tacit and inherent in everyday situations which are first-

person experiences. Objective, vicarious and communal experiences, like those that are explained to us by another person are third-person experience; this is knowledge that has been taught to us.

Winn explains that first-person experiences are characterized by an absence of deliberate reflection such as when we go about daily tasks without too much planning about how to deal with problems until we are confronted by them. Because first-person experiences are natural and non-reflective, "interacting with a computer through an interface is a third-person experience- it precludes interactivity on the basis of natural behavior" (Winn, 1993, pg. 5). He continues, stating that the interface creates a boundary, so we see the computer as something "out there" (pg. 5) which defies first-person experience. However, more intuitive interfaces- those that allow more natural behavior such as in a well-developed IVE- allow us to cross this boundary and create a first-person experience through immersion.

In traditional educational approaches, a person must learn a symbol system in order to understand a knowledge domain, yet the "mastery of the symbol system is often mistaken for mastery of the content" (Winn, 1993, pg. 5). Winn states "Any medium (such as computers) has its own symbol system- we read text symbols and pictorials from the screen- these are conventional and have to be learned some time or other" (pg. 5). He states that learning *about* something (such as mathematics) is not the same as really learning the thing itself.

In a later collaborative study that Winn was involved in (Furness et al., 1998), the authors explain the difference as either language based or picture based symbols. Pictorial symbols resemble what they stand for, and are therefore easier to interpret. "Linguistic or digital symbols have an arbitrary relation to what they represent and therefore have to be learned before they can be interpreted" (Furness et al., 1998, pg.11). The differences in how symbols are represented in a system (or an environment) are important to how the information is understood and used by the learner, which impacts further learning in the future, i.e. appropriation and transfer of learning.

The use of different types of symbol systems by the learner is important to IVEs within education because they allow learners to interact with the environment using the approach more suitable to their abilities and learning styles. Symbol systems that rely less on linguistic data and more on pictorial representation allow the user to learn the conceptual basis of something without learning the conventional symbols "provided that the learning experience is direct, personal and implicit" (Winn, 1993, pg. 5). This is an added benefit of IVEs, as Winn points out, because they allow the user to learn concepts and solve problems non-symbolically, which is good for those that may not do well in traditional symbol-based education (and fits well into informal learning environments). This allows concepts to be mastered which can later be symbolized if needed.

According to Winn (1993), educational computing has entered a fourth generation of evolution which has grown from: 1) a content-driven traditional educational approach (transmission approach); into 2) cognitive theories and instructional methods; 3) to the

belief that the interaction between the student and the instruction determines learning to a greater degree than content (transaction approach); 4) towards the idea that "knowledge is constructed by the students themselves, not delivered by the courseware" (Winn, 1993, pg. 7).

Although knowledge construction is also a part of cognitive theory, much of cognitive theory has been rejected by educational technologists due to the fact that the ideas of cognitive science are based on the idea that the mind works like a computer. This is the same reason why a typical computer interface limits experience to the third person, which does not champion constructivist approaches to learning (Winn, 1993).

As has been stated, from a constructivist approach, meaning is negotiated socially. This is made possible through "structural coupling", which means that humans, belonging to the same species, have the same apparatus for detecting and adapting to 'perturbations' in the environment (Maturana &Varela, 1987). This is similar to the perception-action coupling mentioned earlier in relation to affordances- that our perception is dependant on possible action in the environment. Through structural coupling, a person's structural adaptations will be similar to other people.

However, although structural coupling exists, every person's construction of the world is unique. Each symbol placed in the environment will mean different things to different people. As Winn (1993) points out, this is not to say that pre-specifying content or being concerned about interactions with content or the instructional strategy "is to no avail because learning takes place entirely within the student" (pg. 9). Learning environments

in which students construct knowledge still need to be provided and planned for.

Another concern when dealing with technology and constructivism is that of providing an approach that can help to improve the education and training necessary for living in today's primarily information-based, and exceedingly image-based society (Gros, 2002). The approaches to pedagogy are changing, and the constructivist approach is but one learning theory that illustrates this.

What do all of these differing principles and theories have to do with IVEs and learning? The new highly interactive and usually multi-modal technologies that support learning environments make it possible to learn in and through many different epistemological frameworks. Constructivism embraces and utilizes many of the previously mentioned learning theories and principles.

To summarize, there are a lot of overlaps in the learning theories described above. In fact, certain underlying ideas seem to come up again and again. Amongst them are:

- Learner, not instructor, related practices
- Active, not passive, learning
- Personal interpretation and construction of knowledge and learning
- Engagement (which includes motivation)
- Environmental and social contexts in learning
- Narrative, novelty and personal choice in learning environments.

In the next section, a more concrete relationship will be drawn between the learning theory of constructivism and how IVEs can incorporate and aid this learning theory in creating learning environments.

6.0 IMMERSIVE VIRTUAL ENVIRONMENTS AS AN AID TO CONSTRUCTIVIST LEARNING PRINCIPLES

In this section, it will be discussed how constructivist principles can be actualized by the use of IVEs in education. There are advantages to using this type of technology in learning:

> The computer environment should not be providing the knowledge and intelligence to guide learning, it should be providing the facilitating structure and tools that enable students to make maximum use of their own intelligence and knowledge (Salomon, 1993, p. 122).

In this perspective, the computer system acts as a facilitating companion which makes the student's cognitive activity possible. Cognitive tools are those that allow the computer to act as facilitator and to make cognitive activity possible and "are given to learners to express and represent what they know" (Gros, 2002, pg. 330). Examples she gives of cognitive tools are databases, spreadsheets, communication software, online cooperation environments, and software. The use of these cognitive tools as an aid to constructivist learning is enabled by acting as an aid to reflective thought, which is necessary for significant learning and fostering the development of many abilities, such as strategies for problem-solving, searching, project organization, presentation, reflection, and so forth (Gros, 2002, pg. 330).

As previously stated, many researchers in education and technology feel that constructivism provides the best theory on which to develop educational applications of

immersive virtual environments (Gros, 2002; McLellan, 2004; Winn, 1993; Furness et al., 1998). As Winn (1993) explains "immersion in a virtual world allows us to construct knowledge from direct experience, not from descriptions of experience" (pg. 10). Therefore, the experience is in the first-person, which allows "the same kind of natural interaction with objects that participants engage with in the real world" (Winn, 1993, pg. 10). As discussed previously, in the constructivist viewpoint, learning is intimately tied to action, and because IVEs allows both action and interaction, knowledge can then be constructed by the learner. There is a heightened possibility of using constructivist principles in an IVE rather than in other non-immersive or non-interactive educational technologies. For example, an application of this in practice is having learners create their own virtual immersive environments. In this case, the learner can be a designer, gain access to and interpret information, and represent and comment on what others know (Reeves, 1999).

Furness et al. (1998) state that an IVE is a great venue for letting students explore, and is therefore potentially very effective for student-directed knowledge construction. To allow the learner to explore in an IVE is to allow learner direction instead of telling learners exactly what to do. In this way, they should be told about the tools they have and be left to explore on their own in order to support the well documented advantages of the constructivist approaches to learning (Furness et al., 1998).

According to Furness et al. (1998), exposure to the types of technology used in IVEs enables the development of the mental skills needed to learn from them. Basically, people

(and especially children) are able to learn with and about the technology at the same time. As Furness et al. point out, "research shows that exposure to a medium develops within the student the mental skills needed to understand and act on the messages the medium communicates" (1998, pg. 23).

Furness et al. created a list of attributes of IVEs that enable constructivist learning principles (1998, pp. 22-25). They include:

1) Allowing the learner to access the unrealizable or inaccessible because IVEs allow learners to experience things that normally would be too dangerous or expensive. This may be an ironic point, as IVEs are an expensive type of technology, but most likely cheaper than, for example, taking groups of students to archaeological digs in remote places year after year.
2) Immersive virtual environments are engaging and seductive- one attribute of IVEs is that they gain and hold attention. This assists learning in two ways- motivates students to learn, and students enjoy working in IVEs and will continue to do so if given the opportunity. Second- the nature of IVEs to keep attention focused on the matter at hand so there is less distraction from learning as the learner cannot look away. Although this may be true if the learner is engaged enough to continue, it should be noted that opportunities for exiting the IVE should be given at all times.

3) They can teach complex topics with less need to simplify them. The simulations that lie behind them can be as complex as possible-students can interact with causes and effects in all their complexity.
4) Furness et al. state that the feedback and affordances of the IVE are important in guiding learner knowledge construction. As previously mentioned, the consequences of a student action must "make sense within the conceptual model that drives the simulation and within the mental model that the student is constructing" (Furness et al., 1998, pg. 25). However, these authors also state that even when making mistakes in these environments, "the feedback from the VE may vary just as it does in other learning situations" (Furness et al., 1998, pg. 25) which allows an opportunity for the student to learn from mistakes.
5) Successful learning construction in an IVE is dependant on how well the representations within it and the level of interaction afforded to the learner are effectively designed and fit together. This is something that goes beyond aesthetics or nice-looking IVEs, they must have high levels of both presence and interaction through an educational focus and good design (Furness et al., 1998).

Other authors, such as Winn (1993) and Roussos (1997) add to this list of attributes of IVEs and constructivist learning:

6) Size: One of the great things about IVEs is that the size of something isn't fixed by the laws of nature. They allow multiple or alternative representations.

This means that students can enter something microscopic on deeper and deeper levels, all the while maintaining relative size- like literally walking into or through a double helix of DNA. Conversely, one can get a "God's-eye" view of the universe, pulling further and further back. Within this is the relationship of time- it can be shortened or lengthened, offer multiple points of view of time in tandem, or allow the learner to explore in their own "real time" in an environment where time has been caused to stand still (like virtually exploring a life size "freeze frame" in a movie).

7) Transduction: "Transducers are devices that convert information that is not available to our senses into forms that are" (Winn, 1993, pg. 11). As technology grows and changes, these transducers, much like interfaces, will become more natural, allowing the enjoyment of first-person experiences and constructing first-person knowledge "about objects and events that are accessible to them in the real world only as third-person descriptions" (Winn, 1993, pg. 11).

8) Reification: "Changes in size and transduction give first-person access to experiences that students could not otherwise have. ...Reification is the process of creating these perceptible representations" (Winn, 1993, pg. 12). Winn states that reification stands in contrast to simulation- simulation in a VR or IVE contains facsimiles of real objects and their behavior, which may be easier and less expensive then creating either a full blown simulation (aided by screens, HMDs, and gloves or wands as opposed to desktop computer types of VR) or real-world environment. However, Winn feels that the real

> power of VR is lost on simulation. He states that a person gains nothing using a virtual transducer (such as a virtual microscope in a virtual lab to look at a virtual drop of water) but rather, VR comes into its own when a person can enter the drop of water virtually, where the size of the drop is larger than life. Roussos (1997) echoes this statement- highlighting the ability of IVEs to make the abstract more concrete and visible. Any type of data can be input into a computer, which means that however abstract their referents (Furness et al., 1998), anything can be created, and explored. As these authors state "The trick, of course, is to represent abstract concepts and principles using metaphors that afford natural properties and means of action" (Furness et al., 1998, pg. 23).

As Winn (1993) states, the convergence of theories of knowledge construction with VR technology permits learning to be boosted by the manipulation of the relative size of objects in virtual worlds, by the transduction of otherwise imperceptible sources of information, and by the reification of abstract ideas that have so far defied representation.

Technology, particularly IVEs, can create learning environments that were previously unable to exist using traditional approaches to learning and traditional approaches of learning with media. As has been seen in this section and the previous one, with constructivist theories of learning, "the focus shifts from the design of prescribed (or pre-specified) interactions to the design of environments that permit students any kind of interaction the system is capable of" (Winn, 1993, pg. 9). In other words, the focus is on

the potential for many types of interaction rather than pre-determined educational goals, a specific attribute of VR and IVEs.

6.1 *A Critical Look at IVEs within a Constructivist Framework*

Recent advances in technology have caused a re-examination of their meaning in education. Educator and educational technology researcher Begona Gros (2002) points out that "technological advances are incorporated into education with no consideration for, or study of, the educational repercussions of these media" (pg. 325). In fact, she states what I consider to be a very good mandate as to the use of technology in education; *not everything that is possible is desirable* (Gros, 2002, pg. 325).

What this means is that technology can show us what *can* be produced, but educators need to determine the what, when, why and how it *should* be used in the most beneficial way possible for learning. To expound on a previous example, although it may be *possible* to create a virtual lab with a virtual microscope and a virtual drop of water, this type of scenario is probably better suited to the real world. IVEs should be used when it can offer something not possible outside of the virtual environment. In addition, when it comes to immersive virtual environments, this technology should be seen as something that mediates in learning, that is, it changes the learning experience to something which includes a more dynamic element. Gros (2002) states that any technology must be looked at within a social context of change and evolution, and so IVEs should also be viewed in the era of time in which they are being implemented and used to more clearly understand their benefits and significance.

Roussos (1997) makes comments within the same vein. She states that beyond the media hyperbole surrounding VRs and IVEs, they do have the potential to become useful tools for learning. As the technology becomes cheaper, it is making its way into peoples homes, mostly through the use of video games. Roussos points out that in relation to education, "if alternatives are not provided, the only developer of virtual learning environments will be the video game industry" (1997, pg. 15). This is not necessarily a criticism of the video game industry, but rather, to show that more can be done with immersive technology than to learn how to virtually shoot people and blow things up with a mouse or a joystick (eg. Warcraft II ™). This is food for thought for anyone that sees potential in IVEs as learning tools outside of the vicarious experience that often define current and popular video games.

In the ancient past, knowledge transmission developed from the primarily oral towards language and the written word. Along with pictorials, as time progressed, more and more reliance has been placed on written texts in the transmission of knowledge. More recently, with the advent of new technologies, "the idea of knowledge as something static are [sic] set against a much more dynamic and complex vision of knowledge" (Gros, 2002, pg. 327). Thus, when considering the incorporation of VRs and IVEs into contemporary culture, Gros (2002) takes a very critical look at the place of this technology in Western society. She points out that the educational and training needs between today and mid-twentieth century are very different. There has been a change in the nature of learning itself, due mainly to the influence of mass media and technology (Gros, 2002). Although currently relying on the mostly oral and written display in the transmission of information

in our schools (including post-secondary), the use of mass media and technology, such as television, films, CD-ROMs and the Internet, have caused writing to increasingly include the pictorial and interactive. This is particularly apparent when students learn on their own using multi-media devices such as the Internet outside of formal learning institutions. This, as Gros (2002) explains, has shown that significant changes in students' learning methods are beginning to appear. Yet the linguistic foundation of our learning structures, and the turn to more visual methods are currently co-existing, and therefore the long term effects of this on learning and society are not yet known. This changing dynamic in both the contemporary theories and practices of knowledge and learning need to be kept clearly in mind for any educator when using new technologies.

In addition, as far as a critical examination of IVEs, something should be said about aesthetics and critical distance in these types of environments. Although it is beyond the scope of this thesis to delve deeply into the large forum and debates surrounding these issues within immersive technologies, a brief note about them will be made here. Research and commentary dealing specifically with these issues within IVEs *and* learning are practically non-existent. So here, I am concentrating on the critiques of Bartlem, a curator with specific interests in art and immersive technology (Reshaping spectatorship: Immersive and distributed aesthetics, n.d.), who focuses on the use of immersive technologies in art work and their influences on perception, aesthetics and critical distance. Many of the points she makes are readily applicable to IVEs as they are discussed within this thesis.

First of all, is the issue that through immersion:

> The user becomes deeply embedded in this illusory space and their faculties of perception—their senses and processes of cognition of space, time and motion—recognise this experience as being akin to an embodied form of perception (Bartlem, Reshaping spectatorship: Immersive and distributed aesthetics, n.d.).

Through this, the space between the IVE and the viewer seems to collapse. In traditional approaches to aesthetics, generally based on Modernism and the ideas of Kant, the viewer must maintain a physical and perceptual distance outside of the artwork to have a true understanding of its aesthetics, that is, to be able to reflect on and understand the art work. What Bartlem argues is that through the interactivity and the perceptual processes that occur within an IVE, it is not a perceptually removed place outside of the virtual artwork (or other type of IVE), but the fact that they are *within* the space that allows reflection. Basically, in an IVE, self-reflection takes place during the engagement with the environment "It takes place while one is engaged in the act of play or interaction within the immersive environment" (Bartlem, Reshaping spectatorship: Immersive and distributed aesthetics, n.d.). Not only does this concern tacit knowledge, which can be defined as bringing into consciousness "a dimension of personal knowledge [which begins] in that internal place where experience, feeling, and meaning join together to form both a picture of the world and a way to navigate that world" (Sela-Smith, 2002, pg. 60) but also the use of the perceptual processes inherent in immersive technologies that can be used to draw attention to the technology itself. This allows the user to think about the technology and its processes during their interaction with the IVE.

This is an important point because any time an IVE is used, the developers must question

the purpose and possible effects of the collapsing of the space between the learner and the IVE. Anything particularly violent or of questionable educational goals must be viewed within the context that the learner will experience the IVE as a first-person experience, which can have some drawbacks. For example, if the visitor feels present in the IVE and has a negative experience, it will most likely be heightened by the incorporation of all the senses. This is something that should be a major concern, but seems to be sidestepped in current discourse surrounding the use of IVEs. According to Bartlem, this goes much beyond the debate about the Cartesian mind/body split that seems to be the core of much critique about the use of IVEs, and delves deeply into the constructivist principles of direct experience, social collaboration, knowledge construction, and appropriation. I hypothesize that, as direct personal experience, IVEs should be used with caution and with as much planning as possible about the cognitive and emotional effects on the learner. Currently, there is very little literature focusing on these issues, so there is obviously a need for further research in this area.

Bartlem concludes by stating that "The traditional relationship between the viewer and art object has been radically reconfigured by new technologies that situate the viewer in different spatial and perceptual relationships with the work" (Reshaping spectatorship: Immersive and distributed aesthetics, n.d.). Like movies in the past, this can also be said of any IVE, there are new relationships being formed by the experiential, perceptual, cognitive and emotional responses IVEs offer. Bartlem highlights the point that "aesthetic judgment takes place in 'a dazzling immediacy' of thinking and feeling while interacting with the work of art" (Reshaping spectatorship: Immersive and distributed aesthetics,

n.d.). IVEs expand on this because they transform the role of the viewer from a passive spectator (such as in cinema) to a participant, collaborator, or even creator. This effectively helps to create both the content and the meaning of the environment as they interact with it (Bartlem, Reshaping spectatorship: Immersive and distributed aesthetics, n.d.).

Other important aspects to consider with the use of IVEs include ergonomics- the system should be designed to be as comfortable as possible, if it is too cumbersome or doesn't match up with our natural perceptive and kinesthetic abilities, learners will choose not to use it. Therefore, whatever interface or transduction devices the IVE may use must match as closely to our perceptive abilities as possible. This should be done in order to lessen the degree of the possibility of something such as motion sickness, or confusion about how to interact. Obviously these can be very critical distractions in which the IVE cannot accomplish the purpose(s) it was created. Another consideration is whether or not the IVE is designed to ensure people with differing abilities are able to use it-to have full user control. Although beyond the scope of this thesis, one branch of the use of IVEs is as an assistance technology for people with a range of abilities, which shows great promise for the future (McLellan, 2004).

Other important considerations in the use of IVEs in an educational framework include 1) the awareness of who the IVE is designed for (population type, age, gender etc.) and the flexibility to meet varying needs, 2) Relative emphasis on entertainment value- the purpose of the IVE needs to be kept in mind, so a balance between education and

entertainment can be met. In reference to museums, this concern becomes even more pressing, as there has been much debate about this balance in museum education. 3) Sense of ownership operationally defined as building vs. visiting worlds, an important constructivist learning principle. 4) The time it takes to learn and use the technology effectively in education- this is an especially important point for informal learning places such as museums where often the visitor is only going to have the opportunity to use the IVE once. How is this consideration going to be incorporated into the design of the IVE? 6) Cost to acquire, maintain, network and update systems, including planning for obsolescence- for any learning institution, this is a major concern because of the financial constraints (Furness et al., 1998, pp. 18, 32). These additional concerns are mentioned because they show a more practical side to using this type of technology in an educational setting. To summarize all of the following points in the last section:

1) Theoretical constructivist principles can be actualized by the use of IVEs in education.
2) This convergence of theories of constructivism and IVEs allows learning to be heightened.
3) IVEs used within constructivism allow first-person experiences.
4) Exposure to the medium develops the ability to learn with and from the technology at the same time.
5) Feedback and affordances of an IVE are important in guiding the learner's knowledge construction.

6) Size manipulation, transduction and the reification of abstract ideas can create learning environments that were previously unable to exist using traditional strategies.

A summary of concerns and drawbacks include:

1) Not everything that is possible in an IVE is desirable.
2) There has been a change in the nature of learning due to the impact of new technologies which needs further exploration, critical analysis and research.
3) The collapse of the space between the viewer and the IVE has direct impact on reflection and understanding, which can have drawbacks.
4) Design for physical and perceptual comfort in an IVE should be a major concern for people with a range of abilities. If it is not designed well, people will not use it and it will lose its value as an educational tool.
5) The time given to learn with and from an IVE as an educational tool.
6) Cost, maintenance, upkeep and obsolescence are a major concern in using IVEs in education.

Although the relationship between constructivism and immersive virtual environments creates unique learning spaces, this summary shows that this relationship is both layered and complex, with many considerations concerning the value of using them in education, the least of which is the undervalued and understudied concern of how they affect learners emotionally. However, the convergence of the theories of constructivism and IVEs has made IVEs especially appealing to the informal learning sector, which includes

museums. In the next section I will explore the conceptual and practical territory formed by this convergence.

7.0 EXPLORING THE CONVERGENCE: CONSTRUCTIVISM, IVEs AND MUSEUM EDUCATION

In the last few sections, it has been seen that there is a struggle between objective and subjective approaches to learning and knowledge; the position of dominance has changed over time. The history of education in museums has not been immune to this struggle, as museum education develops its own history. In this section, a brief review of the developments in museum education will be added to the relationship between museums and technology. The defining elements of IVEs (presence, immersion, interaction, etc.) will then be matched up with constructivist learning principles, and how these combine with the aims of current museum education. The majority of information about these relationships, as has been stated, comes from both the disciplines of science, and from science and history museums. Art museums rarely use interactive exhibits, and therefore there has been little research focusing on the use of IVEs in art museums.

One museum educator and researcher who has a distinctly lucid and thorough understanding of the place of digital technologies in current museum education is Richard Hawkey (2004) who will be heavily relied upon in this section. As previously stated, museums are not one homogeneous entity, but diverse institutions "with a dual purpose: the creation of new knowledge (research) and dissemination (education)" (Hawkey, 2004, pg. 8). In the past, the main function of museums was to collect and conserve artifacts for the viewing public with little more than labels written by expert curators to give the public information. As Hawkey (2004) states, if any learning programs were offered by the museum, they were for school children taught in separate school rooms with little, if

any, contact with the exhibition or real artifacts and artworks. Unfortunately this is still a common perception today by non-museum visitors. However, Hawkey also states that eventually, exhibitions began to change. Visitors could not, after all, be expected to learn for themselves, to see the world from the curator's perspective, without support and guidance. "A new generation of exhibits emerged-in which specialist interpretative devices were utilized to make clear the message that the visitor was expected to heed" (Hawkey, 2004, pg. 5).

Because of this, artifacts often became secondary to the message the museum was trying to get across. Yet with the widespread development and use of digital technologies within museums for varying purposes, including education, the perception of the museum educator also changed (Hawkey, 2004). Coinciding with this was a new emphasis on lifelong learning in many parts of society along with the need to justify the use of public funding in museums (Hawkey, 2004, Black, 2005). *And thus emerged a new type of exhibit, with the visitor in mind.* This created a change in most museum mandates to become institutions of education with a full range of audiences, no longer just school children. Perhaps overly idealistically, Hawkey states that museum exhibitions and the educational emphasis changed museums from places of transmissive information using obscure texts for edification, to places where the audience is invited to participate in exhibition development. This includes exhibits and activities founded upon digital technologies. "Today, museums provide a plethora of different kinds of learning activities" (Hawkey, 2004, pg. 6).

Current learning in museums is not focused on formal curricular goals (such as in a school) but needs a wider interpretation that focuses on a range of behaviors, skills, dispositions and experiences of the visitor (Hawkey, 2004). The multidimensional nature of museums has significant advantages over other types of informal learning institutions. Even this distinction between formal and informal learning environments has been undergoing significant change for the last twenty years (Black, 2005). Informal learning can be seen as that which is intrinsically motivated, non-linear and self directed and a focus on this has allowed both a "push" towards informal learning (Hawkey, 2004) and a valuing of learning outside of formal institutions such as schools and universities. Much of lifelong learning has focused on training with the use of digital technologies. This also gives the museum both impetus and advantage when incorporating digital technologies into their exhibitions, such as IVEs. As Gros (2002) has stated, new technologies are changing the way we learn at an accelerated pace. Thus the focus is changing from what a person "needs to know" to building on what a person does know (Hawkey, 2004). This gives a broad range of learners the opportunity to do so, across varying age groups and education levels.

In Hawkey's (2004) review of recent approaches to the advancement of museum education, he states that many researchers, although not necessarily approaching museum education from the same viewpoint, come up with similar conclusions about learning in museums. In the examples that he provides, explicitly or implicitly, many museum educators are leaning towards constructivist learning principles.

Within constructivist approaches to designing and planning museum exhibitions, learning should be "free-choice". Yet what exactly does "free-choice" learning mean? Basically, in most learning environments, people will choose what they learn based on motivation, either intrinsic or extrinsic. If one must learn a new computer program in order to keep one's job, and the learner cares to do so, the learner will accomplish this. In relation to museums, a visitor may enjoy an exhibition, but not really learn anything at all. This may be a result of lack of understanding and/or lack of motivation to do so. Therefore, the museum, to reach educational goals, must offer clear, cohesive exhibits which are stimulating and engaging in multi-disciplinary formats to attract and stimulate the visitor. This may not guarantee learning, but at the very least provides learners the tools and interest to build upon personal knowledge. This is opposed to traditional didactic displays, which although informative, have very rarely, if ever, been described as particularly engaging for the general public.

Thus, as Hawkey (2004) explains, motivation is now considered a key element in learning in museums. "Intellectual progression should be provided within particular programmes and within the museum context as a whole, such that visitors are challenged, stimulated and can develop" (pg. 18). That is, the visitor should be drawn into the exhibit through different avenues, including learning styles and multi-media approaches. This shows that learning strategies do not have a simple, unified approach but should be broad and encompassing for a multitude of visitors.

A summary of Hawkey's viewpoints on current learning in museums is:

- Constructive dialogue rather than as a passive process of transmission.
- Takes on the role of privileged participant rather than that of expert.
- Requires evaluation of the relationship between museums and formal learning institutions such as schools and universities.
- Desires to facilitate lifelong learning by providing a free-choice learning environment that permits many pathways and possibilities of learning.

In relation to museum education and technology, the true potential makes itself clear in the decision-making allowed the visitor through interactivity. This, however, is dependant on how each museum views its visitors. For example, does the museum consider visitors as passive recipients of knowledge or does the museum foster active inquiry in its exhibitions? Is the museum's focus in its educational approach on providing answers or on promoting questions? (Hawkey, 2004, pg. 24). Another important question to consider is: how will museums in the future incorporate learning media in exhibitions that embrace learners on all levels of learning spectrums? Current IVEs and their evolution in the future have the unique ability to address this problem. The software involved, as well as the incorporation of their unique attributes as previously understood and outlined outside of current interface constraints, allow visitors of many abilities to enjoy the museum experience. This is because IVEs may allow differing affordances, as previously outlined, for different people. It is not a leap of the imagination to see that programming can be incorporated to involve those with diminished hearing, sight, mobility and literacy levels. Although the expense of these types of technologies is an

important issue, programming allows IVEs to address many senses on varying levels within the same program, which may, in the end be cheaper than other methods.

As has been explored previously in this thesis, digital technologies, including IVEs, facilitate and/or accelerate long-established learning tasks. More importantly, they permit activities that would otherwise be impossible. They allow unparalleled opportunities for learning. "This includes new approaches to learning by different audiences and for different purposes" (Hawkey, 2004, pg. 2).

Although objects are a unique and important attribute of what museums offer, currently museums are also seeking the "holy grail" of interaction (Hawkey, 2004). Yet many museums fall short of this, offering so-called interactives that are little more than multiple choice scenarios, or push-button, pull-lever exhibits. There is a naïve assumption that digital technologies are inevitably interactive. To counter this, there should be clear learning objectives and provisions for learner choice and initiative. Without these, there is little to promote the learning potential of truly interactive exhibits within museums. Used to their full potential, digital technologies, including IVEs, allow collaboration between museum and learner, between various institutions, and between learners themselves (Hawkey, 2004).

Conversely, digital technologies also allow very personal, direct experience and interpretation of exhibits. "Freed from the constraints, both physical and interpretative, of the curator and exhibition designer, the learner can use appropriate technologies to provide a dedicated and personal mentor" (Hawkey, 2004, pg. 3). Thus, digital

technologies in museums allow both social collaboration and independent learning. Exciting examples include those between real and virtual learners and of learners creating their own associations within and between collections. "A new set of relationships is emerging, between objects, learners and digital technology, in which museums are, above all, places of exploration and discovery" (Hawkey, 2004, pg. 4).

Museum educator Roussou, in a similar vein of thought explains that:

> Museums realize that they are among many components in a panopoly of cultural amenities and that the computer technology can help them quantitatively and qualitatively expand, deepen, and enhance the museum experience for their visitors (Roussou, 1999, Immersive interactive virtual reality).

To paraphrase further, Roussou (1999) states that the potential to transcend the physical location of the built environment and the growing sense of the educative function of the museum, juxtaposed with the commercial pressure on museums to bring in funding has lead museums to consider virtual reality as a necessary component in the arsenal of tools to educate, entertain and dazzle (pp. 2-3).

Thus museums and museum education can be seen as currently existing in a point of transition or what Simon Knell, head of the Department of Museums Studies at the University of Leicester in the UK calls a "technology driven mutation". Particularly in Europe, but certainly becoming a concern in North America, is the dramatic idea that there is a "revolution at hand" (Knell, 2003, pg. 132) in museums. As Knell states "the

opportunities provided by technology have developed so rapidly and become so pervasive" (2003, pg. 132) that computer scientists have joined up with academic researchers and are becoming intimately involved in changing museum missions. He also offers the somewhat overly idealistic view that museums have the power to both reshape and be reshaped by society and social practices. What this means in our current information-driven society is that it:

> Will fundamentally alter everyday practices, and perhaps change the position of museums in society. With digitisation becoming the new watchword for access and preservation, the future for museums appears to be one of new spaces, new collections and new audiences, and rather different risks and opportunities (Knell, 2003, pg. 134).

Knell then makes an important point that seems to have been somewhat overlooked by other museum and technology researchers. What he states is that although it is important to be aware of the range of possibilities of new technologies, the more realistic view is that the market and the consumer will define the actual use, which will be closer to everyday cultural practices. "This is not to suggest that everyday practices cannot be fundamentally altered by technological change, but rather to say that societies operate through embedded cultural practices which are not so easily displaced" (Knell, 2003, pg. 135).

Although these newer technologies exist and offer the opportunity of the new, we still read books, watch movies, and use the internet as though it is a vast reference book (Knell, 2003). Therefore, although a current novelty, IVEs may not be used commonly in

any educational forum for quite some time, or at least until they are integrated into everyday culture, although with the current advent of video games that incorporate full body movement, we are certainly coming close. Whether or not this is true, as has been stated by other researchers, remains to be seen over time. As with most technology, IVEs will become increasingly affordable as they are integrated more fully into mainstream culture.

As has been previously mentioned, but deserves to be reiterated, many educators have concerns about the purpose of using IVEs in museum education. Museum educators must thoroughly understand the potential benefits and drawbacks of this technology. For example, when speaking of museums and digital technology, Knell questions the interactivity of modern edutainment centers (such as video games) in many homes, and museums today "where there is often no logical point to the interaction and no relationship between action and outcome, and where – because there are no real objects – intellectual depth is illusive" (2003, pg. 141). This is a good point, yet one that may oversimplify findings of research done with educational technologies such as the blurring boundaries between real and virtual. It becomes critical that IVEs are not used only as novel devices or crowd pleasers, although these too have benefits. As a learning tool in museums, IVEs should aim to capture that "illusive" intellectual depth. As previously mentioned it is "more suitable to avoid the idea ..... that "virtual" mediated objects are less real because they only exist in people's heads" (Mantovani & Riva, 1999, pg.7). As Hawkey (2004) notes:

> Questions of real or virtual also have far less meaning even than four or five years ago, as sensitive and appropriate use of technology is seen to enrich the experience of learning from objects and exhibits, rather than competing with them (pg. 29).

As challenging as it may be for museums to keep up with changing technologies "Museums will face up to this challenge in their usual opportunistic fashion: through institutional and personal adaptability; the pragmatic exploitation of opportunities which arise from change; and the use of long-established collaborative methods of working" (Knell, 2003, pg. 143).

At this point in the discussion, I want to shift the focus from the current state of museums and technology to a more concise discussion of how IVEs can be used in museum education through the visitor's meaning making.

The terms "meaning making" and "constructivism" according to Hein (1999) are often used synonymously. However, he points out that:

> Meaning making is a general term that refers to what visitors inevitably do in museums. Constructivism is a particular educational theory that not only acknowledges visitor meaning making but uses it as a central component of a definition of education (pg. 15).

In "Is Meaning Making Constructivism? Is Constructivism Meaning Making?" Hein (1999) explores the links between constructivism and meaning making within the

framework of museum education. At this point, the distinction between traditional objective and transmissive based learning and constructivism does not need to be reiterated. Generally speaking, as Hein asserts, meaning making within current theories about perception and learning conclude that humans interpret data or information through their senses which creates personal interpretations. In addition, we constantly select from and organize information from our world, including its symbols and surrounding culture in a sense making process. Hein takes the Piagetian view that we do this naturally, we are not born knowing the world but enhance our knowledge through experience. In addition, Hein states that there is significant research by cognitive psychologists that inform us that all humans construct knowledge. Of course, this doesn't mean that meaning making is something incorporated into all methods of pedagogy. There are still many educators who ignore possible personal interpretations and meanings made by learners. This, as Hein ascertains, still "influences education in general and exhibit design specifically. [Yet] whether we like it or not visitor meaning making is an inevitable consequence of opening museum exhibits to visitors" (1999, pg. 17).

Thus, what is important here is "this evidence on the emphasis on the process of learning and individual meaning making" (Hein, 1999, pg.16). Whether calling it constructing knowledge or meaning making, "learning *is* meaning making" (Hein, 1999, pg.16). Thus the relationship between meaning making and constructivism is not that they are the same but that the learning theory of constructivism embraces meaning making as a learning practice. In relation to museums, this means that visitors don't necessarily learn what is

intended in an exhibit or in the sequence or structure provided by the museum curators and educators, but by their own interest and personal experiences.

In this way it is important to understand that "if personal meaning making is inevitable, then it is essential to find out what experience visitors bring with them to museums" (Hein, 1999, pg. 17). Next, museums should make an effort to find out what experiences, knowledge and expectations visitors bring with them to museums, what meaning they make from exhibitions and to use this information to inform further exhibition design (Hein, 1999). This becomes a focus for visitor studies: to determine the links between the diverse audience of an exhibit and differing exhibition settings, which should be conducted with each new exhibit (Hein, 1999).

The relationship between meaning making and constructivism in museum exhibits translates to the following points (Hein, 1999, pp.17-18):

- This relationship focuses on the possibilities for visitors to make new connections and expand the scope of their possible understandings, rather than focusing on particular concepts visitors might learn.
- Leads to a concern about the influence of the entire environment of an exhibit on the visitor.
- Encourages exhibit designs that provide alternatives to a linear presentation of information.
- Meaning making is not only accepted but encouraged and accommodated.
- Offers visitors the opportunity to validate and express their own interpretations.

- This relationship within museum exhibits contributes to a rich and interesting perspective on the same material.

With this understanding of what meaning making is and how it relates to constructivist learning theory, attention will be turned to the relationship between these concepts and IVEs. Just as constructivist learning theories embrace meaning making, they also embrace IVEs. Although IVEs were not created to meet the criteria of any specific learning theory, their connection to both constructivist learning and meaning making is actually quite compelling. In this next section, the specific attributes of IVEs will be united with constructivist principles and meaning making in museums. Many of these attributes, in all three categories are separate entities, but overlap and work in tandem, much like the varying learning approaches under the umbrella of constructivism.

Earlier, in chapter 3, the various attributes of IVEs were outlined and explained. That section focused primarily on the perceptual state of presence, but also outlined other important attributes of immersive virtual environments that allow a user to feel that they are within an immersive and interactive environment. Beyond presence, these other attributes were described as: attention, ambiguity, affordance, poly-sensorality, immersion, and interaction. These are unique elements of IVEs, and as previously described, when combined with constructivist learning principles allow unique learning opportunities.

In addition, this chapter explored the relationship between digital technologies (of which IVEs are a part) and museum education. Once again, constructivism was shown to be a learning theory that can both champion and embrace the learning opportunities IVEs offer. Meaning making is a current "buzz word" in much of museum education discourse, and through Hein (1999) the distinctions and parallels between meaning making and constructivism were outlined. In this next section, I will draw relationships between the attributes of IVEs, constructivism and meaning making in order to create a cohesive understanding of how IVEs can be unique learning spaces within museum education, summarized in Table 1 below, and discussed further afterwards.

Table 1- Relationships between Immersive Virtual Environments, Constructivism and Meaning-Making

Attributes of IVEs	Constructivist Learning Principles	Meaning Making in Museum Education
1) Presence- the sense of "being there" and "making sense there" in a computer generated environment.	- learner creation of personal meaning and linking of new ideas to existing knowledge; social collaboration.	- knowledge of personal experiences and ideas visitors bring with them to exhibits; validation and expression of visitors' own interpretations.
2) Attention- coherent stimuli and events allow users to focus on the environment.	-novelty; opportunities for both engagement and self initiated interest.	-influence of the entire environment on the visitor.
3) Ambiguity- all environments and everyday situations have some ambiguity which can be solved by a shared context of meaning between participants within an IVE.	- learning experiences exist in a social context; learning is both an individual and collective activity mediated by cultural symbols and tools.	-influence of the entire environment on the visitor.
4) Affordance- The possibilities or opportunities the environment affords in which people can perceive both themselves and the possible actions they can make through exploration. It is a sense-making process.	-learner autonomy and initiative; opportunities for engagement and self-initiated interest; social negotiation of meaning; guidance of learner knowledge construction.	-influence of the entire environment on the visitor; validation and expression of visitors' own interpretations.
5) Poly-sensorality- multi-modal presentation in the IVE allows an environmentally rich experience by addressing as many of the sense as possible.	-a rich learning experience can be accomplished through full engagement in a cohesive context.	-influence of the entire environment on the visitor; expound the scope of possible understandings and connections visitors can make.
6) Immersion- the perception of being enveloped by the environment where one affects and is affected by the environment.	- Learner control and decision making; engagement.	-influence of the entire environment on the visitor.
7) Interaction- In an IVE this is concerned with user control and decision making in which the environment should respond. This gives a direct sense of engagement that creates an active environment.	-personal construction of knowledge through active participation in the learning environment; learning through problem based approaches.	-influence of the entire environment on the visitor; validation and expression of visitors' own interpretations.

1) Presence: The IVE attribute of presence was previously defined as both "being there" (Grau, 2004) and "making sense there" (Mantovani & Riva, 1999) in a computer generated environment. Presence is important to the mental processes of attention and

informs how we perceive immersive virtual environments. To achieve a feeling of presence is dependant on the various attributes as outlined in chapter 3, which are also outlined below.

In relation to constructivist principles of learning, presence as making sense there is most clearly related to active (not passive) learning, personal interpretation, construction of knowledge and learning, and engagement (which includes motivation). Much of these constructivist principles are dependant on context- the interrelated conditions that allow experience and understanding. In light of presence, this means that in an IVE, context is contingent on the total response of the learner to being in the environment. Just as constructivist principles work in tandem, presence relies on the hybrid application of all of our sense making capabilities in order to affect and be affected by the environment, to understand the environment.

Although presence researchers tend to come from science backgrounds, and meaning making tends to fall under the domain of museum educators, "meaning making" and the ontological perspective of presence as "making sense there" have very obvious parallels.

I have established that for the purposes of this thesis that if presence is "making sense there" in an environment then they are the same. Presence is contingent on the successful negotiation of both the technology and symbol systems within the IVE. This successful negotiation also relies on the other attributes listed below. The ultimate objective of presence in an IVE is to create a vivid communication experience (Riva et al., 2003).

This vivid communication experience is achieved by the full immersion of the user's senses into the IVE. Likewise, it has been stated that in meaning making, humans interpret data or information through their senses which are then channeled into personal interpretations and experiences. Thus we can see that if presence (making sense there through the successful negotiation of the environment) is achieved in an IVE, this unlocks the potential for meaning making which is also dependant on making sense of the information from a surrounding environment. To draw further relationships, Riva et al. (2003) state that "people will naturally and intuitively select and use technology according to their own needs" (pg. 78). Similarly, Hein stated that meaning making, whether incorporated into a pedagogic approach or not, is inevitably what we do, it *is* learning. These are both natural behaviors of people making sense of and learning from their environments and the personal meanings they may hold.

To summarize these parallels, if an IVE successfully supports user's natural actions and perceptions, the psychological state of presence as "making sense there" inevitably will happen. It seems but a short leap to state that when "making sense there" presence happens in an IVE, meaning making will also occur. If meaning making *is* learning, and I argue that it is, presence in an IVE allows meaning making. It then follows that presence allows learning. Presence in an IVE is what unlocks the potential for meaning making and thus learning in a museum setting. Additionally, both presence and meaning making allow vivid personal experiences based on the autonomous decisions of people as they make sense of the environment around them.

In order to exploit meaning making in learning within an IVE, those that design it will have to have a good understanding of visitors' personal experiences and ideas in addition to an understanding of the underlying principles of presence. In addition, in line with constructivist approaches to learning and as an element of meaning making, the validation and expression of visitors' own interpretations should be exploited in an IVE.

2) Attention: This is related to presence, and has been described as a psychological state that allows focus on stimuli and related activities and events. This focus is aided by a coherent set of stimuli in the environment, that is, the sensory channels exploited by the IVE must make sense to the user. Novelty, immediacy and the uniqueness of an IVE experience also allow focus which enables presence through becoming more involved in the environment. The combination of coherent stimuli and novelty will create a greater degree of attention because it will pique the user's interest.

As previously outlined, narrative, novelty and personal choice in learning environments are aspects of learning that are championed by the constructivist approach to learning, and afforded by IVEs. As Hawkey (2004) has stated, these are also aspects of museum exhibits that are designed with the visitor in mind. For example, it has been discussed that narrative in an exhibition allows visitors to frame their experience, which makes it easier for them to add to their personal interpretations and experience. Particularly in science and history museums, narrative is an element that has been incorporated in most exhibitions, which can be carried further in an IVE, as visitors may actively add their own interpretations directly into the database.

3) Ambiguity: This is an unavoidable feature of everyday life. To reduce ambiguity, frames of reference are set up in our cultures through social negotiation. This shared meaning allows social actors to navigate uncertainty in different situations.

Within constructivism, this has been discussed in relation to the use of symbol systems, and social collaboration. This approach consists of conceiving reality as a series of socially mediated activities, and through appropriation we take from our experiences the tools, instruments and symbols in our society and incorporate them into our existing knowledge. This is very close to the definition Hein (1999) gives for meaning making, and so we can see how constructivism exploits this principle in its approach to learning.

In an IVE, intuitive interfaces and affordances of the environment allow first-person experiences, that is the subject/object boundary is blurred and learning is direct and personal. In relation to meaning making, on an individual level, visitors have the opportunity to validate and express their own interpretations within an IVE through having direct impact on the environment. Social negotiation of the symbol systems used in an IVE is accomplished through collaboration. Thus, differing interpretations of subject matter contributes rich and interesting perspectives on the same material.

4) Affordance: Affordance has been described as the possibilities that the environment offers or affords. It is a theory of perception in an IVE and is dependent on the context of the environment. What surrounds the user gives the user the cues needed to interact successfully in the environment, and this is accomplished through exploration. Closely

related to presence in this way, affordance allows a sense-making process of the environment to occur.

From a constructivist perspective, successful interaction means that through the use of engagement (which includes motivation) and opportunities for self-initiated interest, the learner can perceive what is possible in the environment. It is debatable of course that any museum exhibition can actually offer such an interaction, but if a museum is using constructivism in its pedagogical approach, then this is a goal that can certainly be aimed for. In an IVE the visitor can both affect and be affected by the environment, which is an important element of affordance. Constructivism has been criticized for its seeming lack of learner guidance, but through affordance and exploration in an IVE, the learner can be guided without losing autonomy or personal initiative. In a museum exhibition, and through meaning making, this means that there should be a concern about the influence of the entire environment of an exhibit on the visitor. An IVE used this way also allows the possibilities for visitors to make new connections within their previous existing knowledge structure and also between elements in the exhibit.

5) Poly-sensorality: is the use of multiple senses in an IVE environment. Using multiple senses in any environment allows fuller engagement and the possibility of an environmentally rich experience. In exhibitions, and in IVEs, this is dependant on a cohesive context for the experience, which, as previously outlined, can be accomplished mainly through affordance, narrative and negotiation of the symbol systems incorporated. The more completely and coherently all the senses are stimulated, the greater the

capability for experiencing presence. Poly-sensorality links constructivism and meaning making through the engagement factor.

In relation to meaning making, when as many senses as possible are addressed, this expands the scope of possible understandings and connections visitors may make. This is because they can use a multi-modal approach to their interpretations. This also corresponds to diverse personal learning styles- i.e. those that prefer to learn visually, or/and through touch, etc.

6) Immersion: Immersion is the experience of not only "making sense there", but being "enveloped there". It is a process and change from one mental state to another, characterized by being included in and interacting with an IVE (Grau, 2004). By the very act of immersion, one is affected by the surrounding environment.

This allows direct, personal experience, which is an important component of both constructivism and meaning making. Direct personal experience and feeling enveloped within an IVE allows greater learner control and decision making because they feel actively engaged with the environment, not separated from it, which is one of the defining features of IVEs, as opposed to other types of media. Although meaning making does not discuss immersion as a principle, it makes sense that one should feel immersed in an environment in order to take first-person experience of the symbols and other information in order to construct personal knowledge. Within an IVE and museum

exhibition this translates into visitor centered exhibits that are aware of the impact of the complete environment on the visitor.

7) Interaction: Interaction is the user control and decision making that allows the learner to feel both present and immersed in the environment. As previously stated, this goes beyond the typical push-button, pull-lever approach to interactivity seen in many museums. Black (2005) describes interaction as not "hands-on", but "minds-on", which means that the visitor should be both motivated and engaged when interacting in an environment. An IVE allows many levels of user engagement through poly-sensorality, and feedback through affordances in the environment. In an IVE this should be intuitive, and the IVE should respond to user action in order to produce a more direct sense of engagement, presence and immersion. This heightens the ability for the learner to make sense of where they are and what they are doing. As a constructivist principle, this makes an allowance for the employment and validation of knowledge construction and meaning making.

7.1 *Summary*

Just as we saw in chapter 5, varying approaches to pedagogy have fallen under the umbrella of constructivism, such as the socio-cultural and experiential approaches to learning. Similarly, in IVEs there are a series of attributes that allow them to be unique learning spaces, particularly in museum exhibitions. In both, there are overlaps, yet in tandem both the pedagogical approaches of constructivism and the attributes of IVEs work towards a greater goal- the personal experiences and interpretations of the people using IVEs or visiting museum exhibitions. This section has focused on drawing relationships between constructivism, IVEs and meaning making. To my knowledge, this three-way interface has not been addressed in current literature in this particular way.

Although this thesis has been mostly exploratory and literature based, it has become clear that although IVEs, constructivism, and meaning making have been developed and researched in different and often isolated professional disciplines, some significant overlaps have emerged. While not intended by the disparate researchers in these fields, I have drawn them together in order to identify the potential for a more meaningful and effective personal learning experiences for museum visitors. Meaning making is concerned with the influence of the entire environment on the visitor, which is also a key concern in the development of IVEs to produce a sense of presence. I find it quite interesting that, although borne of different research objectives, IVEs and meaning making have such a strong relationship.

In addition, IVEs are capable of encompassing constructivist approaches to learning and recognizing meaning making as a pedagogical approach. Based on the technology, IVEs are multi-dimensional spaces that are defined only by the imagination of those who create them. There is much that is still unknown about this technology. The summarizing point I want to make is that they can be an incredibly useful tool in achieving the aims of both constructivism and meaning making in a museum context.

8.0 **CONCLUSION**

Although virtual environments are becoming a part of our everyday technological experiences, particularly in the entertainment realm, the general topic is only vaguely understood. There is very little research that goes beyond explaining what the technology is or how it works, even less that considers the personal impact on the user (beyond whether or not presence was achieved). The overall goal of this thesis as stated in the introduction was to look at museums as a catalyst for including new technology as a pertinent educational and social tool that involves both positive and challenging experiences for the visitor. Art museums are one particular kind of museum; however, the majority of the literature found dealt mainly with science and history museums. A conceptual synthesis in this thesis is: 1) an exploration of the definitions of IVEs and a short history of their development; 2) definitions of the core attributes of IVEs; 3) learning theories that are both compatible with and embrace IVEs; and 4) a look at IVEs as unique learning spaces which was then applied to museum education, constructivism and visitor meaning making. One of the driving goals through all of these sections was to move beyond the time bound nature of current immersive virtual environments, that is, a focus on how the technology changes, and focus more on how they affect learning, experience, and personal interpretation of the users.

There was a three part question asked at the beginning of this thesis: 1) What are the elements of immersive virtual environments? 2) How are they unique learning spaces? 3) What are the possible applications to museum education and visitor meaning making in museums? These questions were addressed in the following ways:

1) Through an exploration of the research, I found the main elements of IVEs to be presence, defined as "making sense there" in an environment, in addition to the need for attention, the successful negotiation of ambiguity, the possible affordances of the environment, poly-sensorality, immersion as the sense of being enveloped by the environment, and interaction, where user control and decision making is enhanced and exploited in the environment.
2) These attributes create unique learning spaces by offering learner, not instructor, related practices, direct personal learning experiences that incorporate personal interpretation and construction of knowledge, and engagement through attention, novelty, narrative, and social context. In addition, IVEs allow learners to access the unrealizable or inaccessible, motivate and engage learners, and can teach complex topics using feedback and the affordances of the environment to modulate current knowledge structures. This allows full interaction where the learner can affect and be affected by the environment, and the creation of learning environments that were previously unable to exist through size, transduction and reification.
3) The applications of this to museum education and visitor meaning making, as outlined in the last chapter, show that when presence is achieved in an IVE, particularly in an exhibition that embraces the constructivist approach to learning, presence becomes the key that unlocks the door for meaning making to be both recognized and cultivated.

Throughout the exploration of IVEs as learning spaces and educational tools in this thesis, it is clear that IVEs are geared to have a strong place in current museum education.

However, we must question, very seriously, what new technologies bring to education and how, as museum educators, we are going to use them for reasons that go beyond the novelty of what they offer to visitors. The use of technology does not always lead to visitor's reflection on their learning (Gros, 2002). Museum educators must ensure that the technology is adapted for education (Castle, 2004; Gros, 2002) rather that education is being adapted to technology "just because it can". So, although IVEs can match up with constructivism this does not guarantee that all of the goals of constructivism and meaning making will automatically occur. The designers and educators in museums must make a concentrated effort to see that learning and meaning making happen. If IVEs are not the most appropriate educational tool to use, if more appropriate and cheaper resources are available to meet the needs of the visitor, then of course those tools should be used. Little research has been done to clearly prove that IVEs allow learning or personal and vivid experiences to happen. The cost of IVEs is another major limitation, not only of the purchase of the technology, but also its maintenance and updating. As this type of technology becomes more popular, there will likely be a marked decrease in the cost of implementation and maintenance- as we have seen with most digital technology. However, obsolescence then becomes a major hurdle.

More research on digital technology as learning devices needs to be done. There is also a need for research that uses specific approaches to evaluate visitor preferences and to

identify related recommendations for the use of this specific type of technology in museum education. It is quite possible that current museum evaluation methods do not encompass the various attributes of on-site digital technologies. Therefore, it is important that research and evaluations have an understanding of the underlying attributes of these technologies, such as presence, immersion and interaction. Museum education must consider both positive and negative aspects of IVEs, and all digital technologies, when applying them to specific learning environments.

As the technology becomes both cheaper and widespread, the focus of research should shift from an emphasis on the interfaces, transducers, hardware, software, and the novelty of this technology towards addressing the emotional, self-reflexivity, and personal interpretations of the museum visitors that experience these technologies. Much research to date is focused too much on the nuts and bolts of the technology and less on the impact it has on the actual users (emotionally, cognitively and experientially). Further research should focus on how the museum environment (including IVEs) impact visitors, how this environment relates to the exhibition experience as a whole, and what the users' experience was. Some questions for further consideration are: What are the long term emotional and learning effects of these types of technologies? How does the possible collapse of space between the visitor and the environment affect meaning making and knowledge construction? If an IVE is used as an adjunct to a larger museum exhibition, did it punctuate the points, experiences, and ideas the exhibition was trying to get across?

In the words of Hawkey (2004):

> A new set of relationships is emerging, between objects, learners and digital technology, in which museums are, above all, places of exploration and discovery. In the museum of the future, distinctions between real and virtual, already blurred, will matter even less as both museums and learners better understand the processes of inquiry and of learning itself (pg. 4).

In concluding this study, I believe that this thesis has offered useful and novel insights into immersive virtual environments, museum education, and meaning making by and for museum visitors. I believe that IVEs can create unique learning spaces within museums, and offer exciting potential for visitor meaning making. How museums embrace the potentials of this technology remains to be seen.

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