# Experiencing Conceptual Design in Three Dimensions: An Evaluation of CAVE-like Environments for Interior Design Education

By
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# Dedication

To my mother who instilled in me the value of a good education and that dedication, hard work and perseverance pays off.

To my husband Don, you have been patient and supportive, have traveled on homework filled vacations and have been left alone many times but most of all are very much loved and appreciated.

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# Abstract

The purpose of this research is to determine the value of CAVE-like immersive environments to interior design education. The immersive environment can provide experience in and visualization of conceptual designs and life safety elements in interior spaces. In the narrative of lived experience programmatic requirements such as aesthetics, ambience and functional use of space are identified as elements and principles in conceptual design while the narrative of regulatory requirements and life safety markers ensure the safety of users and their ability to safely evacuate in case of emergency. The research aims to identify the possibilities of the three dimensional immersive environment to provide experience, to visualize conceptual designs and to understand the impact of life safety requirements. More specifically the dissertation explores how CAVE-like environments can provide spatial experience to give meaning to conceptual designs and life safety narratives. As an alternate to two dimensional surfaces CAVE-like immersive environments provide a place for exploration, development and assessment of concepts. The methodologies employed in this research included a site visit to CAVE2™ the Electronic Visualization Laboratory at the University of Illinois at Chicago which provided me with first-hand experience and, examples of applications and other research using CAVE™ and CAVE-like environments.  An online survey was used to determine if CAVE-like environments were perceived to add value to design education.  Results suggest a willingness by educators and students to further explore CAVE-like environments as tools to add value to interior design studio teaching and learning by providing experience in an immersive three dimensional environment.

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## 1.0 Introduction: Education, Interior Design and Technology

Growing up my mother maintained that "education was very important". While I heard what she was saying the value and meaning escaped me. I never gave it much thought, there were no role models, societal expectations seemed to be focused on making a living; careers were for the privileged. Years' later life experiences taught me differently and I finally understood the value, meaning and connection between education and the ability to live my life doing something I enjoyed. The importance of an education has been ingrained in me ever since. Education was to provide me with knowledge and skills to advance in a career in interior design.

Design school gave me the opportunity to challenge my imagination and critical thinking skills and to develop my ability to evaluate, synthesize and apply information. The design narrative was developed with skills I acquired through an integrated design process to create spaces for meaningful experiences. My designs were presented as plans, elevations and perspectives on two dimensional surfaces or scale models and built prototypes. The narrative complete with characters, plots and locations tells a story about the users of the space, the interaction within the space and the space's ability to support functional use, life safety and the wellbeing of users.

The opportunity to pursue a graduate degree in interior design materialized while in transition between teaching and full time employment. While interior design is the focus of my degree, education and more specifically design education is a primary element of the research. I will explore education in the context of experiential learning and its application to design teaching and learning. I want to define the framework and link between experience and design education.

The design profession and design education have prospered and created successful design projects despite the limitations of presentation of concepts in two dimensions. The two dimensional surface is the most usual method for conceptual representation. Spaces are built from detailed construction drawings. Regardless, the ability for learners to experience being in the spaces they design is restricted to viewing images on the two dimensional surface of a presentation board in perspectives or on computer screens. In my opinion there is an experiential disconnection between the design of spaces presented in two dimensions and that of physically being in the designed space. Learners design spaces to provide experiences for others yet they do not have the opportunity to experience their designs in the built environment; to experience the functional use of the space as users would, the ambience, the interaction with other users and with the space itself. Learners select materials and finishes that best represents a user's culture or need. While the selection of furniture and finishes provide the aesthetic quality of a space, the circulation within the space provides functionality and life safety requirements. How can a learner develop spatial understanding of a space they have not experienced? How can they understand the impact of their design to the wellbeing and life safety of users? My dissertation aims is to study the gap between experience as an observation of design concepts and experience as lived experience in a three dimensional immersive environment.

Technology is significant to my research for three reasons, first and foremost technology, and more specifically digital technology, is so entrenched in everyday life that it merits attention. What is it about technology and mobile devices that so captivates our attention? Digital media is transforming how we live, work, and play and communicate. The second reason is that technology is immersive and transformative, having the potential to provide an immersive three dimensional environment to experience; it potentially provides spatial understanding and an environment where learners can explore, test theories and collaborate. The final reason is that my understanding and ability to grasp the meaning and value of technology has been limited. I want to understand what I am missing and need to contextualize technology's place in my own life so that I can advance in my ability to explore its place in design education. As a result, I will strive to uncover, explore and define technology, its role, options, application and impact for design education. While I am able to use the various software that are now established in design education keeping up with the speed of change in technology, devices and software is difficult and sometimes overwhelming.

In design education technology is often in the form of desktop computers tethered to desks while mobile devices enable students to save CAD drawings on a USB drive and transfer the information to laptops. Software developments such as Revit and Sketch Up have become more prevalent for their rendering and three dimensional capabilities to provide students with more realistic images of conceptual designs. 3D Studio Max animation software transposes two dimensions into three dimensional images to provide animated cinematic narrative walkthroughs of a designed space. With the use of a mouse the participant is able to navigate in and out of rooms, up and down corridors; can stop, advance and turn around. Spatial understanding and directional cues in a simulated environment remain remote on a computer screen. Experience is observed not lived. The study of technology and immersive environments in my thesis is a significant step in understanding the value and meaning to design education. My aim is to contextualize technology's role as a tool in design education and evaluate its effectiveness in supporting design teaching and learning beyond the CAD plan and virtual walkthroughs.

We live, work and play in a three dimensional world at full scale. We immerse ourselves in our cities, town and neighbourhoods. We operate in three dimensional learning environments. In many design schools space to build in three dimensions beyond the design studio is unavailable, but what if the opportunity existed to provide design students the ability to experience their designs in an immersive three dimensional environment without having to construct them physically? They could experience being active participants in the process rather than being passive programmers. What is technology's role in creating experience? The thesis will explore the technological options that can provide the opportunity to experience designs in a cinematic three dimensional environment and determine if the immersive environment can add value to design education. While my intent is to investigate the possibilities of an immersive environment, I do so in the context of constructing design narratives to provide an experience with meaning for learning. The technology to develop the technical data sets required to initiate the cinematic narrative is not an element of my research as it pertains to an area of expertise outside the realm of current design education. I assume that educators and students will work with qualified programmers to create the immersive three dimensional environments.

I will outline a framework for education, interior design and technology. I will uncover and evaluate their meaning and relationship and how each plays a role in the development of conceptual design narratives. While education provides the foundation of the research, experience provides the context within which education is achieved. Experience can provide design students the ability to be part of the environment they are creating. Unfortunately, the University's ability to provide students a space to build and experience the meaning and impact of their designs remains restricted. The validity of the student's experience relies on two dimensional surfaces and computer screens. Three dimensional immersive virtual environments can potentially provide students the environment they require to experience meaning and spatial understanding. CAVE-like immersive virtual environments can offer an opportunity to add value to design education.

My research will consist of defining education and educational theories and will explore experiential learning and its use in design education. Design teaching and learning provides students the opportunity to develop conceptual design. The design concept will be studied as a narrative that tells a story about the space being designed and the people using the space. Technological options will be explored to determine the value of immersive three dimensional environments as a place where students can be active participants in the spaces they design. As firsthand experience CAVE2™ in the University of Illinois at Chicago will be analyzed to determine the credibility and potential of immersive environments.

CAVE™, CAVE2™ and SAGE™ are trademarks of the University Of Illinois Board Of Trustees. For all intents and purposes CAVE™ refers to the Electronic Visualization Laboratory CAVE™ and CAVE2™ at the University of Illinois at Chicago; any other mention of CAVE refers to a CAVE-like environments. An online survey was disseminated to design educators and learner to determine if they feel immersive three dimensional environments can add value to design education. In addition, I will present examples of applications of immersive environments to support my findings. These examples supplement the contextual use of immersive environments that provide experience with meaning, test theories and opportunities for collaborative research.

### 1.1 First Impressions

Central to this thesis is the ‘experience’ a three dimensional environment that can provide design students. While “experience is the best teacher” (Buchmann and Schwille 30), classroom lectures provide access to thoughts and theories that surround experience. Design studio addresses ideas, experience and theory, but often fails to provide and achieve the experience of a full scale designed space. To experience a designed conceptual space remains a hypothetical scenario presented in the form of three dimensional images on two dimensional surfaces of presentation boards or computer generated rendered images. In a thirteen week semester there is usually insufficient time or funding for students to design and build full scale spaces, or to install prototypical designs in office buildings, hospitals and construction sites to experience the realization of their conceptual designs. This leaves students missing a vital piece of the design process, the final design for evaluation. As a design student my greatest challenge was to understand and visualize the link between concept and reality. Elevation and perspective images on presentation boards were just that – images. They had little meaning beyond the two dimensional surface. Although we see in three dimensions, visualizing in the same manner takes practice, experience and an understanding of the conceptual link between what we see and what we draw.

The virtual space of a CAVE-like environment can bridge this gap and provide the missing link between the representation, the hypothetical design studio scenario and the physical environment. In a virtual environment the various components are assembled to present an immersive cinematic environment allowing the student to experience their designs in virtual 3D.

Daniela Bertol states that “only in a virtual reality application can the interaction between the perceiving subject and the object of perception be possible” (xv). She further defines virtual reality as “the ultimate interface between human and machine” (Bertol xv). This raises several questions about the perceiver and the perceived and whether the adage “seeing is believing” holds true in a virtual environment or even holds true in physical reality? Is perception altered in a virtual environment? And how does the virtual environment differ from reality? Perception is defined as “the process by which stimulation of the senses is translated into meaningful experience” (New World Encyclopedia), whether applied to a virtual environment or a physical reality.

The purpose of designing interior space is to create meaningful experiences. As designers we interpret client requirements to transform spaces into places that signify a client’s culture. “Place identity” (Dohr and Portillo 153) is a term used for a sense of place that captures design thinking and experience. Regardless whether real, virtual or hypothetical, spaces become what we transform them into; they are places that invite real or hypothetical interaction and observation, they “…become dynamic places of lived experience” (Vaikla-Poldma 63). There is no escaping interior space; we live, work and play in them; we interact and engage with and in them, regardless of weather conditions the exterior directs us to the interior for shelter. As designers we have the distinction of having the “greatest impact on the quality of life” (Rengel xi). We transform spaces from mere geographical or geometrical co-ordinates into places that have meaning. The client’s request to be represented authentically through the conceptual design hopefully forms an emotional attachment between the designed space and its occupant and places a value on the experience and objects within the designed environment. A designed environment has different value and meaning to clients depending on how they experience and interact with the space; designers create perceived value by linking the interior space and the objects within to create meaning (Vaikla-Poldma 63). Place represents the narrative of the design that characterizes the client while value and meaning shape their emotional response. What one client may see as an inviting environment another may see as mundane. A client or occupant’s personality will influence their response to the designed environment. Common to all spaces is the three dimensionality of the lived experience. No one lives in a corner or at a specific wall. While our eyes may only be able to focus on one location at a time it is the whole environment that influences our lived experience.

CAVE-like environments through the use of computers simulate conceptual interior designs. Rather than waiting until a space is physically constructed digital space can be experienced at the conceptual phase. Technology has evolved at a rapid pace. Historian David E. Nye notes that it is not until the late twentieth century that technology has come to be associated with computers (15). The computer’s ability to simplify tasks, provide access to information at a moment’s notice and to communicate ideas interactively has been woven into the fabric of society. Integrated into education and the design profession computers provide the means for collaboration. Technology has evolved socially to be a tool inseparable from personal and professional growth. We are seldom without our cellphones and there is a growing need for constant communication, to know at any given time what is happening at work and home. The cell phone provides access to information and friends satisfying the need to stay in touch. Laptops, iPads and playbooks travel with us to enable a seamless continuity of work, research and play. Marshall McLuhan identified the shift in which mediated electronic information began to drive communication from the experience of individuality to the experience of multi-disciplinary connectedness (McLuhan and Zingrone 3). Mediated communication provides the context for experience and transforms physical reality into a perceived reality within a virtual environment. Renowned digital culture theorist, data visualization artist and educator Lev Manovich describes this environment as something “which will let cinema tell its story in a new way” (Manovich 2001). Physical reality is becoming entwined with the virtual world; we are part of a virtual cinematic narrative environment we create for ourselves through the use of technology.

Comparable to the cinematography of virtual environments, conceptual design communicates a narrative. Both cinema and design have their beginnings in their conceptual thinking skills. While the narrative reveals the interpretation, meaning and impact of conceptual design, its content is a multi-layered sequential process dealing with place, interaction and conceptual development. The narrative content in turn reaffirms the concept of a sense of place in interiors (Dohr and Portillo 153). A sense of place in interiors is defined by the components that encompass the whole including furniture, walls, light fixtures, colour, texture and materials. These components are the layers, that when combined creates meaning and value for a lived experience. The educational opportunity for students to experience reality through the use of CAVE2™ technology has the potential to stimulate the thought process of design development.

Many educators believe in the importance of manual drawing skills as an immediate method of recording conceptual development, as it establishes a relationship between the designers hand and their imagination.  The thought process, generated through hand drawn sketches provides an immediate chronicle of the design thinking process and a connection between the pencil, paper and the imagination; sketches can then be translated into 2D CAD to create a platform for the generation of three dimensional digital images (Bertol 44).

The interior design profession demands a computer literate graduate that can transform their thought process into detailed three dimensional renderings of conceptual designs. The design profession has come to rely on the computer as its primary tool for communication with clients, contractors and consultants, the development of construction drawings and conceptual presentations to the clients. Design educators use computers primarily for developing and presenting teaching materials; videos, precedent projects, past student work, and communication with students, colleagues and the professional community.  Their students use the same computer technology to research the requirements for projects, to complete and present their assignments and to communicate with their peers and their professors. Computers provide the rapid transmission of the outcome of these tasks in a digital format. The graphic software provides an alternative visualization of the potential experience of the student's conceptual designs. In a CAVE-like environment the experience of a sense of place and being in place is visually enhanced by three dimensional full scale features. Conceptual designs are presented as they would be in physical reality. Images of the physical space are observed through the use of 3D glasses and presented in full scale.

Current methods of computer visualization use two dimensional CAD drawings as a platform to create three dimensional rendered images of spaces. Conceptual designs are represented as static perspectives or “walkthrough” which provide the observer the opportunity to traverse through a space. The computer operator navigates the space using a mouse to change direction, enter rooms and view objects. This method places the viewer in front of a computer screen where computer generated animated images provide the cinematic aspect of visualization through the use of software such as CAD, Revit, 3D Studio Max, Blender and Sketch Up. Cinema uses moving pictures to tell a story. The cinematic images are captured on film then transported to their intended audience for viewing. Unlike the computer generated model, cinema does not generally provide real time viewing or support audience interaction (Blundell 4-7). A computer generated walkthrough uses a different technique to visualize conceptual design and offers to some extent similar moving pictures as a narrative to conceptual design.

Computer aided design (CAD) is an industry standard for producing construction and presentation drawings. Using a multi-layered structure as an organizational method it records commands in a database management system. The advantage of this computerized method allows images to be drawn in full scale on the computer. Plans, elevations and sections can then be sized according to the required presentation medium. The database of drawing attributes such as length, width and height of doors, walls, and windows are linked to modelling software.  The rendered image offers a realistic three dimensional simulated view of the interior space by the addition of texture and lighting. The development of three dimensional images requires advanced knowledge in using the software, is very time consuming and represents CAD's greatest disadvantage (Bertol 47). Although the walkthrough is an effective method to present design intent, it does not provide the reality of experience offered in a virtual environment in three dimensions at full scale. The user is on the outside looking in. Architect, designer and artist Daniela Bertol captures the relationship between digital media and user experience as follows:

> "Virtual Reality represents the ultimate interactive walkthrough, where the viewer not only passively looks at a video animation, but can also interact in real-time with the path of motion and direction of sight" (52).

This relationship further endorses the importance between the use of digital media and experience to design education. Interior design educators Katherine S. Ankerson and Jill Pable describe the evolution of design education from pencil and paper to computer assisted design expressing their views on the potential use of technology in design education:

> Students enter a world where now, more than ever before, they are a part of a global design community. They must be facile with technology for collaborative design for effective presentation of ideas at all stages of the process (whether through rapid prototyping, animated walkthrough, immersion in a virtual world), and for communication and documentation. They must have an open mind to the critical use of technologies (rather than technology for technology's sake), the confidence to embrace it, and the wisdom to recognize the circumstances of its appropriateness. (Ankerson and Pable 203)

Technology is no longer simply a tool to communicate and gather information. It can also be a tool to provide a virtual digital environment that transforms experience in three dimensions at full scale and provides a new venue for visualizing conceptual designs. The uniqueness of this method includes the participant who becomes part of the cinematic environment and not just an observer. As a participant centered approach conceptual designs are experienced before they are built.

## 1.2 Establishing a Foundation

The purpose of this research is to determine the value of CAVE-like environments to the visualization of three-dimensional images, at full scale, in interior design studio teaching and learning. For the purpose of this research value for design education is defined as giving meaning and usefulness to experience, place and perception. The three dimensional image at full scale acts as an interactive learning environment and offers the ability to experience conceptual designs before they are built.

Interior design education provides students the opportunity to acquire knowledge, explore and apply design elements and principles to develop conceptual designs of interior spaces. The complexities of design problems challenge students to make sense of a project's requirement by translating information into a physical experience. Like a giant puzzle a design solutions contains many components but differs in that the pieces fit in many alternative ways and impact other pieces around them. Conceptual design solutions are resolutions of a multitude of problems (Rengel 5). The development of a conceptual design begins with programming which provides the designer not only a synopsis of a client's requirements for their space but also integrates regulatory requirements necessary to ensure occupant wellbeing and safety. Several months can pass between the programming and implementation stages. During this time clients revisit adjacencies, add additional personnel or modify, delete and increase additional requirements. All of which can impact the final solution. The advantage of a three dimensional full scale environment is the ability to present ideas before they are built to identify areas of improvement, relational interferences and design details. Modifications can be completed and reviewed to substantiate design concepts and theories.

The design studio is an important part of design education; it provides a site for review and inquiry where students are challenged to develop their critical thinking skills. Most conceptual designs are drawn images presented as plans, sections and elevations on two dimensional surfaces.

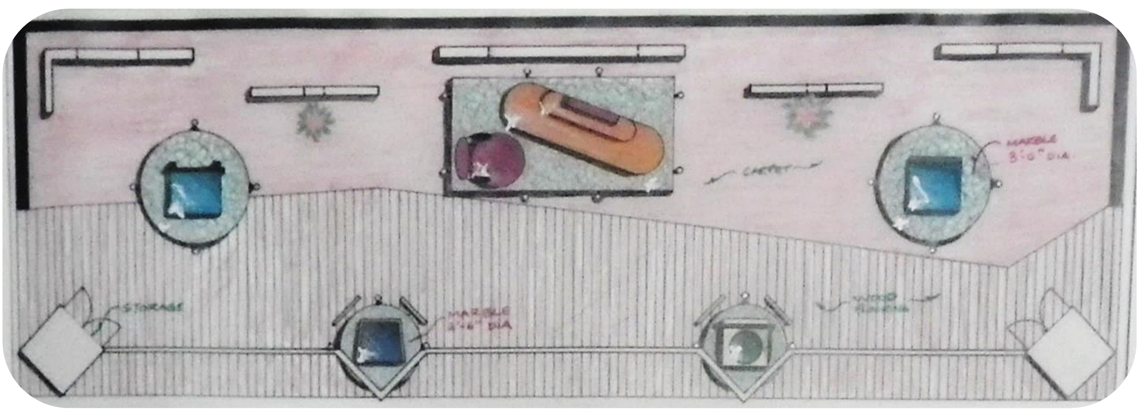


Figure 1 Plan (by author)

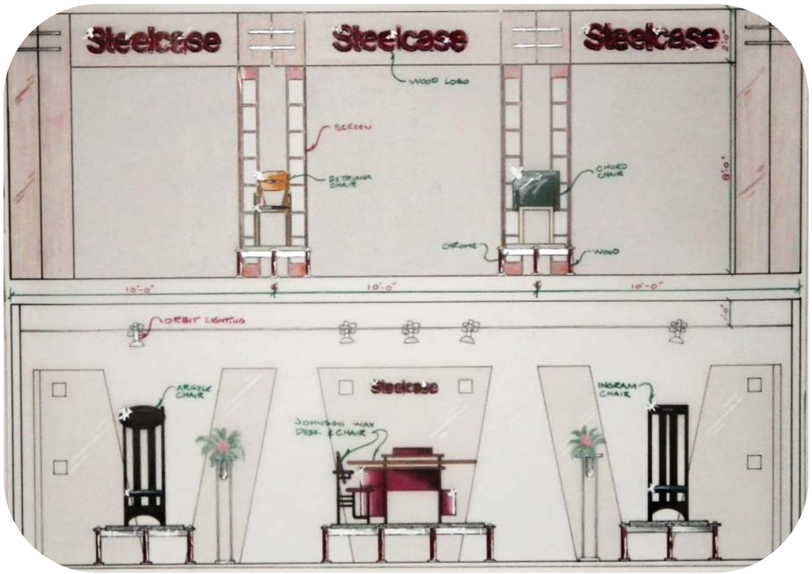


Figure 2 Elevations (by author)

Perspectives offer a three dimensional view of spaces one room at a time. Images on two dimensional surfaces are viewed independently of each other leaving the viewer to connect the spaces by referring to the plan and then the perspectives.

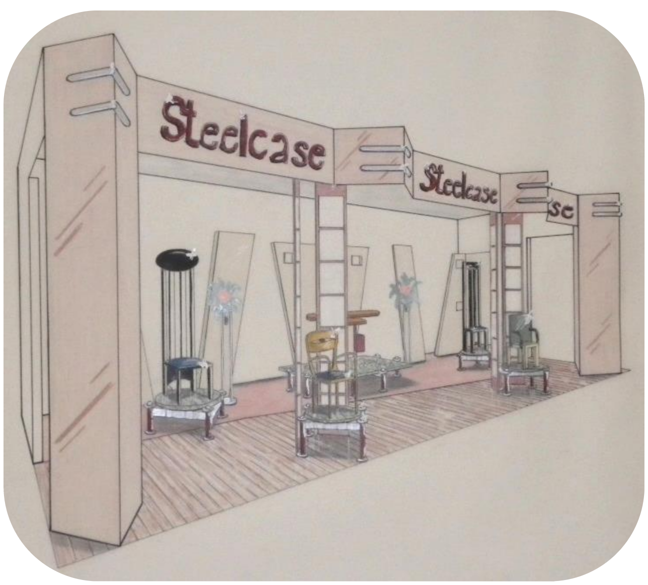


Figure 3 Perspective (by author)

Scale models are used as a built interpretation of a designed space. They communicate design intent in three dimensions. As a design student the three dimensional study model helped me better visualize and understand my concepts, the functional use of space, scale and proportion. More importantly it provided a link between the design concept, the scale of the space it was designed for and the space as a whole.

Figure 4 Scale Models Chair and Coffee Table (by author)

The full scale prototype while providing the most realistic visualization method can often only address limited components of a given designed space and few students work can be accommodated in a studio already crowded with drafting boards, computers and other related equipment.

Figure 5 Full Scale Prototype Chair and Coffee Table (by author)

Of the options available site visits also provide students with experiences of the constructed environment. A thirteen week semester limits the ability for frequent visits to take place during class time.  Places of lived experience that we experience daily provide content to a student's conceptual design. As a student I relied on my professors to provide examples and demonstrate the links between their own design concepts, methodologies and the final built space. The examples helped to validate the theories being taught and the concepts presented also had more meaning.

Computer models called a walkthrough enable the observer to view a space from any angle as if they were travelling through it.  The rendered image present materials and finishes, light and shadows are can be added to supplement the effect of texture. In the same way scale models or full size prototypes, computer models are labour intensive and require specialized skill to operate the software. To enrich the experience of design education the three dimensional full scale virtual space of a CAVE-like environment has the potential to become a surrogate reality to visualize and experience conceptual designs of interior places. The narrative of conceptual designs can be visualized in three dimensions at full scale. Conceptual designs of spaces create places for lived experiences. In a real environment occupants sit at their desks, walk around the office interact with other occupant and objects. The observer in a three dimensional full scale environment as an active participant can become part of the lived experience. The participant in the virtual environment can walk around the space, enter rooms, and turn around to look down the corridor. Experience in a virtual world is a simulated lived experience. The difference and CAVE's disadvantage is that the participant cannot sit at a desk, pick up items or physically perform tasks.

# 2.0 THEORETICAL FRAMEWORK

## 2.1 Building a framework for design education

My hypothesis is that CAVE-like Automatic Virtual Environments can add value to interior design education. As a unique tool the CAVE-like environment can provide experience and visualization of conceptual designs of interior spaces in an immersive three dimensional full scale environment. In the literature review I will identify theorists and authors whose research has informed my investigation into the subject areas of education, experience, interior design as narrative, and virtual reality. My investigation will uncover the relationships and synergies between education and experience. I will explore impact of one on the other and the outcome as an appropriate option for design education to present a cinematic narrative in an immersive three dimensional virtual environment. The theories and critical ideas presented provide the foundation and framework for the “value” of a three dimensional immersive virtual environment to design education with value measuring the benefits and appropriateness of the immersive environment to design studio teaching and learning.

### 2.1.a Acquiring Knowledge and Developing Skill Through Experience

Education depends on the transfer of information from one source to another; it can be verbal, written or in visual format and can vary from lectures to activities. The benefit of the transfer provides learners with knowledge and skill they do not have or are unable to provide for themselves. Much of the educative information received by the young in primary and secondary schools is prescribed. As adults we have the opportunity to pursue the information we wish to acquire. Such is the case for students pursuing a career in interior design. To become professionals design students require a balance of theoretical knowledge and practical skills. The curriculum based learning environment provides students with a progression of theoretical knowledge and practical experiences. This educative method allows the learner to mature as they acquire knowledge and skill. The type of experience provided is of significant importance to design students. Education and experience is explored in this dissertation through theorists and authors whose beliefs emphasize experiential learning.

The awareness initiated by John Dewey, Jean Piaget and Lev Vygotsky that experience can shape an outcome or influence behaviour is essential to the perception of that experience. In an educational environment it is generally understood that “experience arouses curiosity” (Dewey 38). John Dewey emphasises that the “quality of the experience” (27) is the educators’ challenge.

By contrast Vygotsky’s work in developmental psychology identifies the presence of advanced understanding with practical application. Vygotsky argues that, “rather than examining what a student knows to determine intelligence, it is better to examine his or her ability to solve problems independently and his or her ability to solve problems with an adult's help” (Berk and Winsler 25-34). Vygotsky’s “zone of proximal development” identifies a learner’s achievement with or without assistance. It is a progression of maturing and learning through activity and experience (Vygotsky 86).

According to Dewey the role of educators is to create an experience that will entice the learner to explore the subject matter and awaken an enthusiasm for future experiences (Archambault 360). The educator’s approach in design studio learning requires a balance between theory and experience. Piaget takes the position of advocating for an “open system” for the advancement of knowledge through active participation (Schwebel and Raph 192). The individuality of learners in an open system is sustained by the relationship of both outside sources and sources within the educational environment.

Dewey's educative philosophy of experience and education illustrates the importance of learning by doing. This supports my theory that education is not solely based on the delivery of theoretical information but that experience in an educational environment has an important role in the education of learners. "Those who teach must think about the experiences which they choose for those who are taught" (Moore 4). Educational theorists David Kolb and Roger Fry agree that experience is vital to education as the cycle of teaching and learning relies on actions, observations, analysis and reaction resulting in experience (M. K. Smith 14). This cycle provides the foundation for a design narrative to provide experiences for users of interior space.

### 2.1.b Experiencing Interiors Spaces as Design Narratives

Experience and meaning are significant components in interior design and interior design education. Design narratives are stories told through the creation of space or form. Similar to literary works they have a beginning, middle and an end. The design narrative places the user in the environment as a participant in the experience of space whereas the literary reader's experience relies on their imagination to locate them in a space. I would like to provide learners with an opportunity to experience the spaces they design in an immersive virtual environment where they can be in the space and become aware of the meaning created by that space by experiencing it.

Scholars Joy Dohr and Margaret Portillo emphasize the significance of meaning and experience in a design narrative (37-38). They view design as more than a methodical process, rather an accumulation of perceptions, dynamic forces and awareness applied in a “holistic approach” (267). The narrative of the built environment revolves around people and objects; involves interaction between people and between people, space and objects to create a meaningful experience (2). Interior designer’s conceptual designs arise from gathered research to personify people and places, and the relationships between them. Meaning emerges through interaction (Vaikla-Poldma 12-13). Poldma believes that design evolves as society does and that learners in particular must adapt to a changing society.  In the *Meaning of designed spaces* Poldma assembles design scholars who provide substantial evidence and insight to define meaning; they discuss how meaning is created by users of space. Spaces we create are dynamic; they embody not just a person’s character but also the fabric of society.  Poldma asserts:

> As we become increasingly aware of ourselves, our experiences, and attain a heightened sense of self, we have interactions with others and our body is increasingly interacting with space, environment, others and technology in new and different ways not experienced before in history. (x)

As the story evolves in the narrative of the interior the substance of the meaning is experienced.  It embodies the character, culture and value of users and the space itself. By contrast designer and educator Roberto J Rengel states that few professions “can claim the kind of impact on the quality of our lives that the design professions have” (xi). He focuses on the impact of the built environment as it surrounds us everywhere we go. We spend much of our lives in interior spaces working, living and playing. He suggests that spaces are designed to characterize society's need for experience and meaning. Rengel clearly defines experience:

> Designers need to cultivate an appreciation and understanding of the types of rituals and events associated with different project types. By listening, observing, and most of all by experiencing directly the realities of those who use specific project types, designers can acquire the insights and sensibilities necessary to inform their designs. (12)

He sees the designer "as a movie director" (xii) that assembles spaces beyond functionality, aesthetics and cultural expression to achieve a narrative to enrich experience and meaning. The spirit of interior design is to create meaningful experience within a space. Yet the design learner's experience of their own conceptual design often remains elusive. How can students fully understand and critique or analyze what they have not experienced? And how can they better understand the experience they have designed and its impact on others?

"Different users of a space have different perceptions…Designers affect the experience of … users" (Rengel 12). Educators present and guide learners through repeated tasks and various scenarios where the learners apply knowledge. Students learn to investigate, evaluate, and synthesize data gathered for activities associated with occupants such as: coming and going, interaction with others or objects, performance of tasks, and resting and relaxing. Hypothetical scenarios are often provided for studio learners as a narrative based on an educator's past design experience or developed from a visiting expert's perspective. Images on presentation boards are static and unrepresentative of a fluid and mobile environment. The journey from thought to designed space is a road worthy of exploration, possibilities and opportunities.

### 2.1.c The Learners Journey

The learner's journey begins by gathering information to provide a framework for a designed space. As the story unfolds initial concepts begin to form in our head as ideas or mental images; we imagine, remember, interpret, evaluate and explore to help us find form, make decisions and solve problems. The perceived image is often within the realm of our thoughts. "Seeing in design terms moves beyond the physicality of vision to imaging in the mind's eye" (Dohr and Portillo 66). This is the beginning of the narrative approach to developing conceptual design (Flemming 32). Images within our mind's eye are an endless cinematic narrative in space that can adjust between two and three dimensional images and can metamorphose into any shape, colour or texture. Yet, the design narrative is presented and formalized through two dimensional drawings on presentation boards rather than in physical space.

In the design process pursuant to conceptual thought is the gathering of information and research related to the unfolding narrative. The process, divided into phases includes but is not limited to: programming, schematic design, design development and implementation (Nussbaumer 6-7). An organized, logical method the programming phase helps students learn to analyze and synthesize information gathered to provide a design outcome - the designed space. A review of requirements is conducted to determine the scope of the project; in addition the programming phase also investigates the site's condition and wellbeing and safety requirements which can impact the outcome.

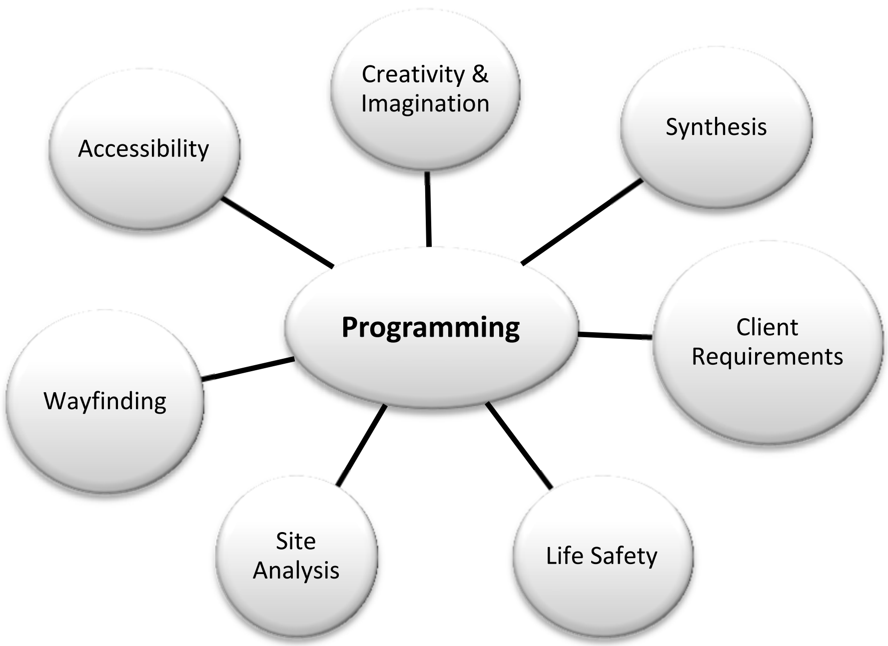


**Figure 6 Conceptual Design – Programming (by author)**

The narrative in a digital environment uses software such as MS Excel, MS Word and AutoCAD to synthesize and organize information in digital format, documents can be formulated and modified at a fraction of the time it would take to produce them manually. The benefit of the digital version is its multi-layered colour coded presentation that can be instantly modified and saved as different versions. The design narrative through the use of digital technology is communicated in the virtual environment of the computer's database. The narrative continues from programming to schematic design and design development as the concept takes the shape of plans and elevation drawn on the computer.

### 2.1.d Schematic Design, Design Development

Elements and principles of design such as line, shape, plane, balance, harmony and proportion are individual components that together provide the unified expression of a unique conceptual design. If as Rengel suggests "the best way to learn design is by doing" (6) then it stands to reason that 'doing' implies an activity that provides experience. While the experience of doing differs from the experience of being in a space both allude to actions and interactions that create meaning. Schematic design and design development explores the possibilities of placement, aesthetics, character and function to create meaningful experiences. Visualization of these experiences is largely through two dimensional surfaces of presentation boards or computer screens. Experience and meaning is observed not lived.

The implementing phase of the design concept alludes to the possibility of a three dimensional full scale space. Although some design students have the opportunity to select a building of their choice to provide designs for hypothetical scenarios they do not have the opportunity to experience being in the spaces they design. The buildings they select remain as what they are. In the absence of implementing their concepts within a real site technology through CAVE like environments can replicate the spatial volume of a student's design. Immersed in the simulated virtual environment students can experience being in the designed space in three dimensions at full scale and can gain an appreciation of the space itself, its character, structural components and size; they can move through the space experiencing being there. Kolb and Fry's theory of experiential learning can be applied to the immersive environment as it can provide learners' experience of designed spaces, can facilitate observation, analysis and reflection on design intentions, can encourage development of abstract thought and can provide the opportunity to analyse new experiences within the environment.

### 2.1.e Experience and Meaning in an Immersive Environment

The greatest challenge is to provide students the “experience” of designed space other than an abstracted understanding. Through my research I acquired the knowledge and understanding to evaluate the usefulness of an immersive virtual environment as a teaching and learning tool for design education. I have built on the ideas of designers and architects such as Shashi Caan (Taraska and Makovsky), Daniela Bertol (108) and Charisse Johnston (205-210). The impact of technology and virtual environments are reviewed with reference to theorists such as Marshall McLuhan and Howard Rheingold to project immersive images, by exploring the concept of experience, virtuality and interactive visualization in three dimensions.

The goal of a virtual environment is to simulate reality and provide the experience of being within a space. Within this immersive environment design students will gain a better understanding of the aesthetic elements that create the form of their ideas, how the various building systems, regulatory requirements and design components relate to each other and to the concept as a whole. The proposition to use visualization technology provides an alternative for students to hone their skills in comprehending the relationship between concepts on paper and the reality of the built environment through an immersive simulated experiential environment. Visualizing in the CAVE-like environment provides several viewers the interactive ability to experience issues as if they were on location. Since experience is part of design education then experience in an immersive environment that simulates reality can provide students an opportunity to practice their skills in a location, free of construction hazards and is all the more valuable to their capacity to understand the complexity of the building site and construction methods. The immersive experience relates to experiential learning as a "continuous process grounded in experience" (Hopkins 48). In addition, the three dimensional immersive CAVE-like environment can provide exploration of elements somewhat unattainable through any other medium for reasons of safety and practicality, that of being immersed in a virtual place while being somewhere else. Designers are trained to be forward thinkers, researchers, analysts and creative designers. The use of a virtual space that can replicate a student's design concept presents an ideal model for the transformation of a design narrative into an immersive cinematic representation of conceptual designs.

Marshall McLuhan anticipated the influence of electronic media on society. He sought to understand media as a tool characterized by its use rather than by its ability to entertain. According to McLuhan's philosophy CAVE creates its "own environment as a continuation of ourselves" (McLuhan 7). He believed that experience through the senses was an extension of society. Described as a philosopher and theorist of digital media and communication McLuhan strongly believed that technology as a medium was the message. He believed that society's use of technology reversed the role it was meant to play. Technology became a gadget rather than a tool to enhance or support society. By contrast the presence of a CAVE-like environment engages participants differently. Its use provides an immersive environment to present cinematic narratives of conceptual designs. The use of CAVE-like environments re-establishes technology's role as a tool to support teaching and learning and provide an environment that characterizes the fabric of society.

Critic, writer and educator Howard Rheingold in his text *Virtual Reality* addresses the implications of technology and more precisely of immersive environments and its influence on society. Society's motives for using technology as a tool to enhance and support living, working and playing will define future applications of digital media. In design education technology and digital media are used in an educative environment that can provide a collaborative atmosphere to support design studio teaching and learning. Technology's integration into design studio teaching and learning provides educators and students the ability to explore and test concepts. The mediated virtual environment becomes an immersive extension of our imagination for new experiences.

Digital media can bridge the gap between theory and experience by providing learners the ability to experience and imagine interior spaces in an environment that can simulate reality (Rheingold 29). Traditionally, to achieve three dimensions at full scale requires a physical prototype of a design. This method allows one room to be experienced at a time. Immersive prototypes provide students invaluable experience and understanding of conceptual designs. Construction methods demonstrate the relationship of materials as if built on a construction site. While scaled prototypes of rooms represent an ideal learning environment the space required for all design students to build their designs remains an unaffordable luxury in many educational institutions. The alternative option are site visits around students own educational settings providing access to spaces such as offices, cafeterias, classrooms, libraries and lounges as three dimensional learning opportunities. While these spaces are somewhat accessible they are often too small for a whole class, are often noisy and crowded making it difficult to examine or observe and unsuitable for onsite discussion.

Architect and designer Daniela Bertol defines virtual reality as a responsive world which can distinguish actions and provide a “sense of immersion” where the participant is “surrounded by a three dimensional environment” (57). As a surrogate, CAVE-like immersive environments have the ability to provide an entire suite of offices, retail outlets or hospitality lounges in three dimensions using the simulated physical extent of a designed space but in a virtual environment. Conceptual designs of spaces are transposed to a simulated reality in the CAVE like environment offers unlimited potential scenarios presented in an immersive virtual environment that would otherwise go unexperienced. The medium allows for: demonstrating how design, life safety, wayfinding and accessibility are intertwined to achieve an aesthetically pleasing yet functional space; how architectural, mechanical and electrical components co-habit a space and potentially identifying relationships between building components prior to construction. Students can review millwork details, analyze relationships between people and between people and objects, they can examine placement of light fixture sizes and conflicts between light fixtures and mechanical systems; they can apply accessibility requirements and appropriate light levels, review performance of tasks, apply directional elements and visualize egress distances. Students can gain a better understanding of the relationships of materials, equipment and furniture within a room or suite through the use of CAVE; and how they relate to other components and to occupants.

Digital theorist Lev Manovich explores digital media to determine its ability to analyze huge collections of digital images and text. His interest lies in the “cultural production and consumption” (Manovich.net 25 January 2013) of digital media. Digital data in an immersive virtual environment is addressed in a more technical sense. The data required to present cinematic narratives of conceptual design requires a massive amount of digital text. The digitized information taken from CAD drawings creates a database of information to present a seamless immersive virtual environment for design narratives. Manovich believes that digital media has transformed society into a visual culture using the media to experience life with the portability of technology's devices enabling users to experience life in an augmented virtual environment; while conceptual design experienced in an immersive environment strives to provide immersive experiences with function and meaning (Manovich.net 25 January 2013). The immersive design environment is able to address experience as an emotive response of the interaction between people and spaces.

Perception is the working of stimuli to our sense organs (Hamlyn 1). Professor Hamlyn examines the philosophical implication of Gestalt theory and perception. Various arrangements of lines on a two dimensional surface stimulate our minds to perceive them as two or three dimensional images by drawing representations of conceptual ideas to explore and clarify forms (Ching and Binggeli 68).

Visualizing images on two dimensional presentation boards, on a computer screen or in an immersive environment deliver very different representations of reality. On presentation boards experience equates experience and interaction to the visual observation of a three dimensional image on a flat surface, rooms cannot be entered, views cannot be rotated, other views are required to be drawn, photographed or painted in order to do so. While these representations are beneficial to clients to view spaces as an immediate and informal method it does not provide a view of the space as a whole environment however it does allow the client and designer to communicate regarding the conceptual intent in an effective manner.

### 2.1.f Learning with Digital Media

The integration of computers and digital media into interior design studio teaching and learning provides students the ability to communicate design concepts using computer software. Through the use of software such as Revit, SketchUp and 3D Studio Max users can import or draw two dimensional plans and transform them into three dimensional images by providing the computer with the appropriate data and attributes. Elevations are automatically generated from the plans so there is no need to draw a multitude of individual elevations to produce three dimensional images. Attributes such as length, width, height and depth are entered into the software's database for each component on the plan. The animated digital walkthrough presentation of ideas on computer, although viewed through a flat screen is better suited to present conceptual designs in three dimensions because these images are rendered to represent materials, finishes, textures; light and shadow enabling viewers to travel through the space as if being there. The designed space appears closer to reality as the operator manipulates the mouse to allow the viewer to turn corners and enter rooms. The limitation is the size of the computer's screen. The benefits of a walkthrough are that the final product can be easily modified, rotated and rendered, and sent electronically to others for viewing; it provides an "effective simulation of a design… to test designs and their efficiency" (Bertol 52). In turn students can visualize design concepts in three dimensions from various angles, from the beginning stages of design development through to its virtual implementation.

The walk through method of simulation has its limitations in the size of the computer screen which is meant to be viewed by individuals and while the image can be manipulated to view concepts from different angles it remains a miniature version of reality; the challenge of the miniature image rests on the relationship between scale, proportion and depth. What may appear normal on the computer screen may not be so in reality. Perceptions of relationships, scale and proportion are better understood in three dimensions in an immersive environment to experience the concept, components or place.

Taking the concept of a computer's virtual walkthrough and applying it to an immersive full-scale virtual environment provides design students with a simulated "surrogate for the actual physical environment" (Bertol 67) with which they can scrutinize conceptual designs. Computer generated models in the surrogate environment have the potential to enhance students spatial understanding to further develop their design concepts. The surrogate environment offers visualization in an immersive virtual environment. As such, a student's ability to "read their environment" (Van Schaik 10) nurtures an awareness of how a physical space can impact its occupants and human behavior (Prak 1).

By first experiencing their own design concepts in a virtual environment students can then apply their findings and understanding of volume, shape, form, scale and distance within a space to improve on the organization of the various components of their designs. The immersive virtual environment provides the opportunity to know what it feels like to walk around furniture, hospital corridors and hotel rooms; to understand the length, width and height of corridors, desks, counters and beds and see the relationships between them and details such as ceiling systems, bulkheads, lighting and mechanical components. Interior design students can be provided opportunities to “experience” the ambience and character of their spatial designs to in turn create more complex solutions and experiences with meaning for others. In an immersive virtual three dimensional environment students become real-time participants within their conceptual spaces rather than passive viewers (Bertol xv).

Learning digital technology as a production tool in design studio education dominates the literature in interior design. While there appears to be a general awareness of the potential of software applications in interior design education, the topic of immersive visualization remains a theoretical concept and research has failed to identify the actual gains and contributions to design learning. The desired end result of my research is to determine if CAVE like environments can be applied to and enhance value to interior design education.

## 2.2 The Acquisition of Knowledge

Information transferred from teacher to learner provides the learner knowledge which they do not already possess (Price 126). It is the beginning of a learner’s education. Educator Ernest Carrol Moore endeavours to clarify preconceived beliefs in education by providing a series of concepts which he believes must be at the forefront of educator’s minds to sustain ideas that shape their work (vi). He believes that “…the teachers of the young are engaged in ‘choosing experiences for people’ not for a day or an hour but for life” (3).

Educational theory seeks to provide insight into various educational and pedagogical practices. Although informed by several disciplines, psychology appears as a prevailing approach to behavioral understanding and how it pertains to teaching and learning. While teaching provides a framework for learning by transferring information, guiding and providing opportunities for experiences, learning can be described as the absorption, processing and retention of information for future applications to experiences. The basic structure of learning is framed by an understanding of various learning theories. The figure below identifies the principle ideas behind three prevailing learning theories and identifies theorists whose views are aligned with these theories.

| **Learning Theories** | | |
|---|---|---|
| | | |
| **Theorists** | | |
| Dewey, Moore | Montessori, Piaget, Brubacher, Bruner | Vygotsky, Piaget, Dewey, Montessori |
| **Behaviourist** | **Cognitivist** | **Constructivist** |
| Dependant on instructor to acquire knowledge | Leaner is active participant in the learning process | Learning is an active, constructive process |
| Observes and measures behaviour | Learning opportunities relevant to learner's interest | Learning is based on prior knowledge |
| Memorization of facts, rules and terminology | Cognitive development | Social interaction is critical to development |
| Learning occurs through the senses | Requires experience to build understanding | Integrates new knowledge with existing knowledge |
| Learning through reflex response | Constant state of growth and evolution | Self-directed learners |
| Learning as a social activity | | |

**Figure 7 Theorists and Learning Theories (by author)**

Educational theorists have influenced the course of education through their research, observations and concepts of education; they question if society and culture impacts learning, how learning occurs, when learning begins and how learning relates to growth and development. While many theorists use childhood as the basis of their research their concepts and philosophies can be transferred to adult learning. The following chart identifies several key theorists and their educational theories.

| Theorist | Theory |
| --- | --- |
| **Dewey** | Learning transpires through experience (by doing) |
| | Education is a guide for growth |
| | Education consists of information and skill |
| | |
| **Montessori** | Learner is in a constant state of growth |
| | Development, freedom and self-expression |
| | Sensorial exploration |
| | |
| **Piaget** | Developmental stages |
| | Interaction between cognitive and biological development |
| | Development is independent of learning |
| | |
| **Vygotsky** | Social interaction is dominant to individual development |
| | Consciousness and behaviour |
| | Zone of proximal development |

**Figure 8 Educational Theorists - Key Concepts (by author)**

In Vygotsky's opinion the adults we have become stem in part from our childhood experiences, cultural background and societal milieu (27, 57). We are who we were meant to be as humans and as adult learners. In the pursuit of continued education and as part of design education, the learner is a willing and able participant in their future acquisition of knowledge.

Design studio education is the sequential application of hypothetical scenarios and project requirements to the creation of conceptual designs for interior spaces that create experience and interaction with the environment and experience as spatial ambience. John Dewey views education as consisting of "information and skill" embedded in the past and that the primary function of schools is to "transmit" (17) information and skill. Responsibility and success is the end result of the transmission of this information and skill. While books represent the knowledge and experience of the past, teachers are the link that connects them to the present (Dewey 18). Moore and Dewey both see the educator as an intrinsic part of education but Moore places the educator at the helm of the learning environment whereas Dewey sees the educator as the vehicle for the transmission of information. In his article *Value Education for a Better Democracy* Educator Md. Nijairul Islam states that current educational structures lean towards the production of “information laden” men and woman not “value”-able human beings. He does however agree that values add to the character of learners in that these “internal principles” provide guidance and evaluative tools to analyze actions and ideas. Islam asserts that the aims of value in an educational context should be to “develop habits, attitudes and qualities of character.” He further explains that “knowledge as a value” in education provides the capacity to challenge a learner’s theoretical thinking, understanding, perception and philosophical thoughts.

When using the example of buyers and sellers John S. Brubacher claims that as correlative terms one implies the other but that it differs when it comes to teaching and learning. The presence of a “learner does not automatically imply the presence of a teacher” (235). That is not to refute the role of teachers but it does suggest other legitimate means of learning. The use of computers in today’s learning environment has become an intrinsic part of education as a tool for collaboration and communication. The integration of technology in the curriculum provides students a platform to access information to support what is presented in the classroom, learning through their own research.

Educators Frederick Mayer, Maria Montessori and Jean Piaget agree with Moore and Dewey that the learner must be willing to learn in order to be educated. In contrast Lev Vygotsky believes in the concept of the zone of proximal growth; that behaviour and learning is based on the history of behaviour in the context of social interaction (1). He asserts that social experience plays a dominant role in the development of behaviour. Vygotsky and Dewey share similar thoughts on the mentoring of learners and the notion of support in a social environment. The child, according to Montessori is in a constant state of growth and evolution so this willingness to learn may also be applicable of adult learners (Standing 106). Montessori's primary concern lies with development, freedom and self-expression rather than just learning. She believes that sensorial exploration, sights, smells, and tactile experience in childhood have a great impact on a child's mental development. Montessori understood that the environment in which children learn sets the path for learning as adults and that the value of learning is not just the "acquisition of knowledge" (230) it is also the application of the knowledge learned. In contrast personal values define our beliefs of right and wrong and guide the choices we make. Value and values both represent the achievement of experiences and the means to achieve personal goals. Lesley Ledden assembles a series of components to demonstrate various aspects of value. He explains the meaning of functional, social, epistemic, emotional and conditional value in terms of a student's perspective of what they "get" (965-966). These values link Montessori's beliefs of acquisition to application.

Keiichi Takaya describes Jerome Bruner's theory of education as having a significant influence on education and on the process of educating. As a radical text for its time Bruner's *The Process of Education* (Bruner 1977) influenced educators in their methods and direction. He depicted the learner as an active problem-solver in the exploration of knowledge. Takaya points to Bruner's belief that learners are the masters of their destiny by being active participants:

> He thought that the structure of a discipline would facilitate the learning process; and that discovery learning and spiral curriculum would allow students to be active participants of their own learning. Bruner thought highly of participatory methods or models of learning, rather than mere receiving of information, knowledge, or skill. (Takaya 7)

Transposed this statement accurately describes the intent of design education as students are provided the opportunity for individual study and group activities. Students develop critical thinking skills to address and resolve challenges.

Takaya agrees that the process of development is more significant than the end result (6). The term end in education is ambiguous at best according to Reginald D. Archambault (xxii). What is the 'end'? To end an education means the completion of a course or a degree but does education stop when a course is completed? Frederick Mayer states that Dewey's definition of end "does not stop at graduation but life is our teacher" (96). This statement applies to design education as the end of "schooling" provides a degree but that learning as a design professional begins a new chapter of acquiring knowledge.

In his text *The End of Education: Redefining the Value of schools* Neil Postman cautions that education and schooling differ in that education is relentless in the pursuit of knowledge while schooling starts at a prescribed time, ends the same way and pauses for summer. Postman's dislike for the modern school propels him to emphasize a change in curriculum to educate more reflective beings rather than technicians. He would agree that developing critical thinking skills empowers students. Their ability to analyze and evaluate information enables design students to achieve successful results in producing conceptual designs.

To Postman the education system motivates students to an end where employment, consumer goods and the latest gadget are attained rather than create a reason for being in school. His intent is to promote discourse about reason. What is the "why" of education? Postman's belief in the "existence of shared narratives and the capacity of such narrative to provide an inspired reason for schooling" identifies the principle theory for education (4-18). The narrative provides meaning to life, while meaning provides purpose to learning, and learning in turn invites attention.

The purpose of design teaching and learning is to produce future designers. Students develop the aptitude to think critically about the application of knowledge and the meaning of the result. Developing critical thinking in spatial design requires the student to visualize in three dimensions. Three dimensional drawings on two dimensional surfaces lack the realism of full scale reality. Virtual environments provide students an opportunity to visualize conceptual designs in three dimensions at full scale. The virtual environment answers Postman's "why" as it provides an element of realism to the concepts, it enables students to be a part of their designs rather than be observers of images. Postman urges students to embrace the power of definition and to question, not accept, the pre-packaged knowledge they are presented (61).

Schooling must provide the subject matter but it must also provide the *means* by which we become learned. While this suggests an environment for learning it does not control what the student actually learns. Educators and learners have a common goal, educators provide information and influence outcomes and learners receive information and apply it to outcomes. Outcomes are predetermined within curriculum as an educative goal, by measuring student performance (Ankerson and Pable 65). Moore values the measurement of student performance by way of examinations and reviews as he states that “education is determined by what the student does” (25) with the knowledge they have been given. The activity of learning identifies experience as a factor in an educational environment. Design education evaluates performance in many ways such as, exams, written and visual essays but also the assessment of studio learning by questioning students on their understanding of their own conceptual designs and the meaning of the experience represented.

## 2.3 Perceptions of Experiential Learning

### 2.3.a Experiential Growth

The general understanding amongst theorists and educators such as John Dewey, Neil Postman, Maria Montessori, Frederick Mayer, Jean Piaget, Lev Vygotsky among others, is that experience is an important factor in education. Although Piaget and Montessori both relate experience with the development and growth of children, their philosophies extend to future experiences in the adult world. Vygotsky’s theory relates to child development and focuses on the history of behaviour which impacts future behaviour; behaviour is a child’s action or reaction to cultural experiences. Piaget’s focus is on developmental stages of children’s leaning and the experience of childhood. John Dewey’s theory is based on experience by doing and the continuity of experience. Theorists agree that life experience shapes our thoughts; moulds our character; and develops our performance skills; skills to socialize and our ability to perceive our environment. To that end, life, experience and childhood development shape learners to be who they are as adult learners.

Development, personality and education are expressed by Dewey as "permanent frames of reference" where there exists a "connection between education and personal experience…but that not all experiences are educative" (Dewey 25). He considers any experience that produces in the learner a lack of interest and indifference and thwarts future growth as "mis-educative" (37) . On the other hand his "principle of continuity" (36) epitomises growth not just in the physical sense but intellectually and morally. Intellectual and moral growth can be impacted by direction; decisions are based on available information, prior experiences and societal influences. What is anticipated as a goal is not achieved by a single path. Lived experience will lead to other experiences to be lived; we analyze as we experience, we grow intellectually and morally and make decisions that lead us along diverse paths. In their article on *Characterizing Value as an Experience,* Anu Helkkula et al., consider both "lived and imaginary" (59) experience in their suggestion that the worth of experience is predisposed by "previous and anticipated" (59) experiences. They describe experience as an "interactive circular process" (59) in which the student attempts to make sense of the experience. Whether from lived, imaginary or second hand information value in the experience adjusts to "value-in-context" (61) and becomes situational in nature. The value placed in the experience remains a personal one in which the meaning of value fluctuates as it flows between past, current, hypothetical and future experiences.

As adults we act upon our goals with intentions to become a designer, a lawyer or medical professional. We set up our own environment for learning and develop how we will act, react and interact in the future. As we grow within the direction taken we become more sensitive to certain conditions and experiences and immune to those that would have been motivations if other option had been followed. Dewey identifies two aspects of the quality of experience; the first has an immediate impact and the second has influence on future experiences; with the latter being more difficult to identify as the future can mean anything from one day to ten years or longer. Experience does not provide a schedule for its impact; it is merely there to be lived in the moment and applied in the future.

### 2.3.b Sensorial Experience

Design education begins with the learning of fundamental knowledge as educators hand out assignments that will impact future applications for the conceptual design of interior spaces. Students are presented a progression of information to gain knowledge and experience using the elements and principles of design. The implications of their use may not always be readily apparent until they are applied to more tangible and relevant design solutions. There is a “eureka” moment in a student’s life when they finally understand the interaction between acquired knowledge and application. Theoretical knowledge applied to experience validates its worth as knowledge.

Interaction with experiences are often seen as external situations which impact sight, sound, touch and smell, internal experiences are not as visible as they impact the psyche and emotions. The difficulty with traditional education according to Dewey is the lack of consideration given to internal factors that potentially have just as great an impact on decision making and outcomes. The importance of balance in design education is reinforced as both external and internal factors are equally important in the conceptual design of interior spaces. Joy Monice Malnar and Frank Vodvarka discuss sensory design as they "explore the nature of our sensory response to the spatial constructs that people invest in meaning" (ix). Their theory addresses sensorial experience previously identified as touch, sight, smell and sound in addition to internal experiences such as the emotional responses of meaning, perception and feeling. Processed through our minds the senses enrich the experience and the ambience of a space (Tuan 3). External sensory factors are usually experienced the same way by groups of people as we all see the sky, hear the rumble of cars, smell the flowers and touch the water, the difference lies in our emotional response to these external factors which renders the event through personal and emotional internal factors. A mental image represents the individual's version of their own experience at a "particular moment in time" (Tuan 22).

### 2.3.c Contextualizing Experiential Environment

In a three dimensional full scale virtual environment of the CAVE visual and hearing senses are heightened by the cinematic images presented. Other senses remain hushed by the images, as objects cannot be touched or smelled. The realism of the images and the corresponding sounds heighten the experience of being present in one location while being somewhere else. Can the virtual environment provide the same emotional response to those in a physical environment? Are all the senses required to be stimulated in order for the virtual environment to provide experience, ambience and meaning? Sensorial experience is dependent on the parameters of the research conducted; an example of multiple sensorial requirements is detailed in Chapter 5.3, Application 4 as first responder training. In a virtual environment sensorial experience has a dual meaning first that of being in a virtual environment and second as experiencing the images presented by the virtual environment.

Defining experience means to qualify its value and provide the context for which experience is experienced. To focus on one specific type of experience would be a disservice to this investigation as the various categories provide discernment between what each represents and how they influence learning. The following figure indicates the diverse categories of experiences referenced in this document.

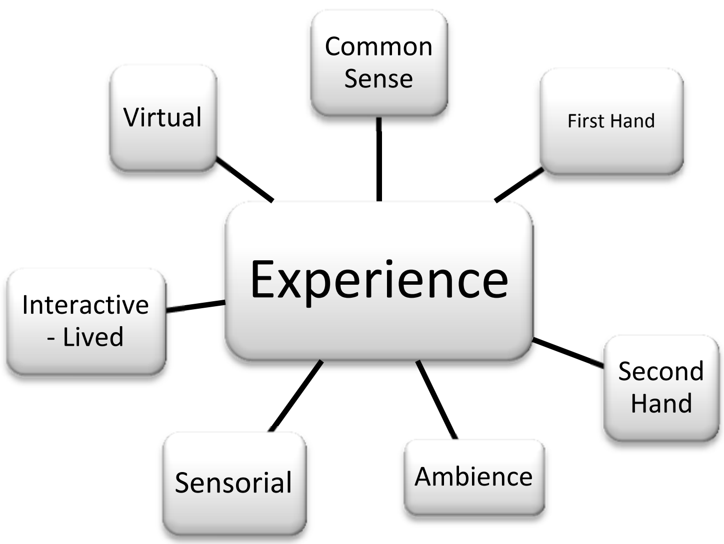


Figure 9 Categories of Experience (by author)

In their essay *The Overcoming of Experience*, Margaret Buchmann and John Schwille examine firsthand experience and its value to education to determine the validity of this belief. They review formal education and experience as equal partners; using research that outlines the pitfalls and erroneous interpretations of firsthand experiences they consider the constraints for change. Second hand information is better suited to provide access to what is factual and conceivable. “Education gives access to thoughts and theories that are beyond the scope of firsthand experience” (30). In my opinion thoughts and theories are meant to support and provide meaning to experience. It does not mean that thoughts and theories must precede experience but that at some point these thoughts and theories are present to support the experience.

This is apparent in design education where experience relies on ideas and theories as a foundation to support conceptual designs. The exploration of ideas and theories enable students to produce designs that can be lived experiences and have meaning. The value is in the connection made by students to the meaning of the experience and to the thoughts and theories that stand behind the experience. Anu Helkkula et al. acknowledge the subjective nature of experience. People strive to make sense of their environment either as individuals or in social circles (59). This defines the value people place in experience as other’s opinions infer credibility based on collective understandings of value. The value of experience in three dimensional environments adds to the credibility of a conceptual design as it provides a potential environment for testing theories and demonstrating intent. Experience can be subjective in nature with different students offering different opinions about its meaning, but it does provide a platform for thought, theory and experience presented as a cohesive whole. The value of the virtual environment is in its ability to provide simulated realistic designs in three dimensions that would otherwise not be possible. This is all the more significant when applied to life safety elements such as distance to egress. In an emergency situation people panic and can misjudge distances (S. P. Smith 559). In a virtual environment preventative measures can be identified and addressed during the design’s development stage. In addition, the virtual environment provides the opportunity for students to experience concepts as part of studio learning without having to schedule site visits in an already time constrained semester.

Another aspect of experience draws on vernacular statements such as “live and learn”, “practice makes perfect” and “let experience be your guide” placing experience in the role of educator and casting firsthand experience as the process by which education is attained. These metaphors encourage us to act on assumptions to set goals. Buchmann and Schwille claim that metaphors function to evoke “thought and action” (32) as inseparable. Education and experience implies thought and action alleging a connection between our minds and reality where metaphor and common sense prevails. Common sense is acceptable as a starting point for inquiry - “if all else fails use common sense”, “let common sense be your guide” – absurdity lies in the unwavering acceptance of common sense and undermines the foundation of education and the acquisition of knowledge (33-34). Brubacher agrees with Buchmann and Schwille stating that we must be careful in using common sense as an educator as it has its shortcomings which he describes as “fickle” (Brubacher 310). Inquiry into the validity of common sense questions its authenticity. What may have been common sense in the year 1250 or 1840 may no longer be common sense today; it should not be regarded as an ongoing process or a final solution.

Sense experience on the other hand is a primary concern for the theory of knowledge and experience. All that is experienced comes into our minds through our senses.  We, as humans intuitively touch, hear, see, smell and taste. Jean-Jacques Rousseau uses an example of sight and touch:

> As the sight is the sense which is the most intimately connected with the judgements of the mind, it requires a long time to learn to see. Sight must have been compared with touch for a long time in order to accustom the first of these two senses to make faithful report of forms and distances; without the sense of touch, without progressive movement, the most piercing eyes in the world could not give us an idea of extension. (Rousseau 106)

The immediate response to sense experience validates itself as the rational side of the theory of knowledge. Conceptual design entices the senses to provide a meaningful experience. These concepts emphasize designs for the senses defined as ambience and accentuate lived experience as a physical interaction with objects and the surrounding environment.

Education and knowledge sustained by the rationality of theory claims to be the “goals of education and methods of effective education” (Buchmann and Schwille 34). The question is whether or not “firsthand experience is as good a teacher as the rational theory of knowledge” (Buchmann and Schwille 34). They reason that firsthand experience is a personal experience that provides us with an unpretentious yet tangible event that did happen. Experience is an emotional response supported by physicality. They quote J. Platt who indicates that “firsthand experience does not have a long term view of its consequence… this requires imagination” (34). In a divergent analysis Buchmann and Schwille quote R. Nisbett and L. Ross who state that second hand information can be unreliable as they provide the adage of “don’t believe everything you read” and “you can prove anything with statistics” (38). What differs between first and second hand information is that second hand information takes its cue from a variety of sources and more readily represents an even distribution of events (43). A reasonable assumption would be that adherence to firsthand experience alone would remain unchallenged and stem future growth. It is interesting to note that regardless of the source of the theory, thought and experience the authors agree on the unity of the three as being a compendium of acquired knowledge and lived experience.

David A. Kolb and Roger Fry extend the idea of experiential learning as a process “grounded in experience” (Hopkins 48) and containing four elements: the concrete experience, followed by observation and reflection, the development of abstract theories and finally the analysis of new experiences (M. K. Smith 2). The learning cycle is described as a “continuous spiral” (M. K. Smith 4) which primarily begins with a specific action followed by resulting analysis of the effect of the experience.

A parallel emerges between experience and the acquisition of knowledge. Learner centered education provides the learner the ability to develop analytical skills to question experience and develop the ability to apply the new found knowledge to create future experiences. Mary Parker Follett’s philosophy of engagement and encounter expand this parallel development as the ability to think, question and learn through experience to acquire knowledge. To Follett “experience is a power-house where purposes and will, thought and ideals, are being generated” (Infed.org). She points out in her explanation that the process of education and experience as an event not only includes the event itself but also the person living the experience. She cautions that relying on “learning by experience” (Infed.org) alone can lead to failure in much the same way as Buchmann and Schwille propose, as the pitfall of first-hand experience. Follett sees past experiences as a precursor to future experiences, as a guide, and those past experiences are the fabric of our lives and must be taken into consideration. They define who we are in the future and we must “rise above the old self” (Infed.org 18 April 2013). The consensus amongst authors’ sees the educative qualities of experience as furthering knowledge, and that the cultivation of knowledge requires experience as a guide for developmental growth. Experience requires the ability of critical thought to question and analyze its meaning in the present in order to create future experiences. Knowledge untested without experience remains hypothetical; it is only through experience that thoughts can be defensible. Responsive educators construct experiences which value the “link between thought and action” (Smerek 38). Without the link between thought and action experience lacks meaning.

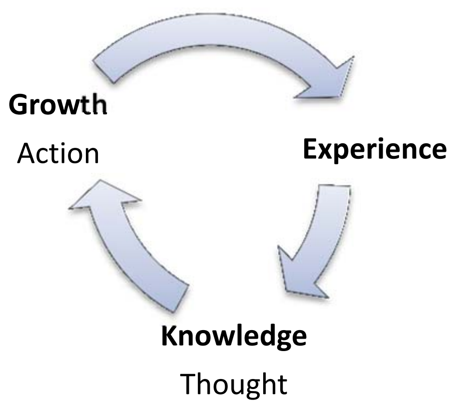


Figure 10 Experience - Thought and Action (by author)

## 2.4 Interior design as a Narrative

The literature review studies experience and its meaning defined as narratives and addresses the narratives of conceptual designs as students strive to achieve to provide lived experience. Design narratives are the storyboards of concepts recognizing the user’s culture while eliciting emotional responses to the space. Experience encompasses a variety of meanings dependent on the context of its situation. I have referred to theory that suggests that sensory experience provides an emotional response to experience while past experiences have the ability to influence future experiences. Whether a response to the experience is immediate and lived in the moment, or recognized at a later time influences action towards future experiences. Active participation influences the knowledge gained through the experience. Three dimensional full scale virtual environments offer an option for studio learning through the experience of being in a simulated spatial environment. The environment places the student in a surrogate reality to better understand the context, impact and influence of designed spaces. The surrogate environment provides an uninterrupted continuous cinematic narrative; it includes the beginning, middle and end; it progresses through scenarios as participants react to images around them, in essence the story contains many plots. While the space's layout remains the same, the story within can change to simulate an emergency, or present different furnishings or atmosphere, lighting conditions or colour schemes.

### 2.4.a Interior Design Expressed as a Narrative

The narrative in design education aims to teach students about experiences and meaning. Conceptual design is about beliefs and values depicted through ideas, lived experiences and social influences. Of the many texts related to interior design and design education only Dohr and Portillo's *Design Thinking for Interiors* addresses the making of meaning through narratives. By providing the framework for a narrative journey Dohr and Portillo identify an important view into the intent and meaning of design.

They explain that “memorable design goes beyond form and function” (Dohr & Portillo 1) to include knowledge, components and requirements to provide a sense of place. They define design as being a relational production of the built environment where experience is based on connections between elements, people, environments and characters, each playing a role in the story to be told. My assertion is that a shift occurs from a designed physical space to a designed place with meaning once the users of the space interact with their environment. This can be as simple as walking into a space or as multifaceted as interacting with people and the surroundings. Place is no longer about the physical components assembled to create the environment but about the memories and connections between people and the environment. Place becomes an emotional investment we as humans make connections to spaces (Cresswell 5). The emotional attachment to place becomes more powerful with meaning and value created through experience.

Understanding people and places is the foundation of the knowledge required to design spatial experiences as “links” connecting people with their environment to become places of “living life” (Dohr and Portillo 2-3). Design students learn to become interpreters who deliver insights into human and environmental interaction.  As with any story a design narrative contains a setting, location, characters, events and an ending. The story unfolds into successive layers that enable the storyteller to convey a narrative (266). The manuscript reveals itself as a place designed for living while the narrative offers the journey towards and about the place for living. In the same way as a writer’s process utilizes a framework within which conceptual ideas are developed so too does the designer. The plot entices emotions; the reader, occupant or visitor to a space acts and reacts to the environment. Their responses speak to how the experience or ambience feels when interacting with the space. Unlike the written manuscript in which we can only imagine being in a place the designed space becomes an individual's personal experience and creates meaning through the design narrative (Ganoe 2). In three dimensional full scale virtual environments the manuscript comes to life as a cinematic platform for presenting conceptual design narratives. While literature, design and virtual narratives contain similar components and aim towards similar goals they differ in their delivery methods. The chart below compares the three narratives and provides an account of their differences in methodology and format.

| | **Literature** | **Design** | **Virtual** |
|---|---|---|---|
| **Story title** | A Day in the Life of a Grad student | Matson Corporate offices | CAVE2 |
| **Beginning** | - Introduces readers to story as a written description of who, what, where, when , why and how<br>- Experience through writer's imagination | - Introduction of client's program requirements, regulatory requirements, site investigation, observations and questionnaires.<br>- Conceptual design begins, sketches, bubble diagrams<br>- Creator of experiences | - Visual and oral introduction of project by student<br>- Identifies programmatic requirements<br>- Experience through participation |
| **Middle** | - Develops the story, identifies conflicts, problems<br>- How characters respond to problems<br>- What they do to resolve them | - Program analysis and synthesis<br>- Design development, plans (identify adjacencies, circulation), elevations, sections and details<br>- Construction contract documents<br>- Design implementation | - Cinematic platform<br>- Animated walkthrough<br>- Participant centered<br>- Lived experience<br>- Immersive |
| **End** | - The result of actions taken<br>- Provides an explanation of how story ends | - Deficiencies<br>- Post occupancy evaluations | - Credits |

Figure 11 Narrative Comparison (by author)

Dohr and Portillo advocate the benefits of incorporating narratives into design and design education. As a compendium of theories, elements and principles that include human and environment interaction, lived experience and products, the narrative generates a place with meaning that provides a “sense of identity, emotional well-being and value” (Dohr and Portillo 38). In their efforts to define the journey and experience interior places Dohr and Portillo enumerate narrative indicators as the “process of engagement, contextual civility, empathy, place identity, innovation and maturation” (ix). They provide explanations to these indicators to demonstrate how design is experienced, not only by designers but more importantly by users. Their intent is to familiarize students to the meaning of design. Dohr and Portillo point out that meaning in design is not only about understanding the client and creating a memorable space but it is also realizing that a client will move in and further alter the space to make it more personal. Quoting Maya Angelou “I’ve learned that people forget what you said, people will forget what you did, but people will never forget how you made them feel” (121) to emphasize the importance of empathy.

Creating a place with meaning is more than just a process. Tim Cresswell explains that “place it is also a way of seeing, knowing and understanding the world. We see attachments and connections between people and place” (Cresswell 11). Dohr and Portillo engage their readers to think about design in a manner that defines memorable moments; the feeling of being in a place as empathy tugs at emotional heart strings. Experiencing design associates the emotion of the experience with values and beliefs and engages students with a new level of design thinking in considering the type of narrative to be lived. The opportunity to experience the emotion of being in a place with meaning in a simulated immersive virtual environment can enable students to better understand the meaning of the success or failure of their concepts as they have an opportunity for evaluation and reflection.

Professors of architecture Lorraine Farrelly and Alberto Pérez-Gómez compare the design of interior spaces to a choreographic scene, song and dance as a relationship between body and environment. Movements transform the space into a place of lived experience. They view interior spaces as an alliance between people and environment but define it in terms of the motion and relationship of that alliance. The body functions as a part of the environment. Farrelly notes the connections of the body as it interacts with its surrounding while providing a sense of scale as it meanders through the space (273-275). Pérez-Gómez identifies the presence of the body in *being* and *becoming* in a space for social interaction (Holl 8). In a similar analogy of body and environment Ann C. Coley discusses the narrative of a conscious relationship. She describes the connection as a dialogue between both body and environment but that the objects within an environment do not define the place until the body enters and moves within the space to begin the narrative (Coley 68). The relationship between body and environment likewise coincides with Fumihiko Maki’s belief that the primary role of design is to respond to spatial elements by addressing the human body’s dimensions as it relates to the space around it (Taylor and Maki 17). Interaction between body and space contribute to meaning in the experience.

A narrative is defined by Lily B. Robinson and Alexandra T. Parnam as a theory. They describe the theory as an outlet to express personal meaning where relationships between people and places are identified. They assert that the application of the theory demonstrates lived experience within place. In this example Robinson and Parnam use the narrative provided by their client of perceptions and sentiments to initiate a dialog to develop an interior place "Personal meaning is expressed through written narratives, providing an avenue for discussion" (Robinson and Parnam 65). The text is a narrative about research and design processes but fails to provide a clear definition as to why the research is being conducted in the first place, what is to be achieved and for whom. While their definition of narrative theory concurs with Dohr and Portillo's, it remains as a theory whereas Dohr and Portillo's narratives use theory as a significant contributor in the narrative and place the narrative as an active component, not only of place and lived experience but also as a part of the research, and the process of design.

Linda L. Nussbaumer in *Evidence Based Design* asserts that in developing conceptual design the appropriate application of any one theory of meaning is dependent on a client's meaning of place and the attachments they have (30-33). The client's culture plays a unique role as a motivating factor in forming behaviours and values about spaces and places. One is equally dependant on the other to create experience.

### 2.4.b Ascertaining the Impact of Design

Cresswell, Dohr & Portillo and Nussbaumer address the narrative in terms of the telling of a story as a whole environment. Regulatory requirements and life safety are addressed as chapters within that narrative. Although it can be considered as a narrative of its own, for the purpose of this research, life safety is considered a part of the story to be told. As part of programming and design development life safety takes its place as a regulatory requirement to ensure the wellbeing of occupants. Its history can be found as far back as 1895 in Boston, Massachusetts when a group of individuals gathered to discuss inconsistencies in the use of sprinklers and insurance concerns. Although early beginnings focused on the standardization of the requirement for sprinkler systems, the National Fire Protection Association (NFPA) fast became an international association whose mission is the "reduction of fire and related hazards on the quality of life" (NFPA.org 20 January 2014). The NFPA strives to provide scientifically based consensus codes, standards, research and educational opportunities. NFPA standards have become part of the regulatory requirements of building codes. Similarly building codes have developed throughout history and have been informed by the tragedies of the past. Traditionally building codes have regulated structures, fire safety and the health of building occupants. More recently they have included accessibility and energy efficiency. While building codes differ from region to region they all have the same goal; the safety of building occupants. The overall narrative of the building code contains many chapters found within the covers of its binders. Most are not applicable to design, but those that address design are confusing at best and offer few visual aids to assist in understanding explanations, rules, regulations and definitions. While many design firms and educators rely on the text of code books, visual aids can supplement the understanding of the regulations. Katherine Ankerson's DVD *Illustrated Codes for Designers – Non-Residential* aims to provide a visual narrative of the written text by providing images to explain the written words.

### 2.4.c Meaning and Value in Design

Perhaps more helpful is Tiiu Poldma, Canadian design academic's definition of experience as meaning that emerges through interaction within places (12). Contrasting

Robinson, Parnam and Nussbaumer, Poldma places greater importance on the meaning of place and its relevance to conceptual design. She affirms that objects and environments affect a person's perception relative to meaning and place and influences future interactions with both. Poldma believes that connections formed in lived experiences mature as humans do supporting Dohr and Portillo's understanding of narrative where lived experience is based on relational connections. Maturity of value and meaning of places evolve as we experience new and existing places (Merleau-Ponty 6). Poldma states that "meanings are what we attach to the experiences and objects…in our daily lives" (12). The narrative in Poldma's text is the narrative of meaning. This is a significant reflection on the interaction between place and experience. The application to an immersive virtual environment would similarly provide experience with meaning. Although the physical components of virtual environments feel real they are not present in the physical location. Nevertheless the images presented are of designed locations. In 3D movies the audience wears special 3D glasses to view images in three dimensions. The full scale virtual environment performs in a similar manner with the exception that in this environment the viewer is the participant and is part of the experience not just viewing it. Being a part of the narrative affords more meaning to the experience.

### 2.4.d Adaptation and Transformation

The narrative in design requires students to understand the meaning of their concepts as they design deliberately to create meaning for the emotional and physical well-being of occupants. But what happens when a space changes? Does the meaning change? Tiiu Viakla-Poldma write about Poststructuralist, Phenomenology, and Lived

Experience: About Meaning Held Within Design with a vignette by interior design educator Drew Vasilevich provides several examples of structures that have outlived the usefulness of their intended use: first church buildings are converted into retail outlets or condominiums; railway roundhouses converted into breweries and furniture stores, and of industrial buildings converted into offices. Vasilevich questions if the meaning of the original building changes. He concedes that in the acceptance of change a narrative shift occurs as the interior space is transformed into an alternative script with different characters but the building envelope remains the same (Vaikla-Poldma with Vasilevich 102). In contrast Bernard Tschumi's concept of disjunction lies in the term "space and use" (5) and the instability of design that is always on the verge of change. Can the experience in a virtual environment maintain the original meaning while presenting a narrative shift?

In Dan Bucsescu and Michael Eng's *Looking Beyond the Structure: Critical Thinking for Designers and Architects* a similar inquiry arises but in the context of identity. The question asked is whether a person's identity changes as the environment is modified. It is understood that objects mean different things to different people, so too do places. What happens to the person living the experience when a place changes, does their identity change or how they identify themselves? Does identity change in a virtual environment? Is meaning altered when experienced in reality or in virtuality? With the intention to promote inquiry and dialog, Bucsescu and Eng discuss various topics related to critical design thinking. Their concern is that without an understanding of critical thought, the value of narratives that provide the context for experience, meaning and identity will be absent in designs of conceptual spaces (80-121).

### 2.4.e The Digital World of Solids and Voids

According to architect and educator Daniela Bertol, narratives view the spirit of design experience through voids and solids providing an unpretentious method for perceiving the environment. She uses the same theory of solids and voids and places the varied context of their existence in a digital world. The digital world is a place where physical space and materials are non-existent and where voids and solids are turned into the numerical format of a database (Bertol 57). In a digital world solids and voids are created through a series of coordinates, the connected points appear as objects which take the shape of furniture as solids and the space around them as voids. Cyberspace serves as a symbol of digital design as it creates a simulated space for interaction.

## 2.5 Virtual Reality

Virtual reality refers to a world that mimics reality, it can look real, it can feel real but it's not real. While our imagination and dreams can be thought of as a virtual environment the intent of this research identifies virtual reality as a digital method to visualize simulated realities. The world of virtual reality encompasses many meanings from the use of mobile devices, to that of simulated reality, communications, computers, access to information, digital media and visualization. The literature in this area provides a broad definition of virtual reality which includes the devices and the varied parts that when assembled provide an environment displaced from reality but now part of society's reality. I review the various meanings and extent of virtual reality as its boundless space simulates the limits of space; the realism of its images juxtapose with reality to provide experience and sensory stimulation.

Bertol explains that in a virtual environment cyberspace does not have physical boundaries or have a physical character other than the computer screen. Manovich on the other hand believes that the technology of cyberspace sets a “new standard for how we interact with computers” (Manovich 288). Images revealed through computer screens represent places, structures and objects. Bertol claims that the traditional understanding of perception and experience is altered in the virtual world of cyberspace. Cyberspace as described by Bertol, is the scientific visualization of computer graphics where the quality of the resolution adds to the realism of the images. In cyberspace, the virtual place is where the participant experiences being in one place, while in reality being somewhere else (Bertol 60-61).

### 2.5.a Society’s Digital Devices

Nicholas Negroponte addresses the virtual reality of cyberspace, accessible through the digital world of electronic devices and mass media as devices for living. Society’s need for communication has altered the method in which we communicate, build, learn, work and play. It has infiltrated almost every aspect of our lives. In a virtual digital world our sense of sight and sound are heightened while the remaining senses lie unchallenged. The computer screen is a flat smooth surface, it cannot feel like bricks, tree bark or burlap; there is no ambience or relationship created. Negroponte compares “being digital” as ones imagination being thrust into action to discover meaning and experience in the image presented, much like reading a book (Negroponte 6-8).

Negroponte provides a general overview of digital technology and what it means to be digital by reviewing the components that make up the digital environment and by applying his knowledge of the media’s influence on daily events. Negroponte believes that in our digital world “the medium is not the message…it is the embodiment of it” (71). He sees it as ironic that his book *Being Digital* it is not in an electronic format and recognizes that increasingly the interaction between people and their environment is mediated through the computer. Negroponte suggest that immersive virtual environments are extensions of society and leaves it up to his reader to place themselves within the context of his book and to recognize their position within the digital world and its future in society. He identifies society as an influencing factor on digital media and in turn digital media’s response influences society’s requirements.

### 2.5.b Medium or Message

In a similar manner Marshall McLuhan stresses the importance of understanding the impact of media and its imposition on our sensory lives (McLuhan and Zingrone 5). McLuhan’s theory recognises the influence an immersive virtual environment can have on educators and learners. Understanding the virtual environment and its impact on teaching and learning will enable educators to better prepare the context of how the technology of virtual environments can be integrated into lesson plans used by students. A man ahead of his time McLuhan foresaw the transformation of media to a more digital environment. According to Zingrone, McLuhan was a staunch supporter of the past. While at first he resisted technology he set forth to discover what it was all about (8). He believed that the encumbrance of experiencing change lay in our inability to understand it. People by nature do not like modifications to their routines but much of this dislike lies in their inability to fully understand the occurring change. Becoming more receptive to change requires the acquisition of knowledge to alleviate the anxiety of change. This illustrates that technological progress in an immersive virtual environment requires an acceptance and understanding prior to its use by educators and learners. McLuhan understood the impact technology would have on a global scale. Electronic media was well on its way to replacing a society who relied on the printed material with one who depended on information in digital form (Marchand 175). I would argue that while much of the information educators and students gather is in digital format just as much is in paper based formats. The immersive virtual environment is a collaborative effort between educator, learner, paper and technology.

While McLuhan's discourse aimed to define technology and its impact on society, Paul Virilio was relaying the message of the speed by which technology was propelling society. Virilio believes that the information age is a global activity in perfect harmony, the speed of which can match the speed of light. It is as much a matter of information content as it is the speed by which the feedback is received. What becomes important is instant delivery, information becomes secondary. He believes that the 'shock effect' that results will always triumph over content (Virilio 206). In the design studio this becomes more relevant as the digital image provides a simulated appearance of reality.

| Theorist | Theory |
|---|---|
| **McLuhan** | Medium is the message |
| | Impact of technology on a global scale |
| | Media effect on society and cultural |
| | |
| **Virilio** | Cultural theory |
| | Technology, speed and power |
| | Information age as global activity |
| | |
| **Negroponte** | One laptop per child |
| | Merging of the interactive, entertainment and information worlds |
| | Digital optimist |
| | |
| **Manovich** | Digital humanities |
| | New media art and theory, software studies |
| | Growth of social media |

Figure 12 Digital Theorists - Key Concepts (by author)

The technology that propelled the information age to the forefront of global communication has likewise shrunk the miles between people. Computer technology is not about machines; rather it is a representation of society. As Nye explains, social development as a process is shaped by a communal context (Nye 47), connecting with Vygotsky's theory of society's impact on growth and development. The virtual world of cyberspace as described by Bertol is further explained by Nye as a relational shift between people and the environment. Nye compares cyberspace to what early explorers would have thought of the new world, open for discovery. The debate according to Nye is whether technology is controlled by corporations or by society as a consumer market. Nye's intent is to illustrate how society and technology have coexisted for centuries. They coexist today in a digital environment and will coexist in the future as yet by unknown means; the consequences of choice made today will influence the results of tomorrow. Studio teaching and learning is an example of the coexistence between technology and society. Students are required to produce results within a thirteen week semester in response to a design problem; technology has enabled students to produce rendered images easily modified to simulate material, lighting and ambience.

We hear and see things as never before. The complexities of technology are so diverse that Nye feels we may be "losing touch with other methods of understanding" (185). Cell phones provide information available in real time giving flexibility to otherwise hectic work and home life; it has become a source of entertainment at our fingertips. Social communication has shifted from face to face conversations to that of chat rooms, emails and text messages. Technology provides a virtual social environment through miniature devices.

The virtual environment of information transfers real data as it is presented; the words written on this page appear as what they really are. In the virtual world of visualization manipulation of content is more readily achievable. A skilled photographer can manipulate images just as well as a cinematographer or a computer animator. These mediums are the blank canvases for artists. Nye questions the consequences of manipulated images. Authenticity becomes questionable but Nye also speaks of authenticity being enhanced as a tool to entertain where reality or images are observed in one place while being somewhere else. Images, whether moving or still and viewed from different angles alter the experience.

### 2.5.c Spatial Experience in Immersive Environments

Lev Manovich explains; "the meanings of the word "visualize" include "make visible" and "make a mental image" (Manovich.net). He implies that pictorial shape is not achieved until we "visualize" something. The image is attained through a development of visualization methods. His principles of reduction and spatial variables are comparable to design in that they describe graphical elements such as point, lines, curve and geometric shapes to represent space and the relationship between objects their position and size (Manovich 2011, 36-49).

Manovich questions how our spatial experience is affected when the mediated environment is manipulated by digital images. He prefers to discuss the poetics of space augmented by technology in a cultural context rather than in a technological one (Manovich 2010). Spatial experience whether imaginary, physical or virtual provides a location where the senses are stimulated to experience the atmosphere of a place. Design education likewise strives to provide spatial experience but currently experience resides on two dimensional surfaces as visualized conceptual designs of interior spaces. The virtual environment provides an opportunity to experience visualization in three dimensions at full scale while providing images of reality through videos or rendered images through digital technology. In the creation of digital images computer technology requires the manipulation of elements and data sets to provide images. Real images transferred from digital cameras do not require manipulation to be transferred to a larger device but can be enhanced, similar to photographic images to remove red eyes or shadows, to add a person or remove them. Although the images have been modified they remain real but maybe not authentic.

Movement permeates interior spaces. The application of interactive design casts interior space into the realm of new meaning and experience. The studs and drywall of an interior environment become pixels in a digital environment (Novak 262-265). Constructing a virtual environment for human habitation takes on a cinematic quality with a plot, characters and place. Interactive spatial movement activated by camera movement within the virtual space of a computer screen flies over the landscape, walks through rooms and navigates around geometrical forms. The realism of a three dimensional digital animation in a virtual world provides the illusion of being in place. Experience is altered as the optical and auditory senses are fooled by the realism of the illusion. The endless virtual world of cyberspace inhabited by objects gradually displays structures, shapes and objects that are placed within relative virtual distance from each other. In virtual space there is no distance. Distance is part of the illusion of perspectives (Manovich 1997 287-299). In contrast and unlike the illusion of a computer screen the narrative of a student's conceptual design transferred to a three dimensional virtual space at full scale enables them to have a "presence" in the immersive virtual environment. Virtual is explained by Andrew Evans as "not exactly real, but real in effect" (Evans 7). Perceived illusions are similar to magic which he also suggests is an escape from reality. Contrary to Evan's belief the aim of a three dimensional full scale virtual environment in the design studio is to encounter reality,

### 2.5.d At the Frontier of Virtuality

According to Jaron Lanier, a pioneer in the field of virtual reality, the technology of the virtual environment is an "extension of ourselves" (4) it takes the reality of our lives and places it at the centre of virtuality. Geographic coordinates in physical reality are replaced by the Cartesian coordinates of the virtual world (Lanier 193). Regardless of Cartesian coordinates Rheingold believes cyberspace is a place (Rheingold 16). Unlike physical place the virtual one is constructed from data and pixels and presented as graphic images. He looks at virtual reality as a type of simulator in which you can be immersed and interact with physical objects but impact virtual ones. Reality takes a backseat to a world of “escapism” as Evans explained. But Rheingold differs in opinion as he sees virtual reality not as an escape from reality but as an opportunity to explore reality using the frontiers of scientific knowledge to amplify reality. He sees a new world emerging from a virtual one where personal simulators become the norm. The mobile device provides the virtual space for personal simulation in Rheingold’s world (15-17).

The benefits of virtual reality can be applied as an architectural and design tool to provide virtual walkthroughs of structures in a three dimensional full scale environment. Rheingold explains that for architects and designers the mental image often sketched and drafted remains on a flat surface. The ability to communicate concepts of complex forms and to validate the life safety and well-being of occupants cannot be properly represented on a two dimensional surface. He sees this two dimensional image as a conflict with a designers thoughts which are primarily in three dimensions. The opportunity to present concepts in three dimensions can benefit design students to conceive complex concepts, integrate regulatory requirement and for educators to better understand what the student perceives through their mind’s eye. He describes the world of virtual walkthroughs as having advanced beyond research into a world of commercial growth where the quality of realism entices its audience’s participation (Rheingold 30). Experience in an architectural virtual world is at the heart of the simulated environment while presence in the virtual world is enhanced by the ability to move within the environment.

### 2.5.e Realism of the Immersive Environment

Realism is explained by Chris Christou and Andrew Parker as the degree of similarity between what is real and what is virtual. While they believe that the complexity of human perception may never be attainable in a virtual world, they do acknowledge that on a computational level well-developed criteria can be applied to achieve a level of realism acceptable in a virtual place. Realism is achieved on two platforms, first from videos of real places and the second platform of rendered images. For The first platform to appear real it requires the additional component of 3D glasses to simulate depth when viewed in a virtual environment. The second relies on the software and resolution of the computer system to simulate reality. Christou and Parker investigate the improvements that can be achieved in a virtual world by understanding the real world of visualization and the limitations of the visual system. They explore the link between the perception of the observer and the display transmitted through the computer's screen (53-62).

Malnar and Vodvarka present a multisensory option to the two dimensional surface in the form of an immersive three dimensional experience. The CAVE™ Automatic Virtual Environment (277) combines three dimensional images, digital graphics and animation to provide a sensory experience to simulate being in a physical place. As its primary concept my thesis *Experiencing Conceptual Design in Three Dimensions: An Evaluation of CAVE-like Environments for Interior Design Education* speaks of experience in an explicit environment to visualize conceptual design. Unlike reality the virtual environment can simulate reality through digital and real images to experience places of reality such as offices, retail outlets and hotels. The more realistic the image the more credible it becomes. Bertol states that realism in the virtual environment is a major achievement of computer technology (116). She explains that the success of the virtual domain rests on the visual testability of realism as quality of images, elements of scale, proportion, relationships, textures and light effects. The viewing position and movement within the environment add to the realistic perception of place.

In her essay *Technology's Role in the Design Process* Charrisse Johnston identifies the role of technology in the design process starting from the "animated walkthrough", all accomplished on a desktop computer. She recognizes the potential of technology's virtual domain as she claims it to have infinite adaptations (209). In comparison Nancy Diniz essay *Sensing the Environment* more accurately addresses experience and visualization in virtual reality and the sensing of the interior environment. She investigates how the latest technologies can "enrich the experience of space" (31-38). The full scale prototype of a virtual environment focuses on space as a place to explore conceptual design.

"I want to go full scale and not monitor because in the monitor, you are still looking at a picture" (Taraska and Makovski 2).There is no sense of presence when working with a computer simulated walkthrough according to Shashi Cann. At full scale reality sets in and challenges critical thinking. Caan defines design as the ability to "make people feel dignified" (2) in a place where they are the center of attention. At full scale clients are in their space not just viewing an image of it. According to Caan the designer has the responsibility to embody a client's personality within the space they are designing (2). This statement represents the spirit of my thesis, to experience immersive three dimensional virtual environments to visualize conceptual designs.

# 3.0 Possibilities for the Technology

## 3.1 Is it Really Real?

Ever since the Star Trek series appeared on television North American society has been enthralled with attaining faster, less expensive entertainment and lived experiences through technology. Transporters, the tricorder and the Holodeck became inspirational goals for many computer technologists and engineers' and something to dream about for society. The Holodeck was a symbol and narrative of a place of desire for transported crew members. What appeared to be distant places were depicted through a virtual environment mediated by a television screen; they were in reality the manipulation of various cameras and special effects. As a science fiction series it appealed to a specific audience but nonetheless it sparked an interest in the scientific community and played a role in the advancement of computers and digital technology on a global scale. Interest, mostly in the realm of the Holodeck's virtual environments has captivated an enduring audience in the field of computer technology. The land line phone, television set, library, and advertising media have been synthesized into a new narrative through digital networked computers (Murray 27).

By contrast the 1999 film *The Matrix* presents a dystopian society. Rather than being a place of desire the matrix is a place of disillusionment. Set in the future machines take over due to the decline in society's ethics, politics, religion and economics. Humans perceive the world as a simulated reality of the world called "the matrix" that has been created by conscious machines to pacify humans. The narrative chronicles the struggle and rebellion between its main human character Neo and the machines that enslave them to free humans from captivity and end the war. This struggle draws attention to the potential disconnection with reality when interacting in a virtual world. Suspension of disbelief is identified as the relinquishing of control to a simulation by ignoring the medium. The two examples given deliver extremes of virtual environments where imagination through the creative use of technology far surpasses technology's current ability to provide real experiences other than in cinematic format. They further demonstrate contrasting views of the technology's potential but both also describe a future inseparable from virtual environments.

To expand on the reality of current technology the following inquiries will provide a review of the various technological tools to support experience in a three-dimensional environment to visualize conceptual designs of interiors at full scale. The first inquiry will identify, analyze and evaluate technological tools. The second inquiry will establish which of the tools best supports experience in a virtual environment to visualize conceptual designs and the final inquiry will determine the value of the environment to interior design education.

## 3.2 Technological Options

### 3.2.a Immersive Alternatives

The following comparative review will identify three technological approaches to visualization in three dimensions and provide a description of their application, implication and limitations. More precisely the review will identify the technological tools of: augmented reality, simulation and CAVE Automatic Virtual Environments. I will provide a definition of each method while also providing a context for conceptual design to determine their viability for design education and their use(s) to create the experience.

### 3.2.a.i Augmented Reality

In its most basic definition Augmented Reality (AR) contains three components. The first component is the application of artificial digital information as an overlay onto reality, the second *registration* or alignment between objects, viewers and locations and the third there must be an interactive environment in real time (Livingston 3). Of all the senses vision is predominant in an AR environment as it is a visual supplement to visual reality (Bimber and Raskar 1-3). While sound enhances the experience the viewer must concentrate on the device emitting the sound by filtering out the noise around them. The user in an AR environment exists and is present in place in reality in real time. Place only changes as the user moves from one location to another. AR uses existing real physical space through miniature mobile devices such as cell phones and iPads; the experience remains bound in reality. Society's attraction to AR is anchored in the miniaturized mobility of the device. AR works as collaboration between technology and industry. Many restaurants display their menus on their windows where customers can view the information presented. In AR viewers can be across the street aim their cell phone at the restaurant and an overlay of information appears as the menu, customer comments and hours of operation. This display of information is made possible by markers placed in the participating restaurant. The marker is a direct link to the reality being viewed.

While being at the forefront of user interaction, augmented reality does have its share of challenges: the accuracy or *registration* is a primary factor in AR. The ability of the AR system to accurately track the viewer, real objects and the virtual information is necessary for believability. The mobility and devices used in augmented reality include but are not limited to: digital cameras, GPS, cell phones, iPads, optical and wireless sensors where the challenge is the ability of the various devices to work with the same operating systems.

*Registration* is defined as the level of accuracy and the link between augmented reality and the real environment (Bimber and Raskar 4). In order for the AR system to function properly the overlay must be placed exactly where it needs to be to have the correct effect. Without accurate registration the user of the AR system receives unreliable information. An example explains inaccurate registration: when looking at oneself in the mirror the entire head, hair and facial features can be seen inaccurate registration occurs when the image appears as a head with its hair off to one side and facial features in disorder. This can further be explained with the example of the restaurant above where the viewer aims their cell phone at a specific restaurant however the menu appears on the window of the store next door the information appears where it should not be. In order to provide a complete and precise image all the components of AR must be aligned (Kipper 23).

On a more social level AR challenges are outlined by Gregory Kipper and Joseph Rampolla and rest on the issues of: privacy as the camera is a key component of AR (24-25). The issue is explained by Kipper and Rampolla as having the potential for people becoming part of the “Internet of things” (25) without consent. They refer to a recent movie entitled “Freedom™” (25) by Daniel Suarez where the main character walking down the street wears special glasses that can identify people, their personal information and their financial worth. While they state that this is an extreme example it does have its possibilities for invasion of privacy. Concern about personal safety and the safety of others have become prevalent to the point where governments have had to institute laws criminalizing the use of devices under certain conditions and prevent drivers from using devices while on the road. Since the personal motor vehicle was invented distracted driving has always been a challenge but never with such a capacity as since the advent of the mobile device. Another pernicious quality of mobile devices is unwanted advertising which can be compared to junk mail. Advertisers and marketers seem to have run out of space in reality and have now entered the realm of virtuality.

Regardless of the challenges AR faces its popularity with the mobility of iPads and smart phones has created a worldwide infrastructure for future development. The speed with which these devices are developing will enable them to better track a user's position and recognize what objects are observed to provide more accurate and useful information. The potential of AR with the increasing acceptance of mobile devices impacts industry, education and places of lived experience and takes its place at the helm of social interaction.

| **Augmented Reality** | |
|---|---|
| **Advantages** | **Disadvantages** |
| Mobility | Security |
| Miniature devices | Inaccurate registration |
| Access to information | Safety – use while driving, walking etc. |
| Present in reality with AR overlay | |
| 3D Holograms | |

**Figure 13 AR - Advantages and Disadvantages (by author)**

Other examples of AR include: sporting events such as football, the "first down" appears on the television screen a yellow line. Spectators present at the game do not see this line as they are not interacting with an AR device. Swimming competitions are another location where AR can be applied as swimmers advance in their lanes their nationality appears in their respective path.

Entertainment remains the most popular forms of AR interaction and the one industry that can boast multi billion dollars in sales. Whether applied to movies, arts or gaming augmented reality has transformed how we experience events. Gaming has gone beyond the living room, as the predominant form of entertainment gaming platforms can include players from multiple locations by using the players real surrounding and apply AR overlay to continue the game (Kipper and Rampolla 58-60).

A day at the museum used to include tour guides familiar with artifacts who could recite memorized information. Today the museum guide is becoming an augmented reality application. In a study conducted at the Louvre's museum lab a multimedia approach to augmented reality was applied to provide visitors "artwork appreciation" and "guidance". The goal was to provide visitors with detailed information about the objects and to provide an orderly method of directing them through the museum. The research sought to compare and evaluate the usefulness of AR interactive guidance with that of paper maps without turning the experience into a science project. The mobile device required battery power to be 1.5 hours in duration, and the device to be lightweight and accurate to the visitors' position.

The evaluation consisted of observations and interviews with staff and visitors. The results were positive as the system allowed visitors to view artwork from different angles without noticing the AR system around it. The device had the ability to take screen shots of their preferred items and users found the organization of information was helpful. On the negative side the device was still too heavy for some visitors; others felt the overlaid text was too small and lighting between the presentation room and the surrounding area to be unequal. The guidance system on the other hand did not fare well as most people pointed their devices everywhere not understanding where the animation was to materialize and could not remember the reference point they were provided at the start of their visit. Animation at some stations was instant while others were delayed; this resulted in some confusion over the systems working ability. On a positive note visitors were impressed with the potential of the AR system and were delighted with the interactive experience. Overall the researchers were pleased with the results both positive and negative as it identified areas requiring additional investigation and development (Miyashita 103-106).

#### 3.2.a.ii Application to Interior Design

In design education show room and plant tours students get the opportunity to see, touch and feel the materials and components they are expected to use in their designs. Subsequent visits are a luxury most students do not have in a thirteen week semester with many deadlines. Beyond initial tours, show rooms are accessible on company websites while binders contain the images and components for assembled workstations. For any student trying to detail the required components necessary for their design is an arduous and time consuming task. What if augmented reality simplified the task? Students can point their mobile device at the computer screen at any piece of furniture or assembled workstation and receive in return the make, model, colour options and components. Similarly if a student sees a piece of furniture perfect for their design while walking down the street they can aim their device at the items and automatically receive the name of the manufacturer, contact information, make, model and colour. Shopping around takes on a whole new meaning as screenshots can be recorded for later analysis and inclusion into presentations saving time and energy. Students can include AR components into their presentation. Images of furniture are common in ideation boards, many include some basic text but AR has the potential to provide supplemental information for the students presenting and for the viewer observing.

Viet Toan Phan and Seung Yeon Choo write about augmented reality in the design of interior spaces. They propose the application of AR technology to view and interact with virtual furniture in a real environment. Tracking markers placed around a real room define the room's coordinates while the user selects virtual furniture. The virtual selection is place alongside a real one. The AR system allows the user to interact in real time to modify the colour, style of the fabric or move the selection to another location. The basic principles of colour, scale and proportion are manipulated in an AR environment to provide different arrangements within a room. The success of their AR application provides the opportunity for additional research and experimentation in the design of interior spaces (Pham and Choo 16-21).

Professor Vincent Hui and his co-researcher Matthew Compeau have developed an AR software App that enables architects and designers to superimpose their design in reality. The Augmented Reality in Development Design project uses student projects and places them on an AR marker (label) which can then be placed on a real site or within a scale model. Observed through a high definition camera students can view the result on their laptop and experience a full 360 degree view of the building or space. This allows the students to assess their designs in place where they are affected by light, shadows, zoning constraints, aesthetics and societal and historical influences. While the use and affordability of AR as a teaching tool has gained in popularity it remains an underutilized tool in architecture and design. Hui and Compeau continue to develop the software not only to benefit students but also the profession (Ryerson.ca media).

### 3.2.a.iii Holographic Potential

In another capacity augmented reality holograms provide a three dimensional simulation. The paper pop-up book that fascinated children before computer technology became a mainstay has been transformed into three dimensional pop-up hologram E-books as AR characters pop-up rather than paper ones as seen below.


**Figure 14 Augmented Reality Hologram - Richtech Augmented Reality System. http://www.bing.com/images/search?q=images+augmented+reality+richtech&qs=n&form=QBIR&pq=images+augmented+reality+richtech&sc=0-36&sp=-1&sk= (Used with permission)**

Holograms have the distinctive ability to present objects in three dimensions from various angles with a visual acuity worthy of its performance. Holograms are an ideal method to display vulnerable artifacts kept in museum archives. It can also be used to reconstruct archeological remains and medical imaging.

Although not currently used in design education holograms present a unique opportunity for students to present their conceptual designs. The time consuming details in scale model building are simplified by producing three dimensional holograms of designed spaces. The two dimensional presentation board takes on new meaning as its surface displays a three dimensional space that rises above its two dimensional surface. The space can be viewed from different angles as the board is tilted and turned. The construction of geometric shapes using three dimensional AR holograms provides educator and student alike with the ability to explore the various properties and surfaces of curves, cylinders, pyramids and cones (Lee 13-21). Furniture catalogues likewise can offer new meaning as items displayed on their pages take on a three dimensional qualities that can be observed front, back, top and bottom. Albeit a great idea as an option for design presentations unfortunately holograms require specialized equipment and technical expertise to transform plans into three dimensional scale models.

### 3.2.b Simulation

By definition a simulation is an enactment or re-enactment of an event, place or action to pretend or practice in preparation for the real experience. In a broad sense it is the act of imitating. It provides a safe manner in which to prepare for reality. Simulations can either be conducted in the real world or as computational models but do not have to be technology centered occurrences. Regardless of the method used simulations are a practice based process to acquire skill. Unlike the mobility and diversity of augmented reality, simulations are more occupation related and as a result are commonly used in education & training.

A common component of simulation is the development of a model which represents key features of the real environment to simulate the behaviours expected in reality. The model that is developed includes the process and the manoeuvres of the real situation such as a flight training simulator. Conducted in a controlled environment simulation allows for errors, repetition and modifications of behaviour and environment. Depending on the complexity of the occupation the simulation can be conducted in as little as one hour or in as much as day, months or even years. The simulation which becomes the training ground for future real experiences is required to be as real as possible. A predominant aspect of simulations is the ability to provide an environment where the hazards of reality can be eliminated or where the location is inaccessible. As a model for reality simulations can also take shape as an innovator in that it becomes the testing ground for undeveloped products, environments or workplaces. How well the model performs directs the viability of production. The model can test scenarios under a variety of conditions and variables; it can be adjusted and modified until the expected or required results are achieved.

In order for the simulation to be relevant the proper information, unique features and behaviours are required to achieve a level of detail similar to reality. Interaction as a key feature represents a major component of simulated environments. The participant or group of participants is expected to behave in a specific manner. The simulation reviewer observes one or more participants either acting alone, interacting with each other or equipment or tests equipment behaviour to evaluate and analyse performance and results.

| **Simulations** | |
|---|---|
| **Advantages** | **Disadvantages** |
| **Full scale prototypes** | |
| Full scale model of design | One corner or room at a time |
| Provides understanding of component relationship | Availability of space |
| Experience in designed space | Cost to build |
| Practice based | |
| Controlled environment | |
| Ability to evaluate and analyse performance | |
| **Computational Models** | |
| Increase awareness of complex models | Limited to computer screen size |
| Speed and accuracy | Experience is a miniaturized version of reality |
| Innumerable scenarios | |
| Can store vast amounts of data | |
| 3D cinematic walkthrough | |
| **Scale Models** | |
| Can build a whole space at a fraction of the size | Miniature version of reality |
| Better understanding of spatial extent | Time consuming to build |
| 3D presentation of space | Cost of materials depending on level of details |
| Better understanding of adjacencies | |
| Better understanding of vertical relationships | |
| **3D Printers** | |
| Speed and accuracy of production | Cost to purchase and maintain |
| High quality details | Single colour, does not replicate actual finishes |
| CAD foundation | |
| Available in a variety of colours (printer model dependant) | |

Figure 15 Simulations - Advantages and Disadvantages (by author)

### 3.2.b.i Educative Assessment of Simulations

Computer simulations or computational models on the other hand are part of mathematical models that replicate natural and scientific systems. These systems include anything from weather pattern and earth movement to biology, chemistry and economics (Wikipedia.org simulation). The computational models are designed to increase understanding and awareness of complex systems. The speed and accuracy of computer modeling provides countless scenarios, analyzes vast amounts data and provides results which would otherwise be unattainable manually.

A different aspect of computer modeling is found in Ankerson's DVD *Illustrated Code for Designers – Non-Residential.* Although not a true simulation the DVD nevertheless provides an interactive illustrated platform that demonstrates animated examples of regulatory requirements. She uses several simulated examples to explain the path or paths occupants must take to reach an exit. These simulations provide a visual explanation of written text and demonstrate the importance of visualization in conceptual design.

Simulations in design education rely on full size prototypes while scale models provide a miniaturized three dimensional version to communicate aspects of design intent and aesthetic elements without the expense of the real building (Loukissas 15). Full scale prototypes of rooms were not part of the curriculum throughout my university education. This method of simulation was considered cost prohibitive given the number of students and the space constraints. Furniture pieces were the only items built to full scale including a cardboard chair and an MDF coffee table. The design process for the chair and table evaluated function, style and material. The experience of building your own design full size provided an understanding linking thought, design and the physical reality of assembly. The construction process and final assembly taught me more about construction than the theory in studio class. Looking back at my education had the opportunity to build full scale rooms been available I would have better understood the application of the theory learned in class and the link from design development to design implementation. Full scale prototypes are often built using actual materials specified and appropriate construction methods of surrounding walls. This method enables students to review their material selections by analysing their appropriateness to the location, function or task, to understand the installation methods for the materials and the ability to resolve proportions and detailing issues.

Scale models in design education are most often built of foam core, cardboard or balsa wood. This simulation method although built at a fraction of the size of the full scale method provides a view of the entire space. Typically residential models are built at a scale of ¼" = 1'-0", commercial models depending on the overall square foot, can either be built at the same scale or smaller but as the scale diminishes so too does the visibility of detail. As students' advance in their schooling, the level of detail required of their models increases. Although plans and elevations form the basis of scale models, building them was more enjoyable than drawing the plans and elevations. The relationship between plans and elevations finally made sense with the production of scale models. The inclusion of a ceiling plane provided a vertical relationship to the design concept in addition to scale, proportion, colour and sometimes texture revealing a unified design concept illuminating the theory learned in class. The exercise of model building explained how components fit together and the relationship they had to each other and to the whole space.

Although relatively new to the world of scale models 3D printers are quickly being adopted for scale model building. The time required to build scale models by hand is eliminated and replaced by technology as the new model printer takes the CAD drawings to build the 3D model. This time saving method enables designers to experiment with complex shapes. 3D printing is a manufacturing process that optimizes the speed of producing models layer by layer. Printers can produce architectural scale models as well as useable adjustable wrenches, miniature cars, light fixtures, tables, medical devices and many other objects. Items can be printed as one object including movable parts, cured by UV light they are ready for use. The estimated cost of a 3 D printer, between $20,000 and $40,000, can be offset by the reduction in cost of labour and materials. Although this offset cost is dependent on the quantity of scale models required to be built for clients and in the case of an educational environment the quantity built by students for their studio projects. As with any business the high cost of ownership provides a market to lower cost by providing a service. 3D printing services are offered by various companies that can print models as required.

#### 3.2.b.ii Digital Modelling of Interior Spaces

More current in design education is the digital revolution as some schools have sidelined the scale model for a more flexible method of viewing buildings and interior spaces. The term “modelling”, which suggests a craft, is more often used in design than the term “simulation” to distinguish the staged representation of reality from digital technology (Loukissas 18). The computer model through the use of software such as

CAD, StudioMax, Revit and SketchUp transform two dimensional drawings into three dimensional images that imitate human perception of space. Although these images are viewed through the two dimensional surface of a computer screen they provide an interactive animation of the space. The software presents flexible design tools to evaluated concepts before they are built, communicating intent to clients and reducing the environmental waste of printer paper copies (McConnel and Waxman 16-25). The digital visual model is rendered to mimic the characteristics of surface textures and colour of materials used in the conceptual design. In addition and to create a better sense of the ambiance of a designed space simulated lighting is added for aesthetic purposes and to add realism. Environmental conditions such as sunlight or night conditions, weather, clouds and sky and gardens can be added to the exterior background of the model to provide a greater sense of depth and location (Bertol 49).

#### 3.2.b.iii Comparative Review of Digital and Real Environments

H. J. North and R. J. Miller conducted a study to determine if a computer's animated environment provided a distorted view of distances. Their study reviewed three areas of animated spaces: the accuracy of perceived distance, the effect of the division of space within the animated model and lastly if gender played a role in the perceived accuracy. The undergraduate student participants in this study were provided with seven different animated scenarios. Once viewed, they were asked to physically walk the distance in a nearby corridor they perceived in the "virtual walk". The result of the experiment clearly showed an underestimation of distance by both male and female students with female students underestimating distances to a greater degree. North and Miller agree that more research is required to determine the viability of animated walkthrough to effectively portray conceptual designs of real places (North and Miller 26-36). This casts some doubt on the ability of computer modelling to provide viewers with an appropriate portrayal of real distances.

### 3.2.b.iv Assembly in a Digital Environment

At the New Jersey Institute of Technology design students are taught that concepts, materials and media are intrinsically linked. The modification of one variable alters the end result of the product or space. Professor Glenn Goldman is of the opinion that the application of digital media should be included to both course work and studio learning. He applies Piaget and Dewey's "educative experience" to a digital context that meaning is created when learning succeeds. He applies the model of discipline specific and multiple-discipline digital learning to develop creative solutions in design. While the student's first year is spent in the discipline specific digital environment to learn the basics of the software their subsequent years are spent in the multidisciplinary environment which encompasses, interior design, architecture, engineering and digital design.

Goldman's outlook is that no one software application satisfies the end result. The selection of the tool must fit the task which in turn emphasizes the tool's strengths. Computer technology and three-dimensional modelling software have advanced at a relatively sober pace. Goldman's approach to open-ended assignments empowers students to create design solutions through the use of software. For example, the study of a chair requires students to analyse the chair as a whole, by its individual components and its construction. Rather than destroy the physical model to analyse it, students can reproduce the chair in digital format. This provides them the ability to deconstruct the chair digitally into the various components that make up the whole to better understand its construction and assembly. For students, the design of complex interiors spaces can be further developed in digital modelling environments with the addition of colour, lighting, texture, shadows and reflectivity. The power of multi-disciplinary modelling works in conjunction with the understanding of materials and structural assemblies in the construction of interior spaces (Goldman 14-21). Digital technology has its place in design education; the extent of its use at the New Jersey Institute of Technology does not appear to provide students enough hands on experience. Sooner or later student need to experience the reality and scale of their designs. The concern is that students will rely too much on the technology and become so immersed that they will lose their understanding of reality.

#### 3.2.b.v Behavioural Evaluation Using Simulations

A crucial aspect of design is the safety of occupants, known as life safety, which addresses hazards to human life and aims to minimize the danger to life from fire, smoke, heat and toxic gases emitted by materials used in building construction and in interiors furnishings. As designs of buildings and interior spaces become more complex and innovative in shape and form, design students must learn to demonstrate the effectiveness of their designs for evacuation in emergencies. Research conducted by S. Gwynne et. al. looks at computer simulated emergency evacuation models which review the actions of people under normal conditions and behaviours in emergency conditions, escaping from buildings. The research evaluates evacuation models. In one scenario people are expected to behave automatically and immediately evacuate the area in an emergency. The second model takes into consideration the layout of the physical space, human behaviour and response to stimuli such as fire, smoke or heat. Factors that affect reactions are encounters with other people, the structure and the environment. Although conducted in the safety of a controlled environment the computer model is unconvincing. While the location of rooms, corridors, exits, stairs in any commercial or residential environment can be replicated and the scenario of an emergency can be created in animated modelling, the unreliability of human behaviour provides its greatest challenge (Gwynne 741-749).

Other examples of simulations include flight training where airline pilots are responsible for the safety of their passengers. The cockpit is the only area of the airplane required for flight simulation. The simulated cockpits are designed as exact replicas of particular aircraft. They provide ideal safe environments to train pilots on the ground before they take to the air. For the simulation to be realistic the simulator's onboard controls are supported by software designed to mimic exterior environmental and airplane system conditions. The purpose of the simulators is to train, test and observe pilots actions and reactions to adverse weather conditions and instrument and hydraulic failures. The use of vibrators and pistons mimic the take-off and landings of the airplane, also including air turbulence, engine noise and wind. Throughout the simulated flight the pilot communicates with operators in a simulated control tower. The visual projections around the cockpit are convincing illusions of existing cities, oceans and runways (Brooks 16-27). The financial benefit of flight simulators lies in the reduced cost of fuel, maintenance and insurance as well as the safety of the pilot, passengers and trainers.

In the field of nursing simulators have been in use for many years but advances in computer technology have enabled nursing educators to provide their students with more sophisticated human patient simulators (HPS). The simulated human patient provides immediate responses to treatment whether favorable or not and in turn the student must decide which course of action is appropriate without causing any harm to the simulated patient. Should the student does not provide appropriate care in a specified manner under emergency conditions the simulated patient can simulate death and dying. The simulated patient is a replica of male, female adult and child patients; they are anatomically correct and encompass physiological responses to illness and injury. The greatest advantage to simulated patients is that the educators can program the illness or injury according to the course lecture for the students to then practice and observe what has been learned. Unfortunately the simulated patient does not talk it only reacts, and as sophisticated as it may be it is not human. Its inability to vocalize issues makes the simulation appear less realistic than the actual human encounter (Gates 9-15).

### 3.2.c CAVE Automatic Virtual Environments

The CAVE Automatic Virtual Environment images are digital media similar to those produced for the computer screen. The modelling software programs such as computer aided three dimensional interactive applications (CATIA) for architectural walkthroughs are digital simulations of conceptual designs. Developed by Dassault Systèmes the software enables the implementation of a completed design rather than being a partner in the design creation. Malnar and Vodvarka refer to this system as “desensitizing” (91) as the computer screen’s environment lacks the ability to stimulate the senses. Manovich defines the virtual environment as attempting to recreate reality to immerse the participant “here the virtual becomes a powerful force that reshapes the physical” (Manovich 2010. 14). In the virtual environment users are unaware of their existing physical surroundings – like the experience of viewing a movie in a darkened theatre their concentration is focused on the images presented.

The digital virtual world encompasses the worlds of television, telephone communication, moving pictures, museums, libraries and advertising, synthesizing the information into digital format (Murray 27-28). The virtual narrative includes characters, plots and locations much like the written text. What differs is the interactivity between participant and the surrounding environment. The reader of the written narrative is now the participant in the virtual one. Murray believes that a “narrative in any medium can be experienced as a virtual reality” (98). A good book or a movie offers us the ability to tune out the world around us excluding our immediate environment. Imagined places become the lived experience in a digital virtual CAVE. Albeit temporary, the virtual place is a lived experience in an immersive and interactive environment.

| CAVE like Automatic Virtual Environments | |
|---|---|
| **Advantages** | **Disadvantages** |
| Immersive and collaborative environment | Cost |
| Three dimensional full scale environment | Mobility |
| Participant centered | LCD panels are not touch screen |
| Ability to physically walk within a space | Time consuming |
| Provides spatial and volumetric understanding | Requires expert knowledge |
| Ability to test theories before construction | Requires dedicated space, power and labour |
| **Challenges** | |
| 1. Lack of available space<br>2. Buy-in from various departments as a collaborative effort<br>3. Funding | |

Figure 16 CAVE - Advantages and Disadvantages (by author)

### 3.2.c.i The Holodeck

The CAVE found its concept in 1986 with *StarTrek: The Next Generation* which introduced the Holodeck to viewers. In an otherwise vacant room the Holodeck was equipped with a Star Trek transporter, replicator and the holographic structure. The database which contained various programs was projected within the room to conjure a narrative based on the parameters programmed. These parameters included characters, scenery, people or aliens and a time, date or era. The virtual environment of the Holodeck provided Starfleet personnel a relief from the isolation of space (Startrek.com). Murray describes the Holodeck as a “black cube covered in white gridlines upon which a computer can project elaborate simulations by combining holography with a magnetic “force field” and energy-to-matter conversions” (Murray 15).

**Figure 17 Holodeck - William Riker entering a Holodeck on the USS Enterprise-D 2364. Played by Jonathan Frakes. this is an image taken from the remastered release of Star Trek: The Next Generation. (Used under fair use guideline)**

Lived experience in the Holodeck is experienced as reality; the believability and realism of the environment is accentuated by the warmth of a fireplace, a walk on the beach, the touch of a hand or a kiss. The crew interact with the characters in the holographic images as if they were real. The Star Trek episodes which include the Holodeck featuring the streets of London, and a San Francisco tavern from long before space travel was a dream. The crew entered a world where technology as they knew it did not exist. They traveled within city neighbourhoods, people and events responded to them and changed around them as their actions changed. The narrative within the Holodeck can be paused, stopped, altered and continued at any time. The Holodeck is the ideal virtual novel as it replicates reality to be experienced in an immersive virtual place (Murray 16-17).

### 3.2.c.ii CAVE™ Automatic Virtual Environments

In the same way CAVE Automatic Virtual Environments (CAVE) take the virtual animated environment of the computer screen and place it in a full size three dimensional physical environment. The CAVE is an interactive environment where sight and sound provide an interactive understanding of spatial places. The concept, then implementation of the three dimensions full scale environment was first created in 1992 by Tom DeFanti and Daniel J. Sandin at the University of Illinois at Chicago in the Electronic Visualization Laboratory (evl.uic.edu). It consisted of a ten foot by ten foot room and comprised three rear-projection screens and a ceiling down projector onto the floor. The viewer moves within the limits of the space wearing stereo glasses with sensors while multiple speakers heighten the experience (sv.tv.edu). Stereo projections combined with the glasses provide an accurate perspective of seemingly endless scenery. Since its inception in 1992 developers at the University of Illinois have worked to refine the software that displays the images and the hardware required to create an even more immersive experience. CAVE2™ is the next generation three dimensional full scale virtual environment. The “telescopic” aspect of CAVE2 provides views of distant places while the “microscopic” aspect can enlarge minute particles to be seen at any scale. The immersive environment allows scientists and designers to visualize and analyze data and images while being surrounded by data sets. The following paragraph illustrates the size, power and technical capability of CAVE2 to provide clarity of images in three dimensions at full scale as a believable and credible method of visualization.

> CAVE2 is a room approximately 24 feet in diameter and 8 feet tall, and consists of 72 near-seamless passive stereo off-axis-optimized 3D LCD panels, a 36-node high-performance computer cluster, a 20-speaker surround audio system, a 10-camera optical tracking system and a 100-Gigabit/second connection to the outside world. CAVE2 provides users with a 320-degree panoramic environment for displaying information at 37 Megapixels in 3D or 74 Megapixels in 2D with a horizontal visual acuity of 20/20 – almost 10 times the 3D resolution of the original CAVE. (evl.uic.edu 17 November 2012)

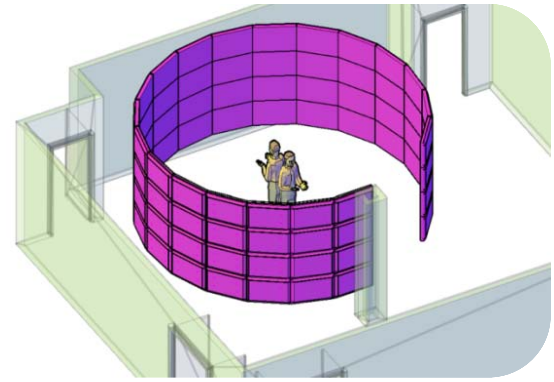

Figure 18 Prototype design of the NG-CAVE or CAVE2, image provided by J. Talandis, EVL (Used with permission)

The multiple screen display available in CAVE2 combines the technology of CAVE and that of LambdaVision, a tiled display on a flat wall measuring 11 tiles wide by 5 tiles high with a resolution of 105 megapixels that began the development of SAGE™ (Scalable Adaptive Graphics Environment) (Sagecommons.org).

Figure 19 3D hospital room model created by the UIC Electronic Visualization Laboratory and displayed using SAGE™ software on a tiled display wall in its Cyber-Commons room. (Photograph by author).

The SAGE environment is similar to a dual or multiple screens on a desktop computer where several documents can be seen and information transferred from one screen to another. The difference between the SAGE environment and the desktop computers lies in the quantity of monitors known as tiles, its ability to display both 2D and 3D images and share data from multiple sources such as MS Excel, MS Word, images, and videos at any given time. The 2D and 3D environments can be displayed on all the tiles or on individual ones.

CAVE's and CAVE-like displays are immersive environments that see participants actively interact with surrounding images. While computers control both video and audio the tracking systems monitors the participant's movement and reacts accordingly, changing directions as the participant does.

Figure 20 3D glasses and antenna (Photograph by author)

CAVE2 environments can accommodate several participants at any one time. Although all of the participants wear 3D glasses to see depth in the three dimensional images, only one person wears the 3D glasses with antennas. The sensor tracks the viewer's position in real time and corrects the perspective as the viewer moves around CAVE2 (Cruz-Neira et al 64-72).

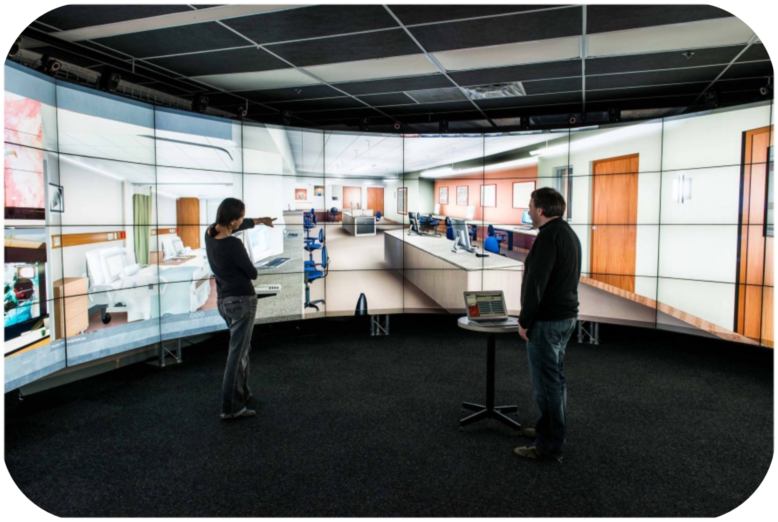

**Figure 21 3D hospital room model created by the UIC Electronic Visualization Laboratory and displayed on its CAVE2™ Hybrid Reality Environment. (Used with permission)**

**An architectural firm approached the Electronic Visualization Laboratory (EVL) about using the CAVE2™ system technology to show clients what a hospital floor layout might look like so that they could approve designs. EVL research assistant and computer science PhD candidate Sangyoon (James) Lee mocked up a scenario using 3D model of a nurse's station and patient rooms available on the web. Here, two observers are virtually waking the hospital corridor and enter rooms. EVL SAGE software is used to display several 3D models in the CAVE2™ system. (photo: Lance Long) (Used with permission)**

The intent of the virtual environment is to be as real as reality itself where the traditional narrative of experience in reality is transferred to a virtual narrative as a new form of expression, experience and meaning. The goal of the Electronic Visualization Laboratory researchers is to make the technology available for research within the university and its industry partners. The CAVE system should be flexible in that it can be converted from 2D to 3D when preferred, must be large enough for its perimeter to be outside the viewer's field of vision, be affordable and most of all, track accurately. While taste and smell remains a challenge, the visual and audio senses are stimulated in real time. (DeFanti et al 16-37). In CAVE2 twenty speakers are placed around the immersive environment to provide a seamless audio reception. As participants move around the CAVE they are simultaneously surrounded by the audio portion in synch with the images. The intent is to enhance the narrative immersive experience. Visualizing three dimensional images provides the experience of being within a place while hearing the hustle and bustle of actions such as people talking, car horn and airplanes overhead provides a more concentrated environment. Unfortunately while the audio portion of the system is an important part of CAVE environments the research conducted centres mostly on the visual aspects of the environment.

Brown University's Center for Computation and Visualization (CCV) built their second generation CAVE in 2013. A much larger space cylindrical in shape measures 16 feet by 9 feet high. The curvature of the screen placement reduces the appearance of seams. At a resolution of 1920x1080 with 65M pixels the system achieves a visual acuity rate of human 20/20 vision. The primary goal of the CCV CAVE is the advancement of research in areas such as art, medical visualization, hypertext development, sciences, and provides support for faculty driven research (Huffman interview).

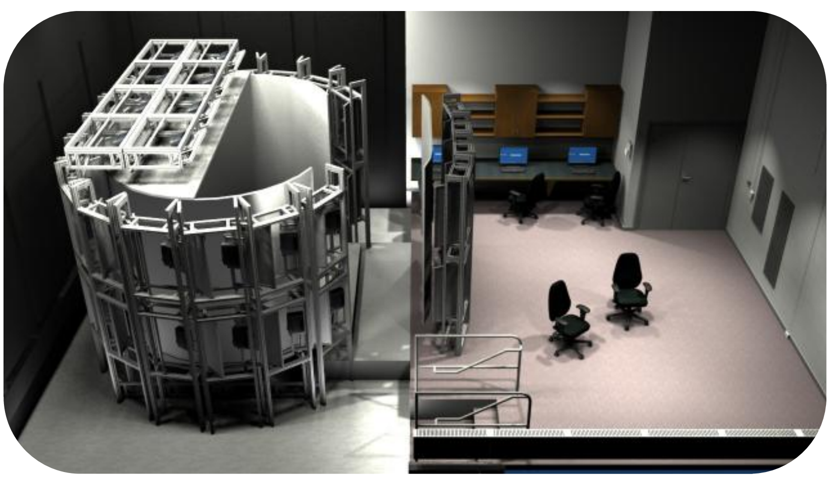

**Figure 22 Brown University Center for Computation & Visualization (CCV) Tan "vr-Cube" (Used with permission)**

Christie® Digital offers visual display solutions for business, entertainment and industry. One such solution is their integrated spatially-immersive display which offers high performance three dimensional visualization in a compact footprint

(Christiedigital.com). They provide digital solutions for a variety of application from aerospace, to design and architecture, education, energy, sciences and transportation. These integrated 3D solutions can produce images at any size and resolution and in a variety of formats. The Christie® CAVE's room size solution in a compact footprint is available as an 8' x 10' configuration or an 8' x 8' configuration or as a 4, 5 or 6 sided solution. Visualization in three dimensions at full scale provides an interactive environment for design teams, increases collaboration, reduces site hazards, and provides the designer an opportunity to immerse themselves in their designs. Images can be produced in any size or shape, can be projected from the front or rear, and can be spherical, cylindrical, conic or flat. Their CAVE structure is light weight yet rigid and enables them to provide an interactive visualization solution. While they have a worldwide reputation as a leader in visual display solutions their claim of affordability remains unsubstantiated by their lack of response to multiple attempts made in this research in contacting their offices. The ability to further explore their technology and its potential application has likewise been thwarted.

### 3.2.c.iii Negative Effects

One of the challenges in virtual environments is cyber sickness which is similar to motion sickness. While participants remain relatively stationary in the virtual environment the speed and motion of images cause the participant to sway in place. The eye's perception is out of synch with the vestibular system of the inner ear creating an imbalance. Symptoms vary from eye strain, to headaches, sweating, dizziness and disorientation. The after-effect of the virtual environment can, in rare cases lingers for hour or days depending on the amount of time exposed to the environment. While the majority of users experience no ill effects it is regardless prudent to limit the time participating within the environment.

Human visual perception and the vestibular system are physiological components that contribute to cyber sickness. Located in the ear the vestibular system refers to the head's orientation and movement. While all humans have the same physiological components the fluids within individual inner ears react to movement and speed differently. Our biological differences such as gender, age and health determine who will get affected by cyber sickness. Digital images are a contributing factor to cyber sickness as the images presented affect visual perception. The wide field of view, speed, motion and depth within the virtual environment under certain conditions creates the misleading feeling of self-motion. Cyber sickness is reduced or eliminated if the participant does not require any movement within the environment (LaViola 47-49). Some people are prone to be sick in amusement park roller coaster rides, others get motion sickness just by looking at the roller coaster's motion and yet some people are not impacted at all.

There are contributing factors to cyber sickness in digital media related to the technology's imperfection. Tracking a participant accurately within the virtual environment, to provide a correct perspective, is of primary importance for the environment and the experience to appear real. Instability creates a jittery effect. Another factor is called *lag* time. This represents the time between the participants actions and the time it actually occurs in the virtual environment. The *lag* occurs when information is sent to the computer which then analyses it before it is able to display the correct information.  Real time refers to action and reaction represented simultaneously. As technology advances occurrences of cyber sickness will decrease however the consideration of human physiology will remain a challenge in the best of virtual reality systems (LaViola 52-54).

#### 3.2.c.iv Passivity

Bertol suggests that while the immersive environment allows participants to walk through the conceptual designed spaces as a passive viewer, the system would require becoming more active in its ability to provide real time modification. Currently the only way to change a colour, brick pattern, and furniture layout is to depart the immersive CAVE environment, modify the CAD drawings, and then reprogram the virtual environment. Bertol identifies the concept of "immersive modelling" as one which would allow modification in real time while being in the CAVE environment. The CAVE environment becomes part of the design's development rather than its end result (Bertol 226). Students can become part of their conceptual design solutions and experience the narrative including its chapters on life safety to ensure the well-being of occupants. Their experience in CAVE can add credibility to their research and subsequent solutions. Regrettably at the moment many applications of virtual environments remain on the desktop computer's screen.

## 3.3 Immersive Environments as Experience

The process of design education and learning through experience provides an understanding of the space as a place for lived experience. The experience of place speaks of an emotional attachment to a location or the memory of a similar location. Spaces are defined by the borders that surround them but places are defined by the lived experience and interaction within them. These physical borders appear as images in a CAVE environment.

The narrative for experience in a virtual world begins with the interaction between computers and humans. The virtual three dimensional full scale environment of CAVE2 provides the participant a life size model of a designed space. Unlike the computer generated model which places the viewer in front of one monitor this environment surrounds the viewer with seventy two LCD panels with an acuity rate near perfection. The viewer becomes a participant immersed in the virtual environment. In the CAVE2 environment several participants can be present at any time. The world outside disappears as the immersive world of the virtual environment takes over. Suspension of disbelief a phrase first used by theorists of film defines the ability to relinquish control by giving in to a simulation and ignoring the medium (Cruz-Neira 65). The virtual environment of CAVE strongly supports suspension of disbelief in that human emotions are heightened in the narrative of the image within which they are immersed and interact forgetting where they are physically located.

### 3.3.a Experiential Learning in CAVE2

To appreciate the perceived designed spaces images need to be dynamic with successive perspective views (Bertol 116). The act of walking within CAVE2 adds to the realism of the experience and meaning of place. Students can realize the connection between materials and objects relationships they would otherwise not necessarily notice on plans and elevations. The interactive walkthrough generates the images as the student moves forward or turns. Scale and proportion of walls, doors, furniture and other objects are presented as their real physical sizes. Depth and distance between objects are likewise positioned as they would be in the real physical space. The student can walk around a piece of furniture or walk down the corridor their movement determines the succession of images. Sophisticated walkthroughs can include audio and haptic systems to not only see the space but to feel the texture of fabric, furniture and walls of the designed space. The requirements of our senses play an important role in the credibility of the images presented in a three dimensional full scale virtual environment. In addition the student's ability to review, analysing and evaluating their designs in a CAVE environment as it progresses can only benefit their final solution by identifying potential interferences, adjacencies, functional use of space and life safety elements. It would add credibility to their problem statement and support and be part of the research conducted.

The ability for students to access actual construction sites is hazardous and difficult to coordinate. With CAVE2 the construction site comes to the student. In the virtual environment of digital technology students can view their conceptual design being built from an empty space to the assembly of studs that frame walls, insulation, ceilings, installation of flooring, assembly of systems furniture, and millwork. They can observe how components fit together, analyze interferences and resolve detailing challenges. The goal is to provide students a foundation of understanding by broadening their knowledge of spatial design, construction methods and the application of regulatory requirements through experience. Design education promotes and encourages student to conceptualize designs that provide interaction within spaces, objects and between people as social interaction is a major component of lived experience. Interior spaces form a multifaceted relationship between people, objects, the context of its narrative and its spatial volume. Whether real or virtual, designed spaces provide different experiences to different people. But in a three dimensional full scale CAVE environment they become places where students can interact within its boundaries to gain knowledge and experience the atmosphere, aesthetics and features of any given designed location.

### 3.3.b Using Immersive Environments for Assessment

Conceptual designs of interior spaces impact the health, safety and wellness of occupants. Life safety measures extend to visitors and short term workers as they are unfamiliar with a building's layout and are subsequently more vulnerable to disorientation in an emergency. Full time workers accustomed with a building's layout acquire a level of familiarity knowing where exit doors and exit stairs are located and the path to get there. Life safety elements such as exit signs, emergency lighting, fire extinguishers, sprinkler heads and fire plans placed in specific locations all play a role in keeping occupants safe. The CAVE environment provides full scale representations of conceptual designs including life safety elements. It is important for design students to understand why these elements are placed in specific locations and how they impact exiting in an emergency situation. Successful navigation of corridors in an emergency requires individuals to make spontaneous decisions. Survival is dependent on the occupant's ability to remember a layout or recognize architectural and safety elements that can orient them towards exits. Complex designs of buildings require an integrated method for the safe evacuation of occupants in an emergency. Designers of these complex structures are required to apply life safety elements to demonstrate the efficiency with which these evacuations can take place. For the most part they do so on floor plans for review by building officials. While students are taught to follow and apply the rigorous regulatory requirements to their designs their ability to visualize the impact of the codes remains on a two dimensional surface. Elevations and perspectives drawn by students rarely include these life safety elements. Their elevations and perspectives are about the concepts rather than the life safety elements.

For indicators such as exits signs to be effective they must be placed in strategic location as prescribed by building codes to lead occupants along a path of travel to safety. As a result of past tragedies building codes became more stringent in their requirements. Current codes are primarily based on previous codes but rely on the research of organizations such as the National Research Council, National Fire Protection Agency, and American Standards for Testing and Material to substantiate the requirements. Building codes set the minimum standards for the design and construction of new building and modifications to existing ones. The intent is to mitigate the risks to building occupants. A new method for visualizing life safety requirements would employ Ankerson's animated egress methodologies and apply it to the three dimensional full scale environment of CAVE. These full scale visual explanations can provide the experience of traversing through suites or corridors rather than viewing the path on the computer or floor plan. The virtual walkthrough becomes the three dimensional full scale learning environment to review regulatory requirements as they are applied to conceptual designs. Students can better visualize the relationship between life safety, buildings and conceptual elements.

CAVE can provide an environment to safely simulate emergency situations to assess indicator methods for evacuation procedures, to observe interaction between people, the structures around them and the emergency situation. The results of these simulations can provide insights on the behavioural performance of people in emergency situations. These insights can identify behavioural and perceptive differences between men and women as they act and react differently under stressful situations; how they identify markers and how they use them to safely evacuate.

The fire drills conducted in our youth have trained us to leave the building when alarms sound, as adults we are somewhat more complacent in reacting to alarms and wait for instructions before leaving a building. Interruptions in our busy schedule are a nuisance. Directional signs are primarily used to identify locations such as room 304, or ABC Company suite 450, they are not meant to direct individuals towards exits. In an emergency situation it is important for occupant and visitors to know the path to travel towards the exit. But what if that path is now full of smoke? In a three dimensional full scale environment design students can test the readability of their plans and the location of exit signs by participating in simulated emergency drills.

The following scenario identifies the impact of conceptual designs on reality and the reaction of men and women to architectural aspects of the design in a specific emergency situation. Jin Woo Jung and Kathleen Gibson conducted a study to determine wayfinding performance in an emergency. Their goal was to reinforce their understanding of landmarks as indicators that impact decision making and behaviour in emergencies. Their research included sixty nine students ranging from eighteen to twenty four year of age and almost evenly split between male and female. The variables used for this experiment included gender, smoke and landmarks. A hypothetical three dimensional office building model was created using CAD, 3D Studio Max and WorldUp4. Although the experiments were conducted on a desk top computer rather than in a CAVE the result of this experiment leads to the potential use of CAVE in enabling students to understand, visualize and experience the impact their design make on life safety.

The result of the research indicated that female participants were more likely to use describable landmarks such as arrows to find their way out while their male counterparts used non describable landmarks such as floor patterns or cardinal coordinates. In a computer simulation smoke and the ensuing chaos of an emergency does not feel real, participants navigate through the space in the safety of their chairs knowing all is well. The same experiment in a CAVE would yield different result as the immersive environment surrounds the individual. The suggestion to use CAVE systems is not to create a traumatic event for students but an experience to enlighten them on the potential results of their decisions. Jung and Gibson's research suggests that in developing conceptual designs of interior spaces attention to types of visual markers and their location are required to improve the life safety of occupants (Jung and Gibson 45-57). Experience in a CAVE provides an environment that can contribute to a better understanding of spatial volume, provide experience and stimulate the senses. CAVE as an immersive environment provides a sense of presence surrounded by images to stimulate the senses and provides an alternate environment for developing conceptual designs to test concepts and theories. As an alternate method, CAVE provides an environment to support studio learning; to develop conceptual designs by participating in the evaluation of circulation patterns, explore the scale and proportion of objects in relation to each other and to people and the opportunity to apply code and other regulatory requirements to determine their viability when applied to reality.

## 3.4 The Value of Immersive Environment

Value in interior design practice is often measured by the client's financial bottom line and whether the outcome of a designed space justifies their investment. Value can also be defined as a measurable outcome such as a change in behaviour; an improved patient recovery time, increased sales or improved productivity. The good design of a space adds value to the end result. According to Susan Globus documenting these results provides the proof "that good design means good business" (Globus 5). Good business does not always equate to a profit margin, it can as stated above relate to increased productivity, health benefits and more collaborative environments resulting in better client services and employee morale. Globus also acknowledges that value in interior design is a "vast and somewhat mysterious subject…undocumented, unsubstantiated and, yet, undeniable" (3). All too frequently design and value are associated to aesthetics. However Nussbaumer asserts "A design solution is only as good as the quality of its research" (Nussbaumer 4) where the proof validates value. The proof is the supportive framework of design decisions. It is the information gathered at the programming stage that helps define the problem statement and provides the evidence that the solution achieved is in fact worthy of implementation and will when implemented concur with client's goals and objectives.

In the CAVE Automatic Virtual Environment the difference between seeing and being not only communicates design intent it also alters spatial understanding by providing a full size spatial presence. The experience offered in a CAVE provides the opportunity to test the viability of a conceptual design and assign value to its result. The value of a CAVE environment determines its worth to design education. The question is whether the CAVE environment is a worthy tool as an option for design education to support studio learning. The answer sees the immersive environment as an asset to design education. The CAVE-like environments as an option for design studio enhances teaching and learning. In addition it provides an opportunity to research, explore and visualize concepts and theories in three dimensions.

### 3.4.a Significance to Design Education

The fundamentals of design are addressed in first year studio. For many first year students the elements and principles of design seem like foreign concepts that don't relate to anything, as many lack the visualization skills to associate balance, proximity, alignment, repetition, contrast and space with a conceptual design. While the traditional methods of presentation boards in design education have many past successes CAVE environments add a new medium with which educators can challenge their students. As part of my first year education I was required to research the principles and elements of design, discover their application in magazines or real environments and present my findings by applying the theory learned. Balance, proximity, alignment, repetition, contrast and space are identified in two or three dimensional images. While images are representational of real places they did not provide the reality of volumetric at full scale, the actual physical three dimensional aspect of the environment was absent. Images are miniaturized and otherwise flat versions of reality; while the realism of the location may be present its reality has been reduced. CAVE provides an immersive environment to apply and experience the elements and principles of design at full scale in three dimensions. The value of the experience provides a better understanding of their application in conceptual design development. Whether applied to digitally rendered or real images the CAVE environment links theory and practice.

For the more seasoned students CAVE environments represent a location to explore, evaluate and analyze more complex design concepts. They can challenge themselves by experimenting with the boundaries of shape, function, materials and construction methods. Their designs can be assembled from the foundation of their conceptual ideas to the implementation of their final solutions. Senior design students engage in research to select specific sites and scenarios of interest to them to develop solutions in real buildings. To further enhance the realism of the design solution the selected building can be captured in video format. Then, in a collaborative effort with CAVE's computer technologists, the students design could come to life with plans, elevations, material selection and construction drawings in three dimensions at full scale. Although senior students have throughout their education developed the ability to visualize their conceptual design they have not had the opportunity to observe its application to reality. The value of CAVE environments provides the cinematic realism of the design's implementation in an immersive virtual environment. Lived experience in a CAVE environment provides students the link between theory, application and the experience of being a part of their design's implementation. An opportunity they usually have to wait for until they work in a professional design firm.

Educators add value to design education by providing example of past experience. These are presented as still images in PowerPoint presentation or as site visits and field trips, renderings or construction drawings. CAVE can take these past experiences off the drawing boards and computer screens and turn them into an immersive three dimensional full scale experience of being in a place with meaning. The educator's experience comes to life in a CAVE environment for students to experience and can be modified and adapted in various ways to coincide with theoretical learning. The design studio through CAVE can be redefined as an interactive and collaborative environment to supplement firsthand experience of spatial volumes where students and educators can collaborate, participate and develop ideas.

Experiences of the past can also be adapted to present regulatory requirements. These experiences can focus attention on egress, exits, access to exits, travel distances and many other life safety elements. Many students have not yet garnered the experience of walking through a high rise office building and although they have been to retail malls and other public buildings have not understood or realized the impact of life safety elements within these spaces. The ability to adapt past experience to a CAVE environment allows educators to visually explain examples of life safety and other regulatory requirements. Although many plans are of single tenant locations, with CAD and digital rendering software a dimension of height can be added to the digital image to simulate other floors in a high rise building. The value of CAVE provides students and educators the opportunity to navigate through and experience emergency simulations in a high rise building. As participants traverse the corridors the integration, application and evaluation of life safety elements can be identified. They can experience how far 100'-0" really is; what is meant by a dead end corridor and identify an exit location by following appropriately placed exit signs. The value of this presentation method provides visual examples of regulatory requirements in three dimensions at full scale rather than the two dimensional written text of code books.

The ability for a CAVE environment to provide various experiences as interaction with the surrounding environment adds to its value and worth as a tool for design education. The value of CAVE in design education lies in its ability to provide a sense of presence in the experience; provide an immersive environment as a sense of place for lived experience, provide an educational tool to supplement studio learning to develop and test concepts and theories and provide a participant centered approach for interactive collaboration. CAVE enables students to be active participants in the design, providing a venue for images, plans, sections, elevations, presentation boards, sample boards and perspective drawings by uniting them in a cinematic immersive environment to visualize, evaluate and analyze conceptual environments to support studio learning. The opportunity for students to observe and experience their concepts in a simulated three dimensional full scale environment links the theory learned in studio to the application of the theory in reality.

# 4.0 Methodological Approach

The research methods used to support the theory of *Experiencing Conceptual Design in Three Dimensions: An Evaluation of CAVE like Environments for Interior Design Education* involve multiple methods including an online survey, application examples of CAVE and a site visit to the University of Illinois at Chicago, desk based and online research. While the intent was to contact and visit several universities who conduct research in CAVE and companies who specialize in the CAVE environments the opportunities did not materialize in time to provide additional substance to my thesis. Regardless, the knowledge gained from the survey results and the site visit to Chicago proved to be invaluable in determining the viability of CAVE to design education.

## 4.1 Site visit – CAVE™ University of Illinois at Chicago

The purpose of this site visit was to provide a first-hand account of a CAVE's capability to provide experience that is spatially convincing, visualize conceptual design in three dimensions at full scale and to determine the potential contribution to interior design education. The opportunity to participate in a CAVE materialized on April 23, 2013 when I flew to Chicago for a scheduled open house. The Electronic Visualization Laboratory (EVL) is located in the UIC Engineering Research Facility building on the campus of the University of Illinois at Chicago.

Through prior arrangement with the Associate Director Maxine Brown, I was provided the opportunity to participate in CAVE2 during an open house for industry visitors. Upon my arrival at EVL I was greeted by Research Specialist JD Pirtle. While waiting for the visitors to arrive Pirtle and I discussed the theoretical framework of my thesis and the role of CAVE2 to design education. The tour began in the Cyber-Commons with the Scalable Adaptive Graphics Environment SAGE software. EVL

Director Jason Leigh was entertaining industry visitors; Pirtle and I were at the rear of the room discussing the SAGE software and its ability to present both 2D and 3D images. In the touchscreen SAGE environment users can manipulate images by altering their size and location, and drop down menus appear to further modify, insert, delete or organize images while working on other images. The combination of possibilities mimic the ability to work with paper documents spread out over various surfaces to enable the worker to coordinate information. With SAGE all these paper documents are presented on one surface; they can be sized, inserted, rotated and organized on a twenty one foot surface. This system enables multiple users to collaborate from any connected site to work on projects.

Being used to looking at one monitor at a time I was impressed by the size of this twenty one foot wall of monitors. Pirtle explained that the difference between SAGE and CAVE2 was the size of computer clusters required to run each system. In SAGE one machine is required compared to the 36 for CAVE2. Capable of conducting real time research with any university SAGE provides an opportunity for visualization on a global scale.

Unbeknownst to me at the time the Chicago visit was to become the only CAVE2 that I was to visit. Impressed as I was with SAGE I was to be awed with CAVE2. As the visitors and I entered CAVE2 we were immediately surrounded by monitors placed in 320 degrees circular shape with images wrapped around us. As Pirtle explained the quality of the image was similar to 20/20 vision and that high definition television was nowhere near comparable to the acuity level in CAVE2. Wearing the same type of 3D glasses used in movie theaters we walked around the CAVE2 space, each taking our turn wearing the 3D tracking glasses. Cameras positioned around the space followed the participant with the tracking glasses. As the participant turned in one direction images rotated accordingly while the remaining participant became part of the active person's path. While much of the research conducted in CAVE's is scientific in nature there were three programs in particular that related to architecture and design; the city of Chicago tour, rebar installation and the temples at Luxor in Egypt.

## 4.2 Online Survey

As a broad spectrum method the reason for conducting a survey was to determine the value of CAVE to educators and students. Based on the description provided of CAVE the intent of the survey was to ascertain if participants felt that a CAVE system could add value to design education. The online survey was conducted through FluidSurvey, a Canadian based survey method hosted on Canadian servers. The survey consisted of thirty four questions divided into two groups (see appendix A): students and educator/researcher/professional and was further subdivided into those familiar with CAVE and those who are not. Responses were collected online. The survey was available online for a period of three months. The data collected was analyzed into various reports and then extracted into MS Word documents (see appendices B to F). At no time were participants asked personal information and were able to end the session at any time. The survey was distributed to the Interior Design Educators Council list serve, and to the interior design departments at the following educational institutions: University of Manitoba, Humber College and Ryerson University.

## 4.3 Applications of CAVE

The applications of examples of CAVE provide descriptive analyses of its use in various contexts. The objective is to inform the reader on the various uses of CAVE as a tool to investigate events, behaviours, people and places. The context depends on the topic and the variables that delineate its parameters. The various examples of CAVE applications provide a review of research conducted to test and validate theories or provide a framework for further research. Case studies in interior design are primarily based on past projects and provide an analysis of a project from programming to implementation and can include post occupancy evaluations as supporting evidence. In CAVE, examples of interior design case studies or examples of applications are not readily available as the technology has not yet surfaced as an option to evaluate designs.

From a technology standpoint applications have entered the realm of social media as mini presentations of research conducted. YouTube as a social media and as a demonstration method can be used to posts short videos to exhibit accomplishments; it has become a popular location not only for personal use but for professional use as well. Software developers post instructional videos on the use of their software; consumers post tips and trick to the use of various software. You Tube has become a virtual animated “how to” book; it provides videos as cinematic narratives of research being conducted in CAVE environments.

# 5.0 RESULTS

## 5.1 CAVE™ University of Illinois at Chicago


Figure 23 EVL CAVE2 (Photograph by author)

While we spend most of our lives in interior spaces we do not think about the environment around us until something happens, it's too hot or too cold, a chair is not comfortable or a table leg is broken. Rarely do we stop and think about the processes, mechanical or electrical systems that provide us these services and support our ability to function in a given environment. We expect things to work and become impatient and irritable when they don't. They are interruptions and annoyances to our otherwise busy schedule.

Similarly, we see computer monitors on our desks sitting on top of CPU's; we use cell phones on a daily basis, laptops, iPad and many more electronic gadgets. We have become so accustomed to these gadgets working when we need them to that we get frustrated with technology's glitches ready to throw them out until it starts working again and all is well. People have a tendency to forget that there are many people behind the scenes keeping the various systems working, anticipating potential problems and always on the lookout for new and better methods for providing services.

Being in the design industry and having to access construction sites, mechanical and electrical rooms I should not be surprised at the size of the support system for the Electronic Visualization Laboratory. And yet, I was surprised. As JD Pirtle and I toured the facility, amazed by the infrastructure I could only imagine the electrical and cooling systems required to keep the facility in operation.

Chicago is a beautiful city with a lakefront boardwalk, entertainment and a rich history in architecture. A city I have yet to take time exploring as my visits are always short lived. Flying in from Toronto provided a one sided view from the airplane window and to my disappointment too cloudy to see anything. But in CAVE2 Chicago can be seen from street level zooming out to a bird's eye view with the weather always favourable for sightseeing.  Flying over the city and being able to zoom in closer to a building's architectural features provides a vantage point otherwise not accessible to see details such as gargoyles on the upper floors of a high rise building. Picture books provide similar images but many portray a specific detail with no relation to buildings or an image of a building with the detail too small to appreciate.

As tourists and residents our peripheral vision is limited to a specific range of sight. The more we want to see of the city's architecture the further we have to step back in order to visualize an entire building. With CAVE2 the city comes to you with images so clear that you can easily believe you are in front of the building or turning the corner to see the other side. Walk across the street to visit yet another building from each side or rise to the roof to examine architectural features. With CAVE2 there is no traffic, no pollution, no tripping hazards and no mobility issues, no danger.

The image below shows the City of Chicago from a bird's eye view. The image shows most of the monitors used within the CAVE and are delineated by bezels that surround each monitor. I was so focused on the cityscape that I was not paying attention to the bezels that separated the images; it was like they didn't exist. It is difficult to observe in the image at this scale but Google maps displays augmented reality features such as building names, highways, neighbourhoods and points of interest, any one of which can be increased in size to get a closer view or rotated to observe other views. In CAVE2 I saw more of the city of Chicago than I would have in the twenty four hours of my visit.

On a desktop computer Google maps has the ability to zoom in and out to see various plan views, satellite images, and street views that can be rotated to see the surrounding area. Although images are limited by the size of the monitor it does serve its purpose for providing directions and glimpses of where you need or want to go. Although not physically there in CAVE2 you are where you want to go. The realism of images in CAVE2 far surpasses that of any desktop monitor. Standing at the corner feels like you are standing at the corner. For the time being the Chicago cityscape appears as a still image and does not contain a cinematic real time aspect other than the manipulation of the views.

Figure 24 Google Earth's high resolution image of downtown Chicago displayed in the UIC Electronic Visualization Laboratory's CAVE2™ Hybrid Reality Environment. (Used with permission)
Google Earth is used to display a high resolution image of downtown Chicago in the CAVE2™. (Photo: Jason Leigh).

Figure 25 CAVE2™ Chicago waterfront and city center, (Photograph by author)

On the other side of the world lies Luxor in Egypt. Its majestic temples, columns and carvings are architectural wonders of construction. In CAVE2 I became one of many tourists visiting the ancient temple, the only thing missing was the warmth of the hot sun and the gravel beneath my feet. Wearing 3D glasses provides the three dimensional depth of the temple and size of the columns in proportion to human scale. Columns and distances appeared as they are in real life. I was surrounded by columns and tourists. As one of the EVL guests was wearing the tracking glasses and turned to the left we entered a chamber with him. I've seen the images in books, I've seen movies of ancient Egypt but I have never been to Egypt until now. Unlike rendered images these images are of a real place taken with a digital camera.

**Figure 26 Luxor, Egypt CAVEcam stereo panoramic image of Medinet Habu, the Mortuary Temple of Ramesses III located on the west bank of Luxor in Egypt. The images were taken by Calit2 at the University of California, San Diego, with assistance from King Abdullah University for Science and Technology and displayed in the UIC Electronic Visualization Laboratory's CAVE2™ Hybrid Reality Environment. (Used with permission)**

**As a demonstration of cultural heritage, EVL research assistant and computer science graduate student Arthur Nishimoto displays Medinet Habu, the Mortuary Temple of Ramsesses III located on the west bank of Luxor in Egypt, in the CAVE2™ system. The 360-degree photographic image was taken by Tom DeFanti of Calit 2 at the University of California, San Diego, on April 30, 2011, with the assistance of Adel Saad and Greg Wickham of King Abdullah University for Science and technology in Saudi Arabia, using CAVEcam camera developed by Dick Ainsworth, Dan Sandin, and Tom DeFanti. Images were stitched together by Dick Ainsworth. Calit2's CalVR software is used to display this 3D model in the CAVE2™ system. (photo: Lance Long).**

In order to provide a clear image the image above is presented in two dimensions while the images below represents a 3D image without proper 3D glasses. The image appears to have an offset duplicate image; this is the result of stereoscopic techniques used to create the illusion of depth. Normal vision detects both images separately, one for the left and right eye. Combined in the brain and observed through the use of 3D glasses the images are seen as one. Wearing the 3D glasses provides the reality of walking down the street, as I moved forward the people, columns and buildings became closer and remained in proportion to human scale.

**Figure 27 Luxor, Egypt CAVE2™. (Photograph by author)**

Figure 28 Luxor, Egypt CAVE2™. (Photograph by author)

While ancient Egypt used massive stones to build their temples modern architecture uses a variety of materials to provide the building blocks for skyscrapers. One particular material is rebar a steel bar used as a reinforcing material for concrete. While unreinforced concrete can withstand compression it is a weak material when tension is applied. Rebar provides the tensile strength concrete requires but there is a very specific manner in which rebar is placed and tied together to provide the tensile strength (Rebar.org). Engineers and architects must plan around building elements and penetrations such as mechanical shafts, plumbing and electrical conduit. In CAVE2 visualizing interferences before construction begins provides the opportunity to refine designs and avoid costly errors. The images below were taken with a digital camera and appear with an offset duplicate image. While wearing the 3D glasses I had the impression I was on the construction site in the middle of the rebar. As instructed we all bent down and observed the rebar above our heads but not just on the monitors the images actually appeared to be in the center of the CAVE where we were positioned. The second image shows the location of a plumbing drain and its location within the rebar.

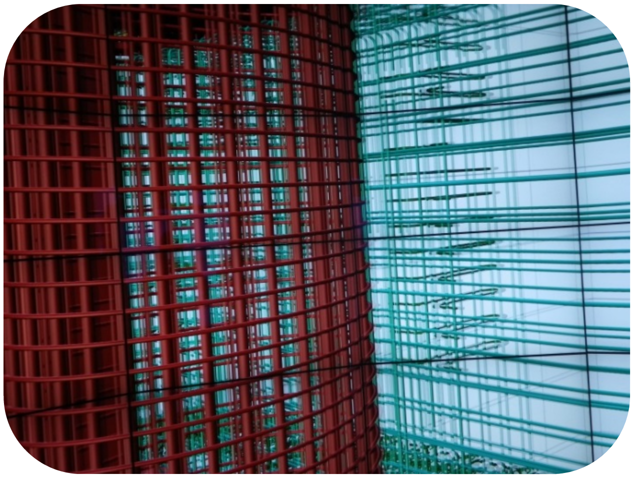

Figure 29 Rebar CAVE2™, data provided by University of California, San Diego, American Bridge Company/Fluor Enterprises Inc. (Photograph by author)

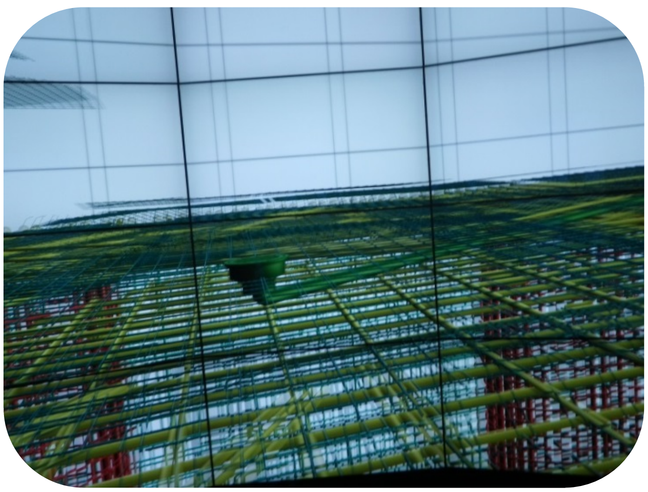

Figure 30 Rebar CAVE2™, data provided by University of California, San Diego, American Bridge Company/Fluor Enterprises Inc. (Photograph by author)

### 5.2 Online Survey Results

The survey conducted online was designed using FluidSurvey, a Canadian web based software. A basic template was used with a drag and drop editor and included features such as linking, URL links and the capability to export data into MS Word documents. The survey consisted of thirty four questions (see appendix A for complete list) subdivided into two categories: students and educators/researcher/professionals. The survey was further subdivided into those familiar with CAVE and those who were not familiar with CAVE. Depending on the answers provided by participants that addressed these topics the participant were redirected to the succeeding questions.  Linking was created within the survey to provide participants with a seamless questionnaire.

| Experiencing Conceptual Design in Three Dimensions: An Evaluation of CAVE like Environments for Interior Design Education | | | |
|---|---|---|---|
| Students | | Educators/Researchers/Professional | |
| Familiar with CAVE | Not familiar with CAVE | Familiar with CAVE | Not familiar with CAVE |

**Figure 31 Online Survey, chart of organization (by Author)**

The appendices document includes the questionnaire in its entirety identifying the locations for each linked question and includes the summary reports for each category

The various reports outline the results of the entire survey and subsequently of each category and subdivision as indicated above in the appendices outline. The general statistical results of the survey from appendix B are as follows: a total of 67 responses were received which includes completed and incomplete surveys.  This indicates a completion rate of approximately 82%. The completion rate can be further broken down by numerical representation as 55 surveys were completed in their entirety, 7 were partially completed and 5 were incomplete. The estimated completion time was 14 minutes per survey. Of the 67 responses received 49 were Canadian and 17 were American. Of the 67 participants 28 (44%) indicated they were students while 36 (56%) identified themselves as educator/researcher/professional. At this juncture in the survey the difference between those familiar and those unfamiliar with CAVE were directed to a different but successive set of questions. In the students category of the 28 students who responded 16 (57%) indicated being undergraduate student while the remaining 12 (43%) indicated being Graduate students. The intent of this question was to gage which group showed an interest in the topic of visualization and the potential of CAVE to design education. The education level was not intended to be a factor in their familiarity in CAVE. In general the response was positive in the future use of CAVE's to design education but more research is required to determine which aspects of design CAVE would be appropriate for collaboration between departments and would benefit participants in their respective programs in terms of experience, collaboration and knowledge of fields other than their own.

The results for appendices C to F are analyzed below.

### 5.2.a Students familiar with CAVE

Three student identified being familiar with CAVE, two of whom used this method primarily for research, the remaining one person for assignments. Perception of reality in a CAVE environment "Allows for the verification of design concepts and enhances visualization skills." This response indicates an understanding of the relationship between conceptual design and visualization in three dimensions at full scale. The added value to design education supports CAVE systems to "enhance" conceptual design and skills required to visualize design concepts. The future according to one participant points to technology's ability to support this method of visualization.

### 5.2.b Students not familiar with CAVE

It is not surprising that 24 of the 28 (89%) of students are not familiar with CAVE. Predominantly used for scientific research as a specialized technology it is not readily available or promoted as an option for visualization for design education. All of the students in this category confirmed having watched virtual walkthroughs on YouTube. Of the 24 students 19 (89%) were not presented examples of conceptual design as virtual walkthroughs in studio class while 5 (21%) had been exposed to virtual walkthrough in studio class. On the usefulness of the virtual walkthrough to present conceptual designs as example the students exposed to virtual walkthroughs showed an even split at 50% very useful and 50% useful. The result for the students not exposed to virtual walkthroughs in studio class but feel that this method would be extremely helpful is 7 (37%), while the useful category indicated 9 or 47% and the somewhat useful selection indicated 3 students or 16%. One explanation of this varied spread in the results can be the student's unfamiliarity with the potential of this visualization method. Although all the students indicated having watched examples of virtual walkthroughs on YouTube they may not understand how this visualization method can be applied to their conceptual designs. Yet when analysing the responses for the potential benefits of virtual walkthroughs to design studio the results indicate a much different picture. Participants were provided with several choices and were able to select all that applied. A better understanding of the overall space was the most important benefits selected at 88%, with a better understanding of proportion and scale in second place at 71%. In the middle is realistic visualization at 58% followed by a 33% benefit for the ability to develop conceptual design. These results combined can be an indicator of the student's ability to visualize and do not require additional support to visualize their conceptual designs. The benefit of virtual walkthroughs to simulate life safety and accessibility requirements was indicated as a 25% benefit. The low result of this selection indicates can be explained that in a virtual walkthrough the user is present at the desktop computer manipulating the mouse to move from one space to another. There is no difficulty in going up ramps or running towards an exit in an emergency. The walkthrough lacks the realism and the urgent requirements that life safety and accessibility requirements.

When provided a description of CAVE and asked whether CAVE's can add value to design studio learning 20 students (83%) said yes, there were no negative and 4 (17%) were unsure. This question was followed by a request for an explanation. The majority of responses indicated that the value of CAVE to design education and studio learning was its ability to provide the "testing" of concepts in a realistic manner. Two dimensional design drawings were referred to as a trap of habit to visualize designs. The value to visualize in three dimensions at full scale would provide a better understanding of relationships, built forms and spatial volume. CAVE would enhance firsthand experience of a designed space, provide a better understanding of volume and what the space would feel like, it would provide students the ability to critique their own designs, address weaknesses and resolve issues. This technology was defined as a progressive method to enhance client experience and provide quicker resolution to challenges. One comment in particular addressed first year studio learning and the difficulty students have to visualize or understand scale, proportion and size. This participant believed that the addition of CAVE to first year studio learning would provide an additional point of reference to help students better understand relationships between designed spaces and the human body. Another stated “I really wish we had a CAVE”. Considering this group of students was not familiar with CAVE this response indicates an understanding of the description provided and its potential use for design education. Another participant identified cost as a concern while claiming Revit was stated “just as good” unless the conceptual design was a complex project.

#### 5.2.c Educator/researcher/professional familiar with CAVE

Similar to the student participants, these groups were divided in two subsections; those familiar with CAVE and those not familiar. Of the 36 participants in the educator/researcher/professional group 6 (17%) indicated being familiar with CAVE. Only 1 participant indicated having used the technology as part of the course/curriculum, 2 participants as part of research and the remaining 3 as part of the profession. The descriptions requested to this question indicated familiarity through research conducted by others. Museum and exhibit design experience was provided as a description but whether this answer was related to the participant with experience as research or profession was not indicated. The integration of CAVE to the course/curriculum did not produce any noticeable changes or impacts but the participants noted its potential usefulness for visualization in design studio. As an alternate tool CAVE would provide students the ability to communicate ideas. The concern for educators lies in the time and skill required to operate new computer software at the sacrifice of creative development. CAVE systems are a specialized field that are found in computer technology rather than in design education. The software required to produce images of conceptual designs is not expected to be mastered by design students or educators. CAVE's are available within some computer technology programs; collaboration between university departments would provide access to the system and the expertise of technicians who would produce the digital images of concepts for student and educators use. The impact of integrating CAVE into research was indicated as being a more collaborative and rigorous deliverable. The use of CAVE in the profession was more subdued in its impact as virtual walkthroughs were used more often and CAVE systems were seen as a positive extension of the walkthrough to avoid expensive errors after construction and enables clients the ability to experience their future space. The disadvantage of technology and computer software described by one participant was the value given to computer skills rather than creative skills. This does raise a good point and I do agree that there seems to be more emphasis on computer skill but the computer does not have a creative imagination; it does not have an imagination at all. Creativity comes from the operator's own imagination but uses the computer's software to transfer information rather than the pencil.

When asked about added value to course/curriculum 50% said yes as the "eye candy effect" is more stimulating and given the complexity of designs would enable the resolution of technical issues. The results for added value for research and profession were evenly split at 25% each describing the value for further investigation an opportunity for clients to experience and visualize spaces. While the cost of implementing CAVE environments was indicated as its disadvantage, conceptual design at 100% was indicated as being the primary use for future applications of CAVE. Design implementation and design detailing were close seconds at 67% each, while programming and wayfinding at 33% each. Accessibility and life safety were regarded as having no future applications of CAVE yet of all categories these if anything should be viewed as more important. This can indicate a lack of available information and research to show how CAVE can be used to address accessibility and life safety. But I do question the 0% of their response as these are the participants familiar with CAVE who should have an understanding of the system's capabilities. On a positive note, if given the opportunity all participants indicated they would integrate CAVE into the course/curriculum, research and the profession.

5.2.d Educator/researcher/professional not familiar with CAVE

Similar to students not familiar with CAVE it is not surprising that 29 (83%) of educators/researcher/professionals were not familiar with CAVE. Rather than continue the survey with CAVE related questions this stream began with 3D walkthrough to visualize conceptual designs. Virtual walkthroughs were used to demonstrate conceptual design in studio teaching by 8 (30%) of participants. Those that did not use this method lacked the technical skill, were not aware of the software's availability, and did not have access to the software or that the school did not have the technology available for their use. When asked if three dimensional walkthroughs could enhance the learning experience for students 20 (74%) agreed while 5 (19%) somewhat agreed and 2 said no. There was an agreement in the ability of virtual walkthroughs to help first and second year students who have not yet fully developed their three dimensional visualization skills. The addition of lighting in a walkthrough would provide students an option to observe of texture, scale and patterns under different conditions. As an alternative, virtual walkthroughs could enhance a student's understanding of a space to create a place of lived experience. Of the many comments received experience was touted as the most important advantage of walkthroughs to provide a learning environment, critical feedback, spatial understanding, used as a method for movement and visualization in three dimensions. Part of school's ability to provide access to software for the creation of virtual walkthroughs is the demand it receives from its students and faculty. If 10 (37%) indicate that students are requesting three-dimensional digital visualization as an option and 25 (92%) are indicating they would encourage students to use the technology if it was made available then it is reasonable to deduce that there is a requirement for this technology. Although 17 (63%) participants responded to the same question they stated that students do not request three dimensional visualization methods as an option.  It does bring into question why students are not asking for it.

Similar to students not familiar with CAVE, educators were provided the same description of CAVE to assist them in answering the remaining questions. If given the opportunity to integrate CAVE into the course/curriculum 16 (67%) of the 24 participants said they would integrate CAVE, while 1 said no and 7 maybe. When the same was asked of research the results were a closer spread at 9 (39%) said yes, 4 (17%) said no and 10 (43%) said maybe, these results are dependent on whether the research conducted relies on CAVE as a variable. As far as the profession was concerned 10 (43%) indicated yes, 6 (26) said no and 7 (30%) said maybe. The variance between course/curriculum, research and the profession in integrating CAVE indicates the importance of its potential for design education.

When comparing the added values results from students to that of educators it is clear that educators better understand the potential use of CAVE for design education. The results indicate that 21 (81%) of participants feel CAVE would add value to conceptual design and wayfinding, 19 (73%) for design implementation, 16 (64%) each for life safety and accessibility and 7 (29%) for programming. The difference in the yes, no and maybe section for programming were more evenly spread, this can be attributed to programming being more of a written method for information and does not necessarily require images for understanding. All other categories had larger gaps between the yes answers and the no and maybes.

They as the students before them indicated a concern with cost but also included the space required and the ability to maintain the system as a concern.  It was also noted that as a user friendly technology it would be favoured but not if it added more time in learning to use it or added more time in the development of conceptual design. One participant questioned whether the technology has the ability contribute to spatial theory. Although the same participant also indicated that as part of a larger framework the technology should be evaluated if it presents itself as “pure spectacle”. This may be for now true in design but not in the sciences where they technology is predominantly used. One participant felt it worthy to experience to better understand its value to design education for conceptual development and implementation of “real-time projects”.

## 5.3 Application Examples of CAVE

The following applications are example of the type of research being conducted and what can be accomplished with CAVE environments.  Whether in partnership with industry or as a commercial venture CAVE has opened the field for research to test theories for its application and also to develop the systems. Clients can view and experience future places before they are built, helping them to evaluate the value of their investment; homeowners can walk through their future homes or condominium to get a better sense of the unit they are purchasing. The study of human behaviour lends itself to CAVE environments as it provides an ideal environment in replicating reality. Research can be time consuming and difficult in a real environment; it can be weather dependant, hazardous and inaccessible. The ability to research within kilometers of city streets without interferences can be in many cases impossible. The third application example can replicate streets in any city without ever leaving a twenty foot area. Although not conducted in a CAVE this system uses the more mobile head mounted equipment to display three dimensional full scale images. In the last application uses CAVE as a method to train first responder's demonstrates the importance of training in responding to emergency situations. It also identifies the significant role of regulatory requirements when applied to the interior of buildings.

**First Application** – Editor-in-chief at Cadalyst Nancy Spurling Johnson writes that CAVE like display technology is not only available it is also affordable (Spurling Johnson). The CAVE like display at Duke University and Iowa State University uses 3D CAD data as a starting point with 24 projectors projecting images on the walls, floor and ceiling and a joystick to navigate through the space. While FullCon Solutions own the CAVE like display units they act as liaison to clients who wish to rent or use the system. FullCon operates, maintains and provides the technical knowledge and skill for the system. The client arrives in a ready to use CAVE like room. President of FullCon Solutions, David Fuller primarily works with commercial construction clients and uses their data from software such as Revit, 3DMax, SketchUp and Rhino. Fuller states that using the CAVE like display "levels the playing field" (Fullcominc.com) for clients to help them better understand and visualize their future buildings. David Fuller, president of FullCon Solutions states "Our intent is to assist with the integration of tools that improve design, clarify expectations, impact process work flow, and improve stakeholder communication with an ultimate goal of differentiating our clients over their competition" (Fullconinc.com).

The system enables architects and designers to evaluate decisions before construction resulting in fewer change orders and less cost. Fuller sees the future of this technology to visualize complex details during construction. While the use of the CAVE like display is primarily academic, the commercial sector is fast realizing the value of this system is its ability to test and evaluate design prior to implementation. This article provides credible application and evidence for the use of CAVE like displays in the architectural and design communities.

**Second Application** – YouTube video. Netwell CASALA Centre based in the Dundalk Institute of Technology. Carl Flynn demonstrates a 3D CAVE like display. This video demonstrates the use of a tracking system within a CAVE like display. This system consists of rear stereo projectors which project images on the three walls and the floor. Stereo 3D glasses are used to provide a sense of depth. The tracking balls attached to the glasses act as sensors to provide the participant's position. Flynn narrates his actions in the space as he navigates with the joystick to enter and move around the space. The virtual apartment appears as a simulation of a real one (Youtube.com). Unlike the CAVE2 installation this one is more compact and yet provides the similar end result of walking through a space to provide the viewer a better understanding of the layout, size of rooms and distances in the corridors. Rather than rely on one model home to entice potential home or condominium buyers, real estate developers can offer their clients an opportunity to walk into a CAVE to visit the units they wish to purchase.

**Third Application** – YouTube video. CyberWalk, Max Planck Institute for Biological Cybernetics (Youtube.com). This video shows a participant walking on an omni directional treadmill while walking in a virtual city street. The treadmill changes direction with the participant. Walking forward in a CAVE ends at the screens, with this treadmill walking is endless. The treadmill can be compared to escalators as a continuous set of steps as one step enters the housing at the top another one exits at the bottom. Constructed of a series of linear platforms with rotating belts this treadmill moves as a continuous carpet, each platform and belt acts independently as one platform enters on one side another exits the other side. Diagonal movement is possible as the belts within each platform act in a similar manner to an exercise treadmill. Participants on the treadmill use head mounted display to visualize three dimensional images, as a precaution they wear a safety harness to avoid falling. Although located at the Max Planck Institute in Tubingen, Germany the CyberWalk treadmill was built by a conglomerate of German, Italian and Swiss laboratories (Guizzo Spectrum.ieee.org).

The purpose of the treadmill is to provide a continuous walking surface. The Cognition and Action Department used the treadmill to determine what cognitive and sensory skill people use to orient themselves in space. As we move from point A to point B our brains perform a myriad of functions. Whether in familiar or unfamiliar places our brains adapt to our environment using landmarks, architectural features and signs. Visual perception and our sense of balance are key components in directing us from point A to point B but in addition our brains also notice the effort and complexity in getting there. As we traverse between A and B we notice whether the road is uphill, had potholes, is straight or narrow. When given directions we follow the road turn right at the light or left at the church. Spatial orientation and our ability to navigate space is a multisensory process. Researchers at the Max Planck Institute were interested in how we navigate in everyday situations. The virtual reality environment provided a location that allowed them to focus on the sensory responses of participants. What they uncovered was the amount of information we require to navigate. While everyone is different the research suggests that we tend to store small amounts of information. Participants remembered features ahead of them but not behind, they also were better at orienting themselves when positioned in a straight line rather than turning a corner (Reinberger 32-39). The distance between A and B seems longer the first time we traverse.

We all have different strategies to get us from point A to B and now Google maps makes it much easier.  The combination of this treadmill and CAVE environments could provide a seamless environment for design educators to help students visualize their conceptual designs by walking through their space to better understand the spatial environment as a whole, the relationship of components and the integration of life safety elements within building.

**Fourth Application** – The following application identifies the use of CAVE in the training of emergency first responder to identify their ability to maintain composure under pressure. It identifies CAVE as a tool to train first responders in emergency situations and as a tool to observe the actions and reactions of responders to their environment. The purpose of the research was to determine the viability of CAVE to provide a realistic chaotic training ground for first responders but to also determine if first responders could function within the environment.

In case of emergencies proper training is the catalyst for any emergency first responders. The avoidance of mass casualties or disasters relies on simulated events with countless volunteer patients. Proper training teaches first responders to act, react and interact amid the chaos and stress of any given emergency. Similarly the ability for first responders to rehearse is impeded by the lack of simulated opportunities. These simulated events are few as the organizational requirements are enormous and the cost of implementation is prohibitive. William Wilkerson et al. conducted a study at the University of Michigan to determine the viability of virtual environments in training first responders for emergency situations. Combined with human patient simulators that are programmed for any illness or injury the virtual CAVE environment displays the devastation. The environment is enhanced with sounds similar to destruction and chaos such as crying, sirens and fire engines. The

12 participants were 4 year veteran paramedics who were asked to arrive with all their gear. The scenario was set at the Michigan football stadium. For the virtual images to be real the stadium area was recreated with help from the Department of Public Safety, photographs from different views, CAD plans and virtual humans with superimposed injuries. Participants were recorded and observed as they verbalized their actions and responses. Recordings were later used as evaluation and analysis tools. Once the training was completed participants were interviewed to assess their reaction to the virtual environment. Responders were knowledgeable about what to do and able to identify appropriate actions in the classroom. The actions and inactions of first responders' in the virtual environment in an emergency situation indicated a lack of organizational skills in responding to the emergency; an inability to evaluate site hazards, patient conditions and potential for injury to others. During the debriefing participants indicated a level of comfort once they were in the environment that allowed decision making. The images appeared realistic and immersive to participants as soon as they arrived on the scene. The reality of the scene heightened their sense of urgency in performing their duties. Interaction with the human patient simulator proved more difficult than expected as the background noise of sirens, engines and screaming interfered with their ability to properly evaluate the patient's condition. All the participants noted that the realism of the background chaos as a sensory overload was an essential part of the training and realized the need for a concentration level far beyond what they had expected. One participant went so far as to say "… it's the best experience I've ever had…" Although the first responder's success was less than ideal, the result of the study indicated that the

CAVE environment was a positive influence in the training of first responders and merited further opportunities for training. The study also provided useful feedback for future scenarios in virtual environments (Wilkerson et al 1152-1158). It identifies the benefit of CAVE for training first responders in emergency situations; demonstrates how CAVE can be used in a multidisciplinary environment to provide a learning experience for participants as well as observers. The CAVE provides educators the ability to review the recordings to assess reactions, plan for future course outlines and review with participant's skills and abilities for further improvements.

The four examples above demonstrate the varied applications and possibilities of virtual reality environments to simulate reality. Whether to navigate a building's layout or to assess actions and reactions the virtual environment is used in various situations to enhance experiences. As an immersive environment CAVE provides immediate responses as participants interact with the space and images around them. The three dimensional full scale aspect of CAVE with the inclusion of background sounds heightens the experience of being in place as first responders felt the urgency of the scenario around them and agreed it added value to their training. In comparison Netwell CASALA and FullCon Solutions present a perspective of interior spaces and the ability of participants to walk down the corridors, enter rooms, turn around and continue. As a teaching tool for design education these applications provide more relevance to conceptual designs of interior spaces. Both companies identify the ability to walk through a space in three dimensions at full scale as a primary factor in the success of CAVE environments. Although the research conducted at the Max Planck Institute focused on exterior environments to research people’s ability to navigate space, its application to interior space would similarly provide valuable insight into people’s ability to navigate space to reach their destination or in an emergency situation to evacuate a building. While there is considerable research conducted using the CAVE environments a great deal more is needed that focuses on interior environments.

# 6.0 Conclusion

Education provides learners the ability to acquire knowledge, develop critical thinking and practical skills. Experiential learning becomes the interaction between the knowledge acquired and the practical application of that knowledge; it encourages exploration, analysis and synthesis. The complexity of information sequentially presented throughout a four year design program provides the learner the opportunity to progress and mature at a steady pace.

Design educators provide examples of conceptual designs as case studies and supporting evidence of successful design experiences, as a teaching and learning tool. Past successes provide a foundation for future exploration. Educators also strive to provide students with experiences designing for various typologies such as corporate offices, retail, hospitality and healthcare.  Learning through concrete experience tests theories in actual situations. In design education the concrete experience relies on the project brief and user needs to create environments with meaning; they offer learners the opportunity to develop critical thinking, creative and problem solving skills. The design process ensures that aspects such as the integration of regulatory requirements are applied to concepts for the wellbeing of users. To supplement classroom and studio learning students initiate their own research and apply their findings to conceptual designs. During the programming and schematic design phases students develop valuable insights in understanding a client's culture and how the application of design elements and principles can best represent the users of the space. They acquire an understanding of the impact their designs have on the wellbeing and safety of building occupants.

The design of interior spaces creates places for lived experiences. Dohr's theory that experience defines meaning and value by creating emotive connections should be applied to the conceptual design of spatial experience (Dohr and Portillo 153). Design transforms spaces into places; that not only identify a user's culture but also identify a client's values and beliefs. Design reflects cultural meaning and belonging; it is a narrative of interaction, meaning and value. The ultimate evaluation would allow students to experience their designs; to walk through the space, enter rooms turn around and look closely at the detail of a design; to observe and analyse the impact of design elements considering functionality, ambience and life safety. While educators guide students towards successful functional conceptual designs and challenge their thought process, they cannot provide a three dimensional experience of a student's design. Or can they?

Imagine the future of design education able to provide its students the opportunity to not only experience their designs but also to design in an immersive virtual environment. With CAVE-like immersive environments the creation of precedent designs are endless; past, present and future designs become accessible. Plans of designs can be transferred into immersive three dimensional cinematic narratives to support teaching and learning; to provide concrete experience and to explore and test possible concepts.

The purpose of this research was to determine if CAVE-like automatic virtual environments could add value to interior design studio teaching and learning as platform to visualize designs and provide the experience of being in designed spaces in an immersive environment. The research inquiries investigated the unique technology of

CAVE environments to support studio teaching and learning. CAVE-like immersive environments provide an opportunity for educators and learners to research collaboratively and to critique student conceptual designs of interior spaces. Students can not only experience being in their designed space but also be a part of the development process rather than be passive programmers and planners of spaces.

CAVE-like virtual environments provide design education an alternate method to experience spatial design and to analyse and evaluate their effectiveness. Experiential learning is based on information attained through experience and supported by theoretical knowledge. Kolb and Fry's "concrete experience" is able to be realized in an immersive virtual environment. Immersed in the CAVE-like environment learners and educators reflect on the experiences they are creating and how the various components and elements make up the whole. The learners and educators can observe how each component relates in scale, proportion and placement, study circulation patterns, identify interferences and reflect on how design affects users and impacts their wellbeing and safety. Learners can benefit from endless possibilities in an immersive environment; they can create, explore and develop abstract theories; they can analyse and evaluate new experiences in more holistic ways. Experiencing a three dimensional immersive environment from a safe and accessible location provides an opportunity to test theories and concepts, to supplement knowledge and add credibility to suppositions. Experience of the immersive environment is an experience of being in a space that would otherwise remain as a hypothetical scenario on presentation boards or computer screens. CAVE-like environments are a tool of the foreseeable future to support design.

My first experience in an immersive virtual environment occurred in CAVE2 in the Electronic Visualization Laboratory at the University of Illinois in Chicago. This site visit provided the evidence I required to determine the viability of CAVE-like environments as a tool to support design education. As I toured the facility the complexity of the system, the expert resources to maintain and operate the system, and the effort to obtain funding became apparent. The only way that this is possible in the current University environment is for industry to collaborate with education in a commercial venture as an essential source of technological expertise and funding. I was grateful for the opportunity to experience CAVE2, I realized that the experience was fundamental to supporting the premise of my research. Being in the immersive environment was an experience on its own but seeing the clarity and proximity of the immersive images felt like I was in the location, in this case Luxor, Egypt. I was surprised at the realism of images and in awe at the proportions of stones, heights of columns and vastness of the historic site. As I walked away from the University and made my way back to the airport I watched students milling about going to classes and wondered how many actually knew the lab existed and understood the research being conducted with educators, students and industry. Looking back at the building I never would have guessed what was inside. I reflected on the possibilities of CAVE systems and realized that while EVL is at the forefront of technology and has been established for many years, there are many obstacles to be overcome in achieving an interactive immersive environment in the University.

My vision for the future of CAVE-like immersive environments is as an interactive environment where participants can reach out in space and move furniture, windows and doors; where they can make a selection from drop down menus to alter colour, lighting and finishes; where they can add tint, tone and shade and can walk down the corridor reach for a door lever and open the door. In this CAVE system actions are tracked and countered by the system. In essence the system reacts to the participants actions and adapts to the changing environment; the students can pull the blinds down and the room automatically darkens; planning is done in three dimensions by moving things around the space or by moving architectural elements such as doors and windows. The drafting board now replaced by computer screens becomes the blank canvas of a three dimensional immersive cinematic environment. In an interactive and immersive three dimensional environment educator and learner both explore complex designs as an immersive design process.

The experience in this immersive environment is an opportunity to comprehend the impact of design, to be the users of the space not just designers. Experiencing what it feels like to be in the retail outlet, hotel lounge or in an emergency situation. What happens when a fire breaks out? Alarms sound, instructions are provided through the intercom system. Participants experience the fear, what do you do? Is this a first stage alarm? Does it have a second stage? Does the public know? Do I listen to the instructions and stay in place or ignore it and leave? The smell of smoke is permeating through the office; fire can be seen at a distance. Still the instructions are to stay in place; rescue is on its way. A panic start to spread, people cannot breathe, there is coughing, crying and chaos, they want to get out; they want to find and be with their loved ones. Someone opens the door only to let more smoke in, people start running but where to go, visibility is almost non-existent, breathing becomes laboured.

Disoriented and panicked the participants go the wrong way. No longer thinking clearly, they grasp at everything trying to get out. The results of these situations are not always happy endings. The smoke developed from burning fabric, paper, wood and other materials used in interior environments have the potentials for disastrous consequences. This scenario brings home to the participant the realization that design and the selection of materials, furniture and finishes greatly impact users, while the shock of the experience awakens a sense of accountability and understanding of the need for building codes and regulations. In my vision the CAVE like immersive environment is a tool to teach responsibility and to assess and evaluate conceptual designs to mitigate such risks to potential users.

What better way to demonstrate regulatory requirements than to take the black and white pages of building code books by raising them into an immersive three dimensional examples. The immersive three dimensional building codes could be applied to designs to determine compliance:  in sprinklered and non-sprinklered buildings, occupancy load and area impact travel distance, quantity of exits and exit locations. In the immersive environment data sets of building code requirements would evaluate compliance by calculating travel distances and location of exits based on the design's parameters entered into the immersive system. Integrated with design concepts the visual three dimensional building codes would identify areas of concern. Data could be gathered from various regulatory agencies and assembled in an immersive environment as part of the collective design process. Design educators and learners as directors of the immersive environments synthesize the information gathered to produce the cinematic life safety narrative.The team would consist of computer technicians, students, educators, professional, industry and building code officials required to produce and develop the vision. Affiliations with other departments and partnerships with industry offer an opportunity to collaboratively advance design teaching and learning, research, and further the interior design body of knowledge.

Currently the use of immersive environments is primarily scientific in nature. However, many providers of CAVE-like immersive environments, computer technicians and architectural firms are collaborating to employ the technology as a commercial enterprise. The greatest challenge in my search to determine the value of CAVE-like immersive environments to visualize conceptual design was finding information relevant to design and design education. Much of the research has focused on behaviour and cognitive skills within interior spaces.

Additional research is needed both at the educational and professional levels to integrate immersive environments into design teaching and learning. While manufacturers are focused on research relevant to their own products they can benefit from a more collaborative approach. Access to research facilities that can provide immersive three dimensional environments will encourage educators, students, professionals and industry representatives to explore this unique method for acquiring knowledge, develop products and initiating change in how we think about the future of design and the role of technology as a tool to support design solutions.

The renewed interest in visualization in immersive three dimensional environments is providing potential clients with greater options for CAVE-like systems. Additional research is needed to explore applications using CAVE-like environments, identifying other locations of immersive environments, service providers and the costs associated with the various systems, their abilities and limitations. The ability to custom build a CAVE system to the required parameters of an institution is becoming more affordable.

The challenge to implementing CAVE like immersive environments within educational institutions is in determining the parameters of the research required, its use as a teaching tool, faculty and department involvement and industry partnerships. Universities need to understand that the added value of immersive environments to teaching and learning can contribute to the institutions strategic goals and that collaboration with industry partners can support current and future research initiatives.

I recommend that interior design educators embrace CAVE-like immersive environments as a potential tool to enhance and support design education; to seek partnerships in its implementation and to go beyond what is currently available to students by providing them the opportunity to experience their designs in an immersive three dimensional environment. Students would be more employable, with the advantage of this experience and departments and schools would be recognized as forward thinking innovators.

Design educators and learners could be the leaders of tomorrow by embarking on a journey to explore applications of CAVE-like immersive environments to support and enhance design education.

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# APPENDIX A

This appendix includes a copy of the online survey in its entirety. While all the questions are within the one survey, they are divided into two categories that of students followed by educator/researcher/professional and furthermore subdivided into four subsections within the categories; those familiar with CAVE-like environments and those not familiar with them. The following list identifies which questions belong to which group and subsection.

| | |
|---|---|
| Question 1 | Identifies the category of the participant (students or educator/researcher/professional) |
| Questions 2 to 4 | Identifies students as graduate or undergraduate, their program and their familiarity with CAVE |
| Questions 5 to 9 | Identifies questions for student familiar with CAVE |
| Questions 10 to 17 | Identifies questions for student unfamiliar with CAVE |
| Questions 18 | Identifies questions for educators/researcher/professional familiar or unfamiliar with CAVE |
| Questions 19 to 27 | Identifies questions for educators/researcher/professional familiar with CAVE |
| Questions 28 to 34 | Identifies questions for educators/researcher/professional unfamiliar with CAVE |

The following is a copy of the online survey in its entirety.

# Thesis Research - Online Survey

## Experiencing Three Dimensions at Full Scale: Visualizing Conceptual Design.

My name is Rebecca Muyal and am a Master's student at the University of Manitoba. The purpose of my research is to identify the value of experience in a virtual three dimensional environment at full scale, for visualizing conceptual design of interior spaces. Computer technology has the ability to provide a platform for a full scale interactive experience of conceptual designs. The use of Computer Assisted Virtual Environments (CAVE's) provides an opportunity for students to experience the reality of their design projects in a simulated virtual environment at full scale. I invite you to participate in my research study by completing the following online survey. By clicking the "I Agree" button on this page indicates that you have understood to your satisfaction the information regarding participation in this research project and agree to be a participant. In no way does this waive your legal rights nor release the researcher or involved institution from their legal and professional responsibilities. You are free to withdraw from the study at any time, without prejudice or consequence.

### Please check box if you agree

☐ Yes

### 1. Are you a:

☐ Student – (link to Q2)

☐ Educator/researcher/professional – (link to Q18)

### 2. Are you a: (Link from Q1)

☐ Undergraduate student

☐ Graduate student

### 3. Please identify your program of study.

☐

### 4. Are you familiar with CAVE environments?

☐ Yes – (link to Q5)

☐ No – (link to Q10)

### 5. Is your use of CAVE environments primarily for: (Link from Q4)

☐ Assignments

☐ Research

### 6. Has CAVE environments impacted your perception of physical reality?

☐ Yes

☐ No

### If yes, please describe.

### 7. Has the use of CAVE environments added value to your studies?

(value is defined as being useful and having meaning and credibility)

☐ Yes

☐ No

☐ Somewhat

### Please describe

### 8. Additional comments

### 9. Have you ever used 3D visualization?

i.e. SketchUp, CAD or other 3D software

☐ Yes

☐ No

### 10. Have you watched virtual walkthroughs of interior spaces either on YouTube or elsewhere? (Link from Q4)

☐ Yes

☐ No

### 11. Are virtual walkthroughs used as example in your studio classes?

- ☐ Yes
- ☐ No

### 12. If yes, how useful have they been?

- ☐ Extremely useful
- ☐ Useful
- ☐ Somewhat useful
- ☐ Not very useful

### 13. If no, do you think virtual walkthrough would be?

- ☐ Extremely useful
- ☐ Useful
- ☐ Somewhat useful
- ☐ no very useful

### 14. What benefits do you feel virtual walkthroughs would add to design studio?

Select all that apply

- ☐ Realistic visualization
- ☐ A better understanding of the overall space
- ☐ Ability to develop conceptual design
- ☐ A better understanding of proportion and scale
- ☐ Simulate life safety and accessibility requirements

**A CAVE Automatic Virtual Environment (CAVE) is a life size physical room or space, with images projected to each surface. Participants enter the space wearing stereoscopic goggles to allow them to view the images in three dimensions. Similar to 3D movies with the exception that people are active participants in the experience and can move about the space. Projected images are videos and computer generated renderings of real life environments. The most notable examples of its use are in simulation labs for driving schools and pilot training, alternately the Holodeck on Star Trek is another example.**

### 15. Based on the description provided of CAVE environments, do you feel CAVE's can add value to design studio learning?

(value is defined as being useful and as having meaning and credibility)

- ☐ Yes
- ☐ No
- ☐ Maybe

### Please explain

☐

### 16. If given the opportunity, would you be interested in using CAVE environments?

- ☐ Yes
- ☐ No

### 17. Additional comments

☐

### 18. Are you familiar with CAVE environments? (Link from Q1)

- ☐ Yes – (link to Q19)
- ☐ No – (link to Q28)

### 19. Have you integrated CAVE environments as part of your:

- ☐ Course/curriculum
- ☐ Research
- ☐ Profession

### Please describe

☐

### 20. What type of change or impact occurred as a result of integrating a CAVE environment?

Please describe

Course/curriculum

Research

Profession

### 21. As a result of using a CAVE environment, do you feel students are more creative in their approach to design concepts?

- ☐ Yes
- ☐ No
- ☐ Somewhat

### 22. Do you feel a CAVE environment has added value?

(Value is defined as being useful and having meaning and credibility)

- ☐ Yes
- ☐ No
- ☐ Somewhat

### 23. Please describe

Course/curriculum

Research

Profession

## 24. What do you feel can be future applications of CAVE's in design application?

Select all that apply

- ☐ Programming
- ☐ Conceptual design
- ☐ Design implementation
- ☐ Accessibility
- ☐ Life safety
- ☐ Design detailing
- ☐ Wayfinding

## Other

☐

## 25. Are there aspects of CAVE environments you feel are not suited to design education?

Please describe

☐

## 26. Would you if given the opportunity integrate a CAVE environment to your:

| | Yes | No | Maybe |
|---|---|---|---|
| Course/curriculum | ☐ | ☐ | ☐ |
| Research | ☐ | ☐ | ☐ |
| Profession | ☐ | ☐ | ☐ |

## 27. Additional comments

☐

### 28. Have you ever used virtual walkthroughs as a tool to demonstrate conceptual designs? (Link from Q18)

☐ Yes

☐ No

### If no, why not?

☐

### 29. Do you feel three dimensional walkthroughs could enhance the learning experience for students?

☐ Yes

☐ No

☐ Somewhat

### Please describe

☐

### 30. Do your students ask for three dimensional visualization options?

☐ Yes

☐ No

### 31. If resources were available would you encourage your students to explore the potential of three dimensional environments?

☐ Yes

☐ No

**A CAVE Automatic Virtual Environment (CAVE) is life size physical room or space, with images projected to each surface. Participants enter the space wearing stereoscopic goggles to allow them to view the images in three dimensions. Similar to 3D movies with the exception that people are active participants in the experience and can move about the space. Projected images are videos and computer generated renderings of real life environments. The most notable examples of its use are in simulation labs for driving schools and pilot training, alternately the Holodeck on Star Trek is another example.**

**32. Based on the description provided of a CAVE, would you, if given the opportunity integrate a CAVE environment to your:**

| | Yes | No | Maybe |
|---|---|---|---|
| Course/curriculum | ○ | ○ | ○ |
| Research | ○ | ○ | ○ |
| Profession | ○ | ○ | ○ |

**33. Do you feel a CAVE environment can provide added value to experience in visualizing conceptual design?**

| | Yes | No | Maybe |
|---|---|---|---|
| Programming | ○ | ○ | ○ |
| Conceptual design | ○ | ○ | ○ |
| Design implementation | ○ | ○ | ○ |
| Accessibility | ○ | ○ | ○ |
| Life safety | ○ | ○ | ○ |
| Wayfinding | ○ | ○ | ○ |

**Other**

[ ]

**34. Additional comments**

[ ]

**APPENDIX B**

# Summary Report - all questions

*(Completion rate: 82.09%)*

## Please check box if you agree

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 67 |
| | **Total Responses** | | **67** |

## 1. Are you a:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Student | | 44% | 28 |
| Educator/researcher/professional | | 56% | 36 |
| | **Total Responses** | | **64** |

## 2. Are you a:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Undergraduate student | | 57% | 16 |
| Graduate student | | 43% | 12 |
| | **Total Responses** | | **28** |

## 3. Please identify your program of study.

The 26 response(s) to this question can be found in the appendix.

## 4. Are you familiar with CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 11% | 3 |
| No | | 89% | 24 |
| | **Total Responses** | | **27** |

## 5. Is your use of CAVE environments primarily for?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Assignments | | 33% | 1 |
| Research | | 67% | 2 |
| | **Total Responses** | | **3** |

## 6. Has CAVE environments impacted your perception of physical reality?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 33% | 1 |
| No | | 67% | 2 |
| | **Total Responses** | | **3** |

## If yes, please describe.

The 1 response(s) to this question can be found in the appendix.

## 7. Has the use of CAVE environments added value to your studies?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 33% | 1 |
| No | | 33% | 1 |
| Somewhat | | 33% | 1 |
| | **Total Responses** | | **3** |

## Please describe

The 2 response(s) to this question can be found in the appendix.

## 8. Additional comments

The 1 response(s) to this question can be found in the appendix.

## 9. Have you ever used 3D visualization?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 24 |
| No | | 0% | 0 |
| | **Total Responses** | | **24** |

## 10. Have you watched virtual walkthroughs of interior spaces either on YouTube or elsewhere?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 24 |
| No | | 0% | 0 |
| | **Total Responses** | | **24** |

## 11. Are virtual walkthroughs used as example in your studio classes?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 21% | 5 |
| No | | 79% | 19 |
| | **Total Responses** | | **24** |

## 12. If yes, how useful have they been?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Extremely useful | | 50% | 3 |
| Useful | | 50% | 3 |
| Somewhat useful | | 0% | 0 |
| Not very useful | | 0% | 0 |
| | **Total Responses** | | **6** |

## 13. If no, do you think virtual walkthrough would be?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Extremely useful | | 37% | 7 |
| Useful | | 47% | 9 |
| Somewhat useful | | 16% | 3 |
| no very useful | | 0% | 0 |
| | **Total Responses** | | **19** |

## 14. What benefits do you feel virtual walkthroughs would add to design studio?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Realistic visualization | | 58% | 14 |
| A better understanding of the overall space | | 88% | 21 |
| Ability to develop conceptual design | | 33% | 8 |
| A better understanding of proportion and scale | | 71% | 17 |
| Simulate life safety and accessibility requirements | | 25% | 6 |
| | **Total Responses** | | **24** |

## 15. Based on the description provided of CAVE environments, do you feel CAVE's can add value to design studio learning?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 83% | 20 |
| No | | 0% | 0 |
| Maybe | | 17% | 4 |
| | **Total Responses** | | **24** |

## Please explain

The 15 response(s) to this question can be found in the appendix.

## 16. If given the opportunity, would you be interested in using CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 24 |
| No | | 0% | 0 |
| | **Total Responses** | | **24** |

## 17. Additional comments

The 2 response(s) to this question can be found in the appendix.

## 18. Are you familiar with CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 17% | 6 |
| No | | 83% | 29 |
| | **Total Responses** | | **35** |

## 19. Have you integrated CAVE environments as part of your:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Course/curriculum | | 20% | 1 |
| Research | | 40% | 2 |
| Profession | | 60% | 3 |
| | **Total Responses** | | **5** |

## Please describe

The 4 response(s) to this question can be found in the appendix.

## 20. What type of change or impact occurred as a result of integrating a CAVE environment?

| Variable | Response |
|---|---|
| Course/curriculum | The 2 response(s) to this question can be found in the appendix. |
| Research | The 1 response(s) to this question can be found in the appendix. |
| Profession | The 4 response(s) to this question can be found in the appendix. |

## 21. As a result of using a CAVE environment, do you feel students are more creative in their approach to design concepts?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 25% | 1 |
| No | | 50% | 2 |
| Somewhat | | 25% | 1 |
| | **Total Responses** | | **4** |

## 22. Do you feel a CAVE environment has added value?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 50% | 2 |
| No | | 25% | 1 |
| Somewhat | | 25% | 1 |
| | **Total Responses** | | **4** |

## 23. Please describe

| Variable | Response |
|---|---|
| Course/curriculum | The 1 response(s) to this question can be found in the appendix. |
| Research | The 1 response(s) to this question can be found in the appendix. |
| Profession | The 2 response(s) to this question can be found in the appendix. |

## 24. What do you feel can be future applications of CAVE's in design application?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Programming | | 33% | 1 |
| Conceptual design | | 100% | 3 |
| Design implementation | | 67% | 2 |
| Accessibility | | 0% | 0 |
| Life safety | | 0% | 0 |
| Design detailing | | 67% | 2 |
| Wayfinding | | 33% | 1 |
| | **Total Responses** | | **3** |

### Other

There are no responses to this question.

## 25. Are there aspects of CAVE environments you feel are not suited to design education?

The 2 response(s) to this question can be found in the appendix.

## 26. Would you if given the opportunity integrate a CAVE environment to your:

| | Yes | No | Maybe | Total Responses |
|---|---|---|---|---|
| Course/curriculum | 2 (100%) | 0 (0%) | 0 (0%) | 2 |
| Research | 2 (100%) | 0 (0%) | 0 (0%) | 2 |
| Profession | 2 (67%) | 0 (0%) | 1 (33%) | 3 |

## 27. Additional comments

The 1 response(s) to this question can be found in the appendix.

## 28. Have you ever used virtual walkthroughs as a tool to demonstrate conceptual designs?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 30% | 8 |
| No | | 70% | 19 |
| | **Total Responses** | | **27** |

### If no, why not?

The 16 response(s) to this question can be found in the appendix.

## 29. Do you feel three dimensional walkthroughs could enhance the learning experience for students?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 74% | 20 |
| No | | 7% | 2 |
| Somewhat | | 19% | 5 |
| | **Total Responses** | | **27** |

### Please describe

The 17 response(s) to this question can be found in the appendix.

## 30. Do your students ask for three dimensional visualization options?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 37% | 10 |
| No | | 63% | 17 |
| | **Total Responses** | | **27** |

## 31. If resources were available would you encourage your students to explore the potential of three dimensional environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 93% | 25 |
| No | | 7% | 2 |
| | **Total Responses** | | **27** |

## 32. Based on the description provided of a CAVE, would you, if given the opportunity integrate a CAVE environment to your:

| | Yes | No | Maybe | Total Responses |
|---|---|---|---|---|
| Course/curriculum | 16 (67%) | 1 (4%) | 7 (29%) | 24 |
| Research | 9 (39%) | 4 (17%) | 10 (43%) | 23 |
| Profession | 10 (43%) | 6 (26%) | 7 (30%) | 23 |

## 33. Do you feel a CAVE environment can provide added value to experience in visualizing conceptual design?

| | Yes | No | Maybe | Total Responses |
|---|---|---|---|---|
| Programming | 7 (29%) | 7 (29%) | 10 (42%) | 24 |
| Conceptual design | 21 (81%) | 1 (4%) | 4 (15%) | 26 |
| Design implementation | 19 (73%) | 4 (15%) | 3 (12%) | 26 |
| Accessibility | 16 (64%) | 5 (20%) | 4 (16%) | 25 |
| Life safety | 16 (64%) | 3 (12%) | 6 (24%) | 25 |
| Wayfinding | 21 (84%) | 1 (4%) | 3 (12%) | 25 |

## Other

The 2 response(s) to this question can be found in the appendix.

## 34. Additional comments

The 7 response(s) to this question can be found in the appendix.

# APPENDIX B

## 3. Please identify your program of study. |

| # | Response |
|---|---|
| 1. | Interior Design |
| 2. | Interior Design |
| 3. | Interior Design |
| 4. | Masters of Interior Design |
| 5. | Design |
| 6. | Interior Design |
| 7. | Interior Design |
| 8. | Interior Design |
| 9. | INTERIOR DESIGN |
| 10. | Bachelor of Interior Design. |
| 11. | Bachelor of Interior Design |
| 12. | interior design |
| 13. | Interior Design |
| 14. | Interior Design |
| 15. | Master of Interior Design |
| 16. | Master of Interior Design |
| 17. | Environmental design |
| 18. | Interior Design |
| 19. | Interior Design |
| 20. | Interior Design |
| 21. | Interior design |
| 22. | Interior Design |
| 23. | Interiors |
| 24. | Interior Design |
| 25. | Environmental Design - Interiors |
| 26. | Environmental design |

## 6. If yes, please describe. |

| # | Response |
|---|---|
| 1. | Allows for the verification of design concepts and enhances visualization skills. |

## 7. Please describe |

| # | Response |
|---|---|
| 1. | I have not actually used a CAVE environment |
| 2. | Allows for enhancement of concepts and visualization skills. |

## 8. Additional comments |

| # | Response |
|---|---|
| 1. | In the near future, technology does seem to support such three dimensional viewing experience. |

## 15. Please explain |

| # | Response |
|---|---|
| 1. | Allows for "testing" of design concepts and can develop and check a student's visualization skills. |
| 2. | Progression of technology enhances the client experience and resolves issues quicker. |
| 3. | Since design drawings are typically done in 2D, it is easy to get stuck in one dimension. This will help visual the space in 3 dimensions and will provide a better understanding of how the design can work |
| 4. | There can be limitations to other 3D software that CAVE environments could improve on for student's understanding. |
| 5. | Allowing for realistic visualization of concept as well as provide a better understanding of built forms and what can and cannot work for structural or other purposes as opposed to being told it will not work. |
| 6. | it could give a more full experience of the space |
| 7. | Experience a space before constructing it |
| 8. | This will allow students to understand the design of their space as well as flaws in the design. |
| 9. | They would allow students to visualize what a conceptual environment might feel like and subsequently aid in better critiques of the proposed spaces. |
| 10. | Better concept of volume without having to build. |
| 11. | It will only really be practically useful if this technology is adapted for use as a communication tool within the design industry. If not, it seems the time it takes to learn to use this technology or set it up properly may be better spent on other things. |
| 12. | Firsthand experience of a space. Easy to experience without modelling first |
| 13. | My experience as a teacher's assistant for a beginning year made me realize how in the early |

| | | |
|---|---|
| | years of studio it is especially hard for students to visual how big they are making spaces or objects in the space so I always suggested for them to have their tape measure next to them and measure something they are familiar with like the space between their desks or the size of their bedroom so that when they are designing a space they can reference a specific space in mind they have experienced. By adding CAVE environments to design studio learning would only add to help students with this process I believe of understanding size, scale, and proportion in relation to the human body more fully. |
| 14. | I feel it might be helpful to particular work, but could end up being underused. |
| 15. | It seems like a lot of work when using a Revit model walkthrough is just as good. Maybe if your project was super complicated it could help |

## 17. Additional comments |

| # | Response |
|---|---|
| 1. | My only concern is cost. |
| 2. | I REALLY WISH WE HAD A CAVE. |

## 19. Please describe |

| # | Response |
|---|---|
| 1. | Have not used but am aware of CAVES through the research of others. |
| 2. | NO |
| 3. | museum design/exhibit design experiences |
| 4. | Students are required to submit 3D illustrations for their projects. Students also must learn in order to be employable. Professionally integrated for client presentations, project documentation |

## 20. What type of change or impact occurred as a result of integrating a CAVE environment? | Course/curriculum

| # | Response |
|---|---|
| 1. | none to date but see how could be very useful in design studio for developing and verifying visualization abilities and concepts |
| 2. | Students learning to articulate ideas with other tools. Students struggling with time management. Creative development is being sacrificed for learning computer programs. Problem solving is incomplete. |

## 21. What type of change or impact occurred as a result of integrating a CAVE environment? | Research

| # | Response |
|---|---|
| 1. | More rigorous deliverables. Requires more collaboration with individuals as no individual can do everything. |

## 22. What type of change or impact occurred as a result of integrating a CAVE environment? | Profession

| # | Response |
|---|---|
| 1. | None to date but extensively used virtual walkthrough for 18 years in professional practice and see CAVE's as an extension and enhancement of this. Avoids costly mistakes and unhappy clients. |
| 2. | None |
| 3. | the visitors were able to participate in an out of world experience |
| 4. | Individuals are specializing. Companies are siloing individuals. Computer skills valued more than creative problem solving skill. |

## 23. Please describe | Course/curriculum

| # | Response |
|---|---|
| 1. | It has improved the “eye candy effect" which is more stimulating for individuals. Depending on the complexity of the programs it can help to resolve technical issues which arise in design which normally could not be calculated as easily manually. |

## 23. Please describe | Research

| # | Response |
|---|---|
| 1. | More tools provided for deeper exploration and research. |

## 23. Please describe | Profession

| # | Response |
|---|---|
| 1. | Familiar with concept, but never experienced first hand |
| 2. | Provides information formats that clients love to look at. Easily revised (in most cases) for quick turnaround. Increased costs for fees, equipment and materials. |

## 25. Are there aspects of CAVE environments you feel are not suited to design education? |

| # | Response |
|---|---|
| 1. | Cost of implementing the environment |
| 2. | Not at this time. |

## 27. Additional comments |

| # | Response |
|---|---|
| 1. | none at this time |

## 28. If no, why not? |

| # | Response |
|---|---|
| 1. | I have not, but I've had students that have. I lack the technical skills to do so. |
| 2. | Not aware of them being available at a reasonable cost. |
| 3. | not familiar with software |
| 4. | don't know about |
| 5. | Not familiar with the technology for teaching my level of courses |
| 6. | I am a professor emeritus---retired. I used already prepared walkthroughs to demonstrate lighting effects, but I did not prepare the walkthroughs. |
| 7. | Never had accesses to one. |
| 8. | not familiar enough with them, working on an app presently for future educational purposes |
| 9. | Haven't had the need to. |
| 10. | I am unfamiliar with using the technology and don't know whether my school has the capabilities to use them. |
| 11. | technologically challenged |
| 12. | It implies that there is no room for contingency, the spontaneous, or the unpredictable so in this way it is fundamentally opposed to living space. |
| 13. | Did not have the expertise to prepare one. |
| 14. | I have not have access to the program nor the expertise |
| 15. | This technology is not available to me. |
| 16. | The technology is not readily available to me. |

## 29. Please describe |

| # | Response |
|---|---|
| 1. | It provides a better picture in which to conceptualize a space or idea. It can also be helpful if drawing skills aren't great. |
| 2. | Any opportunity for students to better experience an environment that is close to the real world is a benefit. |
| 3. | Students can understand scale, impact of color/texture/pattern, examine light sources' impacts. |
| 4. | don't know |
| 5. | Working with real client projects and/or spaces is always the best experiential learning opportunity but this 3-d virtual space would potentially provide an interesting alternative and engage students. |
| 6. | The volumes of space are more easily understood. |
| 7. | Students need to see to make their thoughts and ideas clearer. |
| 8. | because most people can't see things in 3 dimensional |
| 9. | yes but recommend / prefer it to be combined with the opportunity to physically build full scale |
| 10. | Interior Design students are often challenged to envision the volume of a space, particularly in first and second year. This technology may enhance this learning. |
| 11. | Visualization is a difficult concept for most students |
| 12. | Students who are not able to imagine the spaces they define in their projects can experience them and understand them better. |
| 13. | It will only create a fiction of inhabitation, ripped out of the larger context of the city or the social practices of living. |
| 14. | My first priority is that they understand how to plan in 2 dimensions, second is three dimensional designs which come with more experience. |
| 15. | I feel they could enhance the learning experience for students and professionals. They could also be an excellent presentation tool, especially for custom millwork design. |
| 16. | It would give experiential feedback to students in conceptual interior design development, especially incorporating the element of movement through space. |
| 17. | It would give experiential feedback to students in conceptual interior design development, especially incorporating the element of movement. |

## 33. Other |

| # | Response |
|---|---|
| 1. | Since I am retired, I probably won't be using it, but I understand the value of CAVE. It depends on cost/how much time and space it takes to use. |
| 2. | Custom millwork design |

## 34. Additional comments |

| # | Response |
|---|---|
| 1. | none |
| 2. | Main concern is the cost factor, space requirement, and our Information Technology department's ability to implement and maintain the software. |
| 3. | Cave technology is an interesting concept and it would be interesting to take a field trip to a working Cave to better understand how it functions and aids in design development and execution of real time projects. |
| 4. | GOOD LUCK---sounds exciting! |
| 5. | A good tool for experiential learning because a student can manipulate a simulated environment to asses physical as well as psychological factors relating to spatial analysis and lighting variables. |
| 6. | It is an interesting experiment but the new technology could be part of a larger context, subservient to a strong existing practice to evaluate if it is pure spectacle or can it contribute to spatial theory. |
| 7. | I feel that students may be missing some of the basics as they concentrate on getting the technology right. If this is a user friendly technology that doesn't require additional time in the design/drawing process, I would favor it. |

**APPENDIX C**

# Summary Report - Student Familiar with CAVE™

*(Completion rate: 82.09%)*

## 2. Are you a:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Undergraduate student | | 57% | 16 |
| Graduate student | | 43% | 12 |
| | **Total Responses** | | **28** |

## 3. Please identify your program of study.

The 26 response(s) to this question can be found in the appendix.

## 4. Are you familiar with CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 11% | 3 |
| No | | 89% | 24 |
| | **Total Responses** | | **27** |

## 5. Is your use of CAVE environments primarily for:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Assignments | | 33% | 1 |
| Research | | 67% | 2 |
| | **Total Responses** | | **3** |

## 6. Has CAVE environments impacted your perception of physical reality?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 33% | 1 |
| No | | 67% | 2 |
| | **Total Responses** | | **3** |

## If yes, please describe.

The 1 response(s) to this question can be found in the appendix.

## 7. Has the use of CAVE environments added value to your studies?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 33% | 1 |
| No | | 33% | 1 |
| Somewhat | | 33% | 1 |
| | **Total Responses** | | **3** |

## Please describe

The 2 response(s) to this question can be found in the appendix.

## 8. Additional comments

The 1 response(s) to this question can be found in the appendix.

## 9. Have you ever used 3D visualization?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 24 |
| No | | 0% | 0 |
| | **Total Responses** | | **24** |

# APPENDIX C

## 3. Please identify your program of study. |

| # | Response |
|---|---|
| 1. | Interior Design |
| 2. | Interior Design |
| 3. | Interior Design |
| 4. | Masters of Interior Design |
| 5. | Design |
| 6. | Interior Design |
| 7. | Interior Design |
| 8. | Interior Design |
| 9. | INTERIOR DESIGN |
| 10. | Bachelor of Interior Design. |
| 11. | Bachelor of Interior Design |
| 12. | interior design |
| 13. | Interior Design |
| 14. | Interior Design |
| 15. | Master of Interior Design |
| 16. | Master of Interior Design |
| 17. | Environmental design |
| 18. | Interior Design |
| 19. | Interior Design |
| 20. | Interior Design |
| 21. | Interior design |
| 22. | Interior Design |
| 23. | Interiors |
| 24. | Interior Design |
| 25. | Environmental Design - Interiors |
| 26. | Environmental design |

## 6. If yes, please describe. |

| # | Response |
|---|---|
| 1. | Allows for the verification of design concepts and enhances visualization skills. |

## 7. Please describe |

| # | Response |
|---|---|
| 1. | I have not actually used a CAVE environment |
| 2. | Allows for enhancement of concepts and visualization skills. |

## 8. Additional comments |

| # | Response |
|---|---|
| 1. | In the near future, technology does seem to support such three dimensional viewing experience. |

**APPENDIX D**

# Summary Report - Students not Familiar with CAVE™

*(Completion rate: 82.09%)*

## 2. Are you a:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Undergraduate student | | 57% | 16 |
| Graduate student | | 43% | 12 |
| | **Total Responses** | | **28** |

## 3. Please identify your program of study.

The 26 response(s) to this question can be found in the appendix.

## 4. Are you familiar with CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 11% | 3 |
| No | | 89% | 24 |
| | **Total Responses** | | **27** |

## 10. Have you watched virtual walkthroughs of interior spaces either on YouTube or elsewhere?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 24 |
| No | | 0% | 0 |
| | **Total Responses** | | **24** |

## 11. Are virtual walkthroughs used as example in your studio classes?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 21% | 5 |
| No | | 79% | 19 |
| | **Total Responses** | | **24** |

## 12. If yes, how useful have they been?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Extremely useful | | 50% | 3 |
| Useful | | 50% | 3 |
| Somewhat useful | | 0% | 0 |
| Not very useful | | 0% | 0 |
| | **Total Responses** | | **6** |

## 13. If no, do you think virtual walkthrough would be?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Extremely useful | | 37% | 7 |
| Useful | | 47% | 9 |
| Somewhat useful | | 16% | 3 |
| no very useful | | 0% | 0 |
| | **Total Responses** | | **19** |

## 14. What benefits do you feel virtual walkthroughs would add to design studio?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Realistic visualization | | 58% | 14 |
| A better understanding of the overall space | | 88% | 21 |
| Ability to develop conceptual design | | 33% | 8 |
| A better understanding of proportion and scale | | 71% | 17 |
| Simulate life safety and accessibility requirements | | 25% | 6 |
| | **Total Responses** | | **24** |

## 15. Based on the description provided of CAVE environments. Do you feel CAVE's can add value to design studio learning?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 83% | 20 |
| No | | 0% | 0 |
| Maybe | | 17% | 4 |
| | **Total Responses** | | **24** |

## Please explain

The 15 response(s) to this question can be found in the appendix.

## 16. If given the opportunity, would you be interested in using CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 100% | 24 |
| No | | 0% | 0 |
| | **Total Responses** | | **24** |

## 17. Additional comments

The 2 response(s) to this question can be found in the appendix.

# Appendix D

## 3. Please identify your program of study. |

| # | Response |
|---|---|
| 1. | Interior Design |
| 2. | Interior Design |
| 3. | Interior Design |
| 4. | Masters of Interior Design |
| 5. | Design |
| 6. | Interior Design |
| 7. | Interior Design |
| 8. | Interior Design |
| 9. | INTERIOR DESIGN |
| 10. | Bachelor of Interior Design. |
| 11. | Bachelor of Interior Design |
| 12. | interior design |
| 13. | Interior Design |
| 14. | Interior Design |
| 15. | Master of Interior Design |
| 16. | Master of Interior Design |
| 17. | Environmental design |
| 18. | Interior Design |
| 19. | Interior Design |
| 20. | Interior Design |
| 21. | Interior design |
| 22. | Interior Design |
| 23. | Interiors |
| 24. | Interior Design |
| 25. | Environmental Design - Interiors |
| 26. | Environmental design |

## 15. Please explain |

| # | Response |
|---|---|
| 1. | Allows for "testing" of design concepts and can develop and check student’s visualization skills. |
| 2. | Progression of technology enhances the client experience and resolves issues quicker. |
| 3. | Since design drawings are typically done in 2D, it is easy to get stuck in one dimension. This will help visual the space in 3 dimensions and will provide a better understanding of how the design can work |
| 4. | There can be limitations to other 3D software that CAVE environments could improve on for student's understanding. |
| 5. | Allowing for realistic visualization of concept as well as provide a better understanding of built forms and what can and cannot work for structural or other purposes as opposed to being told it will not work. |
| 6. | it could give a more full experience of the space |
| 7. | Experience a space before constructing it |
| 8. | This will allow students to understand the design of their space as well as flaws in the design. |
| 9. | They would allow students to visualize what a conceptual environment might feel like and subsequently aid in better critiques of the proposed spaces. |
| 10. | Better concept of volume without having to build. |
| 11. | It will only really be practically useful if this technology is adapted for use as a communication tool within the design industry. If not, it seems the time it takes to learn to use this technology or set it up properly may be better spent on other things. |
| 12. | Firsthand experience of a space. Easy to experience without modelling first |
| 13. | My experience as a teacher's assistant for a beginning year made me realize how in the early years of studio it is especially hard for students to visual how big they are making spaces or objects in the space so I always suggested for them to have their tape measure next to them and measure something they are familiar with like the space between their desks or the size of their bedroom so that when they are designing a space they can reference a specific space in mind they have experienced. By adding CAVE environments to design studio learning would only add to help students with this process I believe of understanding size, scale, and proportion in relation to the human body more fully. |
| 14. | I feel it might be helpful to particular work, but could end up being underused. |
| 15. | It seems like a lot of work when using a Revit model walkthrough is just as good. Maybe if your project was super complicated it could help |

## 17. Additional comments |

| # | Response |
| --- | --- |
| 1. | My only concern is cost. |
| 2. | I REALLY WISH WE HAD A CAVE. |

**APPENDIX E**

# Summary Report Educator/Researcher/Professional familiar with CAVE™

*(Completion rate: 82.09%)*

## 1. Are you a:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Student | | 44% | 28 |
| Educator/researcher/professional | | 56% | 36 |
| | **Total Responses** | | **64** |

## 18. Are you familiar with CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 17% | 6 |
| No | | 83% | 29 |
| | **Total Responses** | | **35** |

## 19. Have you integrated CAVE environments as part of your:

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Course/curriculum | | 20% | 1 |
| Research | | 40% | 2 |
| Profession | | 60% | 3 |
| | **Total Responses** | | **5** |

## Please describe

The 4 response(s) to this question can be found in the appendix.

## 20. What type of change or impact occurred as a result of integrating a CAVE environment?

| Variable | Response |
|---|---|
| Course/curriculum | The 2 response(s) to this question can be found in the appendix. |
| Research | The 1 response(s) to this question can be found in the appendix. |
| Profession | The 4 response(s) to this question can be found in the appendix. |

## 21. As a result of using a CAVE environment, do you feel students are more creative in their approach to design concepts?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 25% | 1 |
| No | | 50% | 2 |
| Somewhat | | 25% | 1 |
| | **Total Responses** | | **4** |

## 22. Do you feel a CAVE environment has added value?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 50% | 2 |
| No | | 25% | 1 |
| Somewhat | | 25% | 1 |
| | **Total Responses** | | **4** |

## 23. Please describe

| Variable | Response |
|---|---|
| Course/curriculum | The 1 response(s) to this question can be found in the appendix. |
| Research | The 1 response(s) to this question can be found in the appendix. |
| Profession | The 2 response(s) to this question can be found in the appendix. |

## 24. What do you feel can be future applications of CAVE's in design application?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Programming | | 33% | 1 |
| Conceptual design | | 100% | 3 |
| Design implementation | | 67% | 2 |
| Accessibility | | 0% | 0 |
| Life safety | | 0% | 0 |
| Design detailing | | 67% | 2 |
| Wayfinding | | 33% | 1 |
| | **Total Responses** | | **3** |

## Other

There are no responses to this question.

## 25. Are there aspects of CAVE environments you feel are not suited to design education?

The 2 response(s) to this question can be found in the appendix.

## 26. Would you if given the opportunity integrate a CAVE environment to your:

| | Yes | No | Maybe | Total Responses |
|---|---|---|---|---|
| Course/curriculum | 2 (100%) | 0 (0%) | 0 (0%) | 2 |
| Research | 2 (100%) | 0 (0%) | 0 (0%) | 2 |
| Profession | 2 (67%) | 0 (0%) | 1 (33%) | 3 |

## 27. Additional comments

The 1 response(s) to this question can be found in the appendix.

# APPENDIX E

## 19. Please describe |

| # | Response |
|---|---|
| 1. | Have not used but am aware of CAVES through the research of others. |
| 2. | NO |
| 3. | museum design/exhibit design experiences |
| 4. | Students are required to submit 3D illustrations for their projects. Students also must learn in order to be employable. Professionally integrated for client presentations, project documentation |

## 20. What type of change or impact occurred as a result of integrating a CAVE environment? | Course/curriculum

| # | Response |
|---|---|
| 1. | none to date but see how could be very useful in design studio for developing and verifying visualization abilities and concepts |
| 2. | Students learning to articulate ideas with other tools. Students struggling with time management. Creative development is being sacrificed for learning computer programs. Problem solving is incomplete. |

## 20. What type of change or impact occurred as a result of integrating a CAVE environment? | Research

| # | Response |
|---|---|
| 1. | More rigorous deliverables. Requires more collaboration with individuals as no individual can do everything. |

## 20. What type of change or impact occurred as a result of integrating a CAVE environment? | Profession

| # | Response |
|---|---|
| 1. | None to date but extensively used virtual walkthrough for 18 years in professional practice and see CAVE's as an extension and enhancement of this. Avoids costly mistakes and unhappy clients. |
| 2. | None |
| 3. | the visitors were able to participate in an out of world experience |
| 4. | Individuals are specializing. Companies are siloing individuals. Computer skills valued more than creative problem solving skill. |

## 23. Please describe | Course/curriculum

| # | Response |
|---|---|
| 1. | It has improved the “eye candy effect" which is more stimulating for individuals.  Depending on the complexity of the programs it can help to resolve technical issues which arise in design which normally could not be calculated as easily manually. |

## 23. Please describe | Research

| # | Response |
|---|---|
| 1. | More tools provided for deeper exploration and research. |

## 23. Please describe | Profession

| # | Response |
|---|---|
| 1. | Familiar with concept, but never experienced first hand |
| 2. | Provides information formats that clients love to look at. Easily revised (in most cases) for quick turnaround. Increased costs for fees, equipment and materials. |

## 25. Are there aspects of CAVE environments you feel are not suited to design education? |

| # | Response |
|---|---|
| 1. | Cost of implementing the environment |
| 2. | Not at this time. |

## 27. Additional comments |

| # | Response |
|---|---|
| 1. | none at this time |

# APPENDIX F

# Summary Report Educator/Researcher/Professional - not Familiar with CAVE

*(Completion rate: 82.09%)*

## 1. **Are you a:**

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Student | | 44% | 28 |
| Educator/researcher/professional | | 56% | 36 |
| | **Total Responses** | | **64** |

## 18. Are you familiar with CAVE environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 17% | 6 |
| No | | 83% | 29 |
| | **Total Responses** | | **35** |

## 28. Have you ever used virtual walkthroughs as a tool to demonstrate conceptual designs?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 30% | 8 |
| No | | 70% | 19 |
| | **Total Responses** | | **27** |

## If no, why not?

The 16 response(s) to this question can be found in the appendix.

## 29. Do you feel three dimensional walkthroughs could enhance the learning experience for students?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 74% | 20 |
| No | | 7% | 2 |
| Somewhat | | 19% | 5 |
| | **Total Responses** | | **27** |

## Please describe

The 17 response(s) to this question can be found in the appendix.

## 30. Do your students ask for three dimensional visualization options?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 37% | 10 |
| No | | 63% | 17 |
| | **Total Responses** | | **27** |

## 31. If resources were available would you encourage your students to explore the potential of three dimensional environments?

| Response | Chart | Percentage | Count |
|---|---|---|---|
| Yes | | 93% | 25 |
| No | | 7% | 2 |
| | **Total Responses** | | **27** |

## 32. Based on the description provided of a CAVE. Would you, if given the opportunity integrate a CAVE environment to your:

| | Yes | No | Maybe | Total Responses |
|---|---|---|---|---|
| Course/curriculum | 16 (67%) | 1 (4%) | 7 (29%) | 24 |
| Research | 9 (39%) | 4 (17%) | 10 (43%) | 23 |
| Profession | 10 (43%) | 6 (26%) | 7 (30%) | 23 |

## 33. Do you feel a CAVE environment can provide added value to experience in visualizing conceptual design?

| | Yes | No | Maybe | Total Responses |
|---|---|---|---|---|
| Programming | 7 (29%) | 7 (29%) | 10 (42%) | 24 |
| Conceptual design | 21 (81%) | 1 (4%) | 4 (15%) | 26 |
| Design implementation | 19 (73%) | 4 (15%) | 3 (12%) | 26 |
| Accessibility | 16 (64%) | 5 (20%) | 4 (16%) | 25 |
| Life safety | 16 (64%) | 3 (12%) | 6 (24%) | 25 |
| Wayfinding | 21 (84%) | 1 (4%) | 3 (12%) | 25 |

## Other

The 2 response(s) to this question can be found in the appendix.

## 34. Additional comments

The 7 response(s) to this question can be found in the appendix.

# APPENDIX F

## 28. If no, why not? |

| # | Response |
|---|---|
| 1. | I have not, but I've had students that have. I lack the technical skills to do so. |
| 2. | Not aware of them being available at a reasonable cost. |
| 3. | not familiar with software |
| 4. | don't know about |
| 5. | Not familiar with the technology for teaching my level of courses |
| 6. | I am a professor emeritus---retired. I used already prepared walkthroughs to demonstrate lighting effects, but I did not prepare the walkthrough. |
| 7. | Never had accesses to one. |
| 8. | not familiar enough with them, working on an app presently for future educational purposes |
| 9. | Haven't had the need |
| 10. | I am unfamiliar with using the technology and don't know whether my school has the capabilities to use them. |
| 11. | technologically challenged |
| 12. | It implies that there is no room for contingency, the spontaneous, or the unpredictable so in this way it is fundamentally opposed to living space. |
| 13. | Did not have the expertise to prepare one. |
| 14. | I have not have access to the program nor the expertise |
| 15. | This technology is not available to me. |
| 16. | The technology is not readily available to me. |

## 29. Please describe |

| # | Response |
|---|---|
| 1. | It provides a better picture in which to conceptualize a space or idea. It can also be helpful if drawing skills aren't great. |
| 2. | Any opportunity for students to better experience an environment that is close to the real world is a benefit. |
| 3. | Students can understand scale, impact of color/texture/pattern, examine light sources' impacts. |
| 4. | don't know |
| 5. | Working with real client projects and/or spaces is always the best experiential learning opportunity but this 3-d virtual space would potentially provide an interesting alternative and engage students. |
| 6. | The volumes of space are more easily understood. |
| 7. | Students need to see to make their thoughts and ideas clearer. |
| 8. | because most people can't see things in 3 dimensional |
| 9. | yes but recommend / prefer it to be combined with the opportunity to physically build full scale |
| 10. | Interior Design students are often challenged to envision the volume of a space, particularly in first and second year. This technology may enhance this learning. |
| 11. | Visualization is a difficult concept for most students |
| 12. | Students who are not able to imagine the spaces they define in their projects can experience them and understand them better. |
| 13. | It will only create a fiction of inhabitation, ripped out of the larger context of the city or the social practices of living. |
| 14. | My first priority is that they understand how to plan in 2 dimensions, second is three dimensional designs which come with more experience. |
| 15. | I feel they could enhance the learning experience for students and professionals. They could also be an excellent presentation tool, especially for custom millwork design. |
| 16. | It would give experiential feedback to students in conceptual interior design development, especially incorporating the element of movement through space. |
| 17. | It would give experiential feedback to students in conceptual interior design development, especially incorporating the element of movement. |

## 33. Other |

| # | Response |
|---|---|
| 1. | Since I am retired, I probably won't be using it, but I understand the value of CAVE.  It depends on cost/how much time and space it takes to use. |
| 2. | Custom millwork design |

## 34. Additional comments |

| # | Response |
|---|---|
| 1. | none |
| 2. | Main concern is the cost factor, space requirement, and our Information Technology department's ability to implement and maintain the software. |
| 3. | Cave technology is an interesting concept and it would be interesting to take a field trip to a working Cave to better understand how it functions and aids in design development and execution of real time projects. |
| 4. | GOOD LUCK---sounds exciting! |
| 5. | A good tool for experiential learning because a student can manipulate a simulated environment to asses physical as well as psychological factors relating to spatial analysis and lighting variables. |
| 6. | It is an interesting experiment but the new technology could be part of a larger context, subservient to a strong existing practice to evaluate if it is pure spectacle or can it contribute to spatial theory. |
| 7. | I feel that students may be missing some of the basics as they concentrate on getting the technology right. If this is a user friendly technology that doesn't require additional time in the design/drawing process, I would favor it. |