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Studying Visitor Engagement in Virtual Reality Based Children's Science Museum Exhibits

By

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Introduction

Museums hold a special place in the culture of a society. They operate as educational institutions – archiving, displaying, explaining and sometimes teaching visitors the facts and histories surrounding certain artifacts and concepts. Museums simultaneously operate as venues for entertainment, as well. They are social excursions to be experienced alone, with family or peers. This duality of purposes, and the intricacies surrounding it, is apparent in museum studies literature. Many researchers muddle through what an appropriate overarching definition of a museum would be or how to determine if a certain institution can be deemed a museum[1]. Museum mission statements echo the multiplicity, often containing desires for engagement or inspiration for their visitors, rather than simply a learning or pleasurable experience. Engagement is the starting point for both educational and entertainment goals. As museums evolve and adopt more technology-based methods of delivering information to their audiences, it is important to focus on how the measures used to gauge visitor engagement with these new methods, and therefore learning and pleasure, are also changing with the new technology.

In this paper, I will first give a brief picture of the current landscape of research concerning museums and technology, especially virtual reality technologies, including what avenues have been explored and which are still emerging. Then, I will discuss a project with which I have been involved and the subsequent study I performed involving that project. In the study, I attempt to uncover indicators of visitor engagement in virtual reality based museum exhibits, by studying multiple groups of visitors at a children's science center viewing different virtual reality based exhibits. Once the indicators are found, factors that influence the appearance and frequency of those indicators are determined. The study is exploratory in nature

[1] Lee, 1997

and is meant to provide baseline information for future research in the area of virtual reality based exhibits.

Adding Technology into Museums

As technology in society increases and begins to permeate many realms of the average person's world, museums are infusing technology into any and all areas possible. Museums compete for the public's leisure time, which is becoming more and more dominated by computers and different technologies. Visitors have come to expect more computer interactives at museums and many museums are stepping up to the task. In addition to using new technologies as canvases to showcase exhibits' content, museums are developing administrative technology solutions, such as using wireless personal computing (PDAs, cell phones, etc.) to ease a visitor's navigation[2]. Audio tours have been in use for years, but are getting a new infusion with the use of personal data assistants (PDAs) and other small computing systems that the visitor can carry throughout the museum and learn more in depth information about particular exhibits. These PDAs and computing systems sometimes come with built in tracking software, so path and time spent on particular exhibits is not as labor intensive. Another hot new area of development is in virtual museums, where collections are showcased online and the audience is not limited to geographic location. Research looking at the role of websites in museums is increasing, as many are investigating whether the same trends of visitor engagement that hold true in traditional exhibits are mirrored in museum website traffic, such as prediction of visitation paths (or the order of exhibits visited) both online and off[3].

[2] Manning and Sims, 2004. Tellis, 2004. Wilson, 2004. Larkin, 2004. Gay et al, 2002.
[3] Chadwick, 1999. Schaller, 2004.

While the field of visitor studies is relatively new, there are measures that exist for measuring the effectiveness of an exhibit[4]. Most of these measures revolve around quantifying the visitor's engagement, in hopes of determining their enjoyment levels and/or increased knowledge attainment. Because the technologies that museums are integrating into their exhibits are still so new, museum exhibit evaluators are forced to use the same measures of engagement they use for traditional exhibits on the new technologies[5]. Such measures as time spent on an exhibit, path through the exhibit gallery and level of interactivity are also measurable in an online context or computer aided exhibit and vary in ease of collection. The largest focus of research in technology and museums is with usability, or how well the exhibit functions and the ease with which a visitor can use it. Countless studies exist that detail experiments and trials with users testing interfaces, comfort with equipment and ease of learning how to navigate controls[6]. Of course these are all needed tests, but as evaluation dollars and time allotted are scarce, when usability tests are over, little time and money is left to research the affective and educational benefits of tech-heavy exhibit.

One area of contention is whether the infusion of these different technologies into the typical museum is needed. Using a sexy new computerized system is exciting as far as development is concerned, but what is its worth? Are visitors learning more and/or having a more enjoyable time because of the addition? Are engagement times increasing? Is the draw of the new technology enough – is marketing its only success? These are all questions that come up continually in the field. In an attempt to answer these questions concerning one application of infusing technology into a museum, one educational web design company did a small study on

[4] Korn, 1994.
[5] Diamond, 1999.
[6] Allison et al, 1997. Brady and O'Sullivan, 1998. Hay et al, 2000. Herrington et al, 2000. Honeyman, 2001. Kaufman, 2002. Sauer et al, 2004. Schaller, 2004. Slater, 1994. Snyder, 2004. Sykes, 2004. Wakkary et al, 2004. Yates and Errington, 2001.

what the added benefits of using Macromedia Flash™ [7] were on their client museum's new online Renaissance exhibit[8]. They found that the purpose of the visit was very important in determining which interface the visitor benefited from. Some visitors preferred the less dynamic site if their purpose was research or directed study. The researchers were very surprised, as they felt all visitors would inherently appreciate the vibrant Flash site. This sort of comparative approach, where the same content is displayed in traditional and more tech-heavy ways, is a good starting point for future research to determine whether or not the new technologies are necessary, and if they are, what would be the best way to harness their power.

Virtual Reality and Museums

Virtual reality (VR) is a relatively new technology that museums are beginning to consider using in exhibits. VR is difficult to define, because it has many interpretations. Some consider VR to be anything that alters a person's current point of view, transferring them to an alternate reality for a short time[9]. This alternate reality is sometimes referred to as virtual environment (VE), where the user is completely immersed to the point that any way they look or turn, they are still immersed. The allure of VR has been strong, given it's novelty and imaginative possibilities. Yet, until recently, the actual hardware technology required to achieve this high level of immersion was very expensive and not widely available. Smaller institutions, such as museums, found most VR technology too cost prohibitive for their organization. As the technology continued to evolve, more entertainment venues began using VR and the public became more accustomed to the medium. Educational venues like museums, in an attempt to

[7] Flash is a dynamic animation program for use on websites.
[8] Schaller et al, 2004.
[9] Brady and O'Sullivan, 1998.

stay appealing to the public, wanted to incorporate VR and looked to the research community to justify the move to using it.

Using VR in more than an entertainment capacity, especially as an educational tool, became the focus of much research in the VR community. Most of the available VR research is on usability. Researchers have to get the application working and have users learn it before they can see how a user makes meaning from it. The bulk of the non-usability focused findings are anecdotal affective results, measuring the participant's level of enjoyment, such as a 2002 study teaching philosophy in a VE where participants expressed generally more favorable feelings toward the content when it was delivered in a VE rather than in a more traditional method, such as a lecture or reading in a book[10]. When VR studies are less anecdotal and attempt to find more empirical results, they tend to be either too case specific in design, have too few participants or to not use an experimental design and therefore cannot be broadly applied[11]. For example, one 2001 study used a VE as a canvas for teaching abstract math concepts, but their sample size was too small and no comparison programs were used, which in turn made the results weak and inconclusive[12].

Determining how to use VR in an educational capacity is still a fledgling research area. The first wave of research done exploring VR as a successful educational tool was government sponsored and used in flight simulation training for pilots[13]. These studies found the most effective use of VR to be in spatial reasoning exercises, such as mapping, architectural development and training for combat maneuvers. Based on the success of these uses, VR researchers began exploring its' use in other educational arenas, from university level to

[10] Hedman et al, 2002.
[11] Vekiri and Samson, 2000. Windschitl and Winn, 2000. Slater et al, 1994. Allison et al, 1997.
[12] Taxen and Naeve, 2001.
[13] Youngblutt, 1998.

elementary school. Maria Roussos and Andrew Johnson's team and their work at the Electronic Visualization Laboratory (EVL) at University of Illinois Chicago discovered another successful use of VR which increases the amount of meaning a user gets from a VE or VR display: collaboration[14]. Their work focuses on specific projects tested with elementary school children adding in various directed and collaborative tasks. Over the course of the Narrative, Immersive, Constructionist/Collaborative Environment (NICE) project, they were able to link not only many students in the same room together in a VE, but also other students in other locations, sometimes using different computing platforms.[15] EVL's team developed a conceptual framework to watch for when observing and evaluating children in the NICE VEs. Using Lewin's work as a foundation, while observing users interacting with the VE, they considered the technical aspects, orientation aspects, affective parameters, cognitive aspects and pedagogical aspects that factor into a specific virtual learning environment[16].

This brings us to the current state of research into how VR can be utilized for educational purposes. All of the studies mentioned were concerned with formal learning environments. There is essentially no research in the field of how visitors make meaning from using VR displays in informal learning environments, and museums specifically. Many of the methods used successfully in past VR research studies fail in a less structured environment, such as pre- and post-testing for content knowledge and longitudinal studies. Questions still remain as to the value of implementing VR into museums: Does VR aid in the average exhibit's goals to engage and inspire future learning? Or does it simply act as a marketing tool for the museum to draw visitors in and offer initial engagement? Is it possible to determine what the measures of engagement are and what factors influence them for museum exhibits using VR technology?

[14] Roussos and Gillingham, 1998. Kaufmann, 2002.
[15] For more on the NICE project, see Roussos et al, 1999.
[16] Lewin, 1995.

These are the overarching research questions I used to guide my study of a specific VR installation in a hands-on children's science center.

Project Background

I am currently working with the Center for the Presentation of Science at the University of Chicago on a museum exhibit development project called SCOPE[17]. My team is composed primarily of graduate students from University of Chicago from varying disciplines, including computer science, fine arts, high-energy physics and social science. The goal of the project is to introduce the team to the world of museums and exhibit design, with a constructivist pedagogy where the students learn the exhibit development process by actually creating an exhibit. The project was to focus on the collaborative process from research, to planning, to design, to implementation and, finally, evaluation. One of the main tenets of the project was to bring current research to our target museums, so we began by studying current research at the Kavli Institute for Cosmological Physics and associate cosmology research centers. We finally narrowed our topics for the exhibit down to the Sloan Digital Sky Survey telescope and its data, which represented a 3D map of the universe, the VERITAS array of gamma ray telescopes and Andrey Kravtsov's computer simulations of the structure and evolution of the universe.

Our task was to bring these very difficult and abstract concepts to the public in an easy to understand and engaging manner. The composition of our intended audience varied greatly. One intended audience for the exhibit we were developing was SciTech Hands-On Museum in Aurora, IL, a children's science museum covering many realms of science, including astronomy, whose primary audience is elementary school children, their families and their teachers. We also had the possibility of our exhibit(s) being installed in an array of other small children's science

[17] SCOPE is an acronym for.SciTech University of Chicago Outreach Pilot Exploration.

centers throughout the Midwest. Another intended audience was Adler Planetarium and Astronomy Museum in Chicago, IL, which caters to a broader audience, including school groups, families and adults, and is primarily focused on astronomy, both current research and historical information.

There were multiple inspirations behind our content and format of our exhibits. One was the GeoWall[18], a new, relatively low-cost[19], stereo projection system. Stereoscopic display is a VR method that doubles an image, applies opposite polarizing filters to each image and then displays the images slightly skewed. Users wear special polarized glasses, where the lens over one eye is polarized opposite from the other.[20] Two parallel images are then projected onto a special polarized screen and the user looks at it with the polarized glasses on. Because the images are not aligned, our eyes force the images to converge, producing a "life-like" image, which "pops out" of the screen at the viewer. GeoWall's lower cost allows the smaller institutions to have the capability for VR based exhibits. Plus, any content we designed for the GeoWall could easily be transformed into 2D format for delivery online or on computer or televisions screens.

The research at the University of Chicago and Adler Planetarium was another inspiration. We wanted to design the exhibit to be about cosmological research, yet there were very different areas of research on which we could focus. For this reason, we decided to develop our exhibit in modules and connect the modules via stories. One module could act independently or be coupled with another to tell a larger story. For example, a module about a telescope could act on

[18] More information about the GeoWall is available online at The GeoWall Consortium website at http://www.geowall.org. Last accessed May 7, 2004

[19] An average GeoWall setup runs for $10,000 compared to some VR systems that can cost over $100,000.

[20] Older VR methods used blue and red filters instead of polarizing. The glasses had one red and one blue lens and the two pictures were tinted opposite red and blue.

its own, or be coupled with a module displaying the data that particular telescope collected to tell a larger story of the places at which scientists work and the data they collect.

Another obvious inspiration for our project was the museums at which we intended installing the exhibits. As our prototype was designed and installed only at SciTech, they will be the only museum I refer to in this study. SciTech Hands-on Science Museum is a small children's science museum located in Aurora, Illinois. The demographic of their audience is elementary school aged children, usually age 10 and younger, and their families, school or peer groups. The atmosphere at SciTech is very informal and cheerful, exuding a positive vibe of exploration and discovery. Their mission is to "engage people in experiencing and learning science in a fun and interactive way" focusing on inspiration, enhancement of current understanding and accessibility[21], and they seem to achieve it from a casual walk through the facility. Visitors seem happy playing with the various exhibits and the mood is close to a playground with children running from exhibit to exhibit. SciTech's VR room is located in the basement in a relatively off-the-beaten path corner. It is a very small room with a capacity of no more than 15 persons, the door of which is usually closed. There are no scheduled times for the VR shows; visitors are able to ask for individual showings or they are asked by museum staff if they would like to see a show. The VR shows are included with the admission ticket price, so there is no added price barrier for the average visitor. SciTech employs a full time regular VR facilitator who narrates the VR shows and interacts with the audience by asking and answering questions.

SciTech had purchased their GeoWall via a grant from the NSF with the intent on developing interactive content that could be scalable to other smaller museums. They had been

[21] SciTech mission statement. Approved by SciTech Board of Directors, May 2, 2000.

using their GeoWall for a year and a half, displaying a collection of VR models including a deep-sea anglerfish, a model of the original Wright brother's airplane, a model of the heart and lungs, a globe of the seismic activity on Earth, a carpenter ant, and VE model of New York's Harlem neighborhood during the Harlem Renaissance. All of SciTech's existing modules, save for the Harlem Renaissance module, were 3D models that the visitor could move around, spin, and zoom in and out of. The Harlem Renaissance module was different in that it was a VE including multiple 3D models of Harlem streets that the person controlling could "walk" around in. The visitor could ride on streetcars, go into buildings and see scenes from such places as the Cotton Club circa the 1930's. SciTech's facilitator manually controlled each of the models and only allowed the visitors to use the controller during the Harlem Renaissance module as it used a different controller than the other models, much like a video game joystick. The museum felt the technical mastery of the controls on the majority of the VR models was too much of a hurdle for the average visitor to handle in their short visit to the VR room.

SciTech was eager for more VR content to show on the GeoWall, especially content with more astronomical themes, as they were planning a new "Space Exploration" gallery for their museum. Our hope was that the modules we developed for SciTech could be viewed together with a facilitated story that links them or as independent modules with a recorded storyline. We hoped that this combination of visual and oral information would increase the engagement of the visitor and therefore lead to a more pleasurable and meaningful experience for them.

Installation of Exhibit at SciTech

We were able to design and install prototype modules of a VR-based interactive walk-through of the Apache Point Observatory (APO) in New Mexico[22], the site of the Sloan telescope, using 3D models of the various telescopes at the observatory site. We were also able to install another prototype module of a VR-based representation of the most recent data from the Sloan Digital Sky Survey (SDSS), which provides an accurate map of our universe[23]. Viewers of the latter module would "fly-through" billions of light years of galaxies, "zooming out" by starting at the sun, through our galaxy and traveling out to quasars[24]. These two modules were colloquially referred to as the "space stuff" modules by the facilitator and audience for the duration of the week I observed. We also installed a collection of astronomical themed models of various globes, including Earth with cloud formations, Earth during the Ice Age and Mars. These were delivered in the same independent fashion as the existing SciTech models and were not accompanied by a storyline, but by facts about the model.

Research Design and Methods

Since a visitor's level of engagement is one of the base variables in determining their experience, my goal with this study was to determine what the indicators of visitor engagement were when watching a VR based exhibit at a children's museum. Once the indicators were determined, I would then look for what factors determined those indicators' existence and frequency.

[22] See Appendix C, Figure 1 & 2, for a still 2D picture of exhibit. More info found at http://www.sdss.org
[23] See Appendix D, Figure 1 & 2, for a still 2D picture of exhibit. More info found at http://www.sdss.org
[24] Quasars are the brightest objects in the universe that astronomers have found. They are smaller than galaxies, yet much brighter. For more information on current research concerning quasars, see http://astro.uchicago.edu.

Methodology

I began the study by reviewing the initial objectives and goals our exhibit design team developed for the project. Then, I researched the museums we intended on exhibiting in, including their mission statements, audience demographics, typical effective exhibit criteria and expectations, focusing on what the specific institution considered a successful exhibit. I then worked with our team to rework our own objectives for the project, tailoring our goals to those of the museums at which we intended our exhibit to be displayed. The SciTech facilitator had performed informal evaluations over his tenure in the position, but most of the results were purely anecdotal in nature and therefore only useful as background information. I used the framework that Lewin and Roussos' five aspects mapped out in their projects studying the impact of VR[25], but concentrated mainly on the affective responses in order to focus my analysis.

I did observations by myself and with one other person from my exhibit development group. When the other group member was present, we compared observational findings. As there were no other studies that detailed indicators of engagement and factors that influenced those indicators in VR exhibits at children's museums, we had to hypothesize possible measures of engagement we expected to observe, so as to prepare ourselves for observation. I was able to observe one week's worth of typical[26] activity of casual SciTech visitors viewing our APO walk-through module and our SDSS fly-through modules, as well as many of the other models SciTech had been showing previously. I observed 14 separate VR shows, including 90 visitors total, 64 children and 26 adults. I also group interviewed 10 of those groups including 59

[25] Technical, orientation, affective, cognitive and pedagogical impacts.
[26] As SciTech does not collect regular demographic data on their audience or traffic trends, I had to rely on anecdotal responses from interviews and conversations with museum staff on traffic trends and typical visitor composition.

individuals, with the peers with whom they watched the show. The largest number of visitors in a show was fourteen; the smallest was one.

I was able to closely match the demographics of SciTech's general audience in my sample, including adults, teenagers, elementary school-aged children and toddler-aged children. Of the fourteen groups I observed, two were student groups on a field trip, one was a boy scout troop, two were small groups of teens above fifteen years of age, one group was two adult women and eight were families. The SciTech staff told me that the bulk of their visitors were normally scout groups and field trips. Families were more prevalent on the weekends. The fact that families were the most prevalent group type in my sample was due to spring vacation. The solo visitor is a rarity, and when they appear it is usually for research or project related, yet this was also represented in the sample with a local boarding school principal and a museum volunteer viewing the show. I was even able to interview a VR professional who was coincidentally taking his son to the museum for the day. I tracked all physical responses, including grabbing at the screen, fidgeting, and paying attention as well as verbal responses such as "ohhs and ahhs," discussion, question answering, and talking about non-presentation topics.

Participant Consent/Assent

A signed consent would be a breach of confidentiality as it would be the only personally identifiable information I collect. Because of this, I decided to obtain verbal consent from the participants before interviewing. Appendix A contains the verbal consent scripts for both the parents and the children I intend to survey. Attention had been given to notifying them of their rights as a participant; detailing the process and securing consent from the parent and assent from the child.

Interview Guide

Appendix B is the Survey Interview Question Guide that I used to guide me through the primarily open-ended interview I had with visitors

Observational and Interview Findings

My original intent in analyzing the data I collected from observations and interviews was to look for indicators and factors of visitor engagement applying the five aspects model Lewin developed (technical, orientation, affective, cognitive, and pedagogical)[27]. I found, though, that while I saw all five aspects at work in the data, most of the indicators and factors fell into the affective category. This is not to say that I did not see the other aspects. I saw the technical aspect affecting visitor engagement when the facilitator relinquished control of his joystick to different visitors, but this only happened in the one module, Harlem Renaissance. One indicator of engagement that was primarily due to visitor's orientation was motion sickness. Four of the adults in separate shows complained of motion sickness without prompting during the interviews, whereas the only two shows where a child complained of motion sickness were toward the end of the show that lasted the longest (45 minutes) and the show where the facilitator explained that some people feel sick from the VR. Seeing groups which arrived at the museum with a more focused intent, such as a directed field trip, would have offered more insight to how the group's pedagogical motivations affect their experience and engagement. But SciTech did not include the VR room as part of any directed field trips, so none of the groups watching the show had a focused task to complete, such as a merit badge or homework assignment.

As the mission of SciTech is more focused on engagement and inspiration, analyzing the visitor engagement for cognitive effects did not fit well either. I wanted to maintain the informal

[27] Lewin, 1995.

ambience of their experience, so I chose not to administer a test before or after they viewed the show. I did ask each group I interviewed if they had learned anything, but the answers were extremely vague in each case, including shrugging of shoulders and five of ten interview cases where a child would state they learned about the general content of the module (i.e. "I learned about the heart and lungs," "I learned about stars", etc). In each of these cases, the answers received from this line of questioning corresponded to the modules they identified as their "favorite" or the "best part." In two of the interviews, the children gave facts about the SDSS fly through module as evidence of what they had learned. This was the only time facts were repeated from the facilitator's script or answered questions. In each of the group interviews with adults and children, adults saw the experience in the museum, and VR presentation specifically, as a chance to learn with their children. One woman, who said she worked with deaf children, saw many possible applications of using VR as an educational tool for her students. Another woman, as she was leaving the VR room, exclaimed, "See kids, even grandma can learn things here."

I decided, instead to change my method of analyzing the data I collected. I saw the engagement indicators fall into categories of the either physical or verbal variety and indicating either engagement or disengagement of the visitor. Furthermore, I determined that some indicators were more passive than others. I began to refer to the more active indicators of engagement as deep engagement indicators. For example, a visitor simply watching the movement on the screen would be displaying an indicator of more passive engagement, whereas a visitor asking questions about the image they were viewing or making some connection, relevant or not, would be showing signs of deeper engagement. I see indicators of deep engagement as signs that the visitor is more apt take their experience at the museum to another

level of cognition, such as seeking to learn more information. Although testing this hypothesis is beyond the scope of this project, the foundation of this future research lies in the distinction on engagement indicators.

Indicators of Visitor Engagement

There were many frequent indicators of engagement, which were present multiple times in each show I observed. Many of the indicators I took as visitor engagement were physical and occurred at least once in each show. These included following the movement on the screen with their eyes, leaning when the movement turned, grabbing at the screen, smiling, laughing and raising their hands to ask or answer questions. I witnessed two separate visitors in two separate showings simulating joystick movements with their hands during the Harlem Renaissance module and two other visitors in separate showings rubbing their hearts during the heart and lungs module. All four of these visitors made these movements seemingly unconsciously and were all coupled with intense attention being paid to the VR screen.

Verbal engagement indicators included asking questions and offering feedback throughout the presentation. Shouting out pop culture points of reference was also common. Part of the main facilitator's script was to ask if the visitors had seen a particular children's animated movie, which featured a deep-sea anglerfish like the one in the module. Once this reference was made, all of the visitors would pay closer attention to the screen and, in two cases, explain to their neighbors who were not following as closely. Some verbal indicators did not seem to have absolute reference to the material in the exhibit, although this did not diminish the child's engagement. On three occasions, different children began singing a popular song they were reminded of by a word or phrase from the facilitator's script. After a short time of

disengagement while beginning the song, in each case the child and their neighbors paid closer attention after the song was sung.

In three of the interviews, the visitors that were most engaged in the audience explained that they were impressed by the technology and that it was their motivation behind coming to watch the show. Many children became overwhelmingly intrigued by the medium, to the point where all of their questions concerned the VR software and not the content it was displaying. Another common comment made during the shows and interviews was that the medium reminded the visitors of video games. Children from five separate groups compared the experience to a video game and one parent explained that her aversion to video games was prohibiting her from responding to the VR show like her children were.

Another interesting, and personally, the most enjoyable, indicator of engagement was many children's tendency to slip into non-sequiturs and tangential information. On four separate occasions, children would blurt out the first connection they could find in an effort to participate. For example, while looking at one of the globe modules, one child shouted "I see New York!" to which a younger boy said "My grandma lives in Florida and she is coming back in May…" and continued to explain a recent visit his grandmother paid him. This link was sufficient for him to make a personal connection to the module and consequently maintain his engagement for longer. One of the children offered his own seemingly irrelevant facts after another child offered germane information, presumably in an attempt to not be outdone by the other child. Two of the children, though, were not prompted by another child's information and would offer their tangential information freely. One such child, after the facilitator explained the APO telescope was located in New Mexico, raised her hand fervently to explain that she once did a report on

New Mexico. The facilitator waited to see if she wanted to add more, but after her statement, the girl just sat quietly, hands folded, with a smile of satisfaction.

There were also verbal and physical indicators I took as disengagement that occurred frequently, and specifically in all shows containing young children or composed of large groups. Verbal indicators of disengagement included talking off topic to a neighbor or asking to leave, the latter happening in each of the four shows with very small (two to five year old) children. The physical disengagement indicators included were yawning, which occurred in six of the fourteen shows, and fidgeting in their seat, which occurred in all the shows. Any sort of distraction not related to the show caused disengagement as well. If the children had any sort of prop with them, such as three groups that had posters from another exhibit, that prop became a huge distraction as they would play with it or use it to distract their neighbors. My presence in the VR room served as a distraction as well. My observation location was in the front row of seating, facing the audience. I had a laptop and typed from the beginning of the show until the end. During each show that I observed, at least one visitor for the audience would look at me briefly, but in five of the fourteen shows, children or adults would stare at me for a minute or more or lean over and look at my laptop keyboard at least once during the show as I observed.

Some engagement indicators were more ambiguous and situation dependant, such as playing with one's VR glasses. All visitors had to wear special polarized glasses that were large enough to fit over an adult's normal eyeglasses. As most of the visitors were children, the glasses generally fit, but not very comfortably. Because of this, most children could be found playing with their glasses at some point during the show. While the manner they played with their glasses was consistent, the reasons varied. Through follow-up questions, four children said they would lift up their glasses or shift them down, because they found them uncomfortable.

Five children said they were “testing” to see how the image differed with and without the glasses. Other types of testing took place often during the presentations, as well. During each show, children tried to grab at the models on the screen or holding their thumb or hand up to the screen to compare relative size. One younger child explained he preferred not wearing the glasses because he “liked seeing [the models] in double.”

Factors that Influence Visitor Engagement

There were many factors that influenced a specific visitor’s level of engagement. I determined these factors primarily from the quantity of indicators of engagement I observed that I felt were due to certain factors and the relative amount of deep engagement indicators in a show and specific module. As many of the factors worked in conjunction with each other and my study was not experimental in nature, it is difficult to determine the exact influence each factor had. Due to the exploratory nature of this study, I intend these results to act as a baseline for future research.

I found the VR facilitator to be one of the most important factors in the engagement of the audience. As I stated earlier, SciTech employed a full time regular facilitator who narrated and interacted with the audience for each VR show. SciTech was in the process of training more employees to aid in this position, so I was able to observe more than one person facilitating the VR shows and note the differences. I observed five total facilitators: the regular facilitator during ten shows, two other facilitators present one each of their own shows and two training facilitators sharing a show where the regular facilitator took over half way through the presentation.

The facilitators’ dynamism and confidence in themselves and their grasp of the content were large factors in the visitors’ level of engagement. The two facilitators that shared a show

were noticeably uncomfortable in the role as a facilitator, ran quickly through the modules, offering little information about each model and making no attempt to engage the audience, besides a quick and half-hearted, “Any questions?” before switching to the next model. Audience members of this show gave no indicators of engagement during the portion of the show led by the training facilitator, save for looking at the screen,. When the regular facilitator took over, they began showing deeper engagement indicators such as asking questions, making comments and showing generally higher levels of engagement. The two facilitators who presented their own shows were more comfortable and familiar with the content, especially the “space stuff,” and were able to provide the audience with a number of facts about many of the models. While the audience did not seem disengaged and was paying attention to the screen and presentation in general, their engagement was more passive. They were not displaying signs of deep engagement such as asking questions, smiling or laughing as much as in other presentations. The regular facilitator treated the VR room almost as a stage during his presentations - asking questions, telling jokes and making whimsical metaphorical references throughout the presentation in an attempt to engage the audience members, both young and old. Audience members, especially adults, greatly appreciated this and made it clear in the interviews afterward. During the group interviews, four adults from two different showings responded that the best part of the presentation was the facilitator and many others thanked the facilitator specifically for a job well done as they left the VR room. None of the interviewees commented on or to the facilitators who did not ask questions or attempt to interact with the audience.

With the introduction of our new cosmological material, I was able to watch how changing the comfort level with the material within just the regular facilitator evolved over the week and therefore track the change in the audiences’ reactions in tandem. I began the week

completely in the role of a member of the exhibit design team. I went over intended scripts with the regular facilitator and acted as a helper during his first couple of runs of the show, piping in when he faltered on or missed a fact from a module. When I began observations, even after explaining my desire to take the role of a more passive, rather than active, participant observer, he continued to defer and refer to me at various points during a presentation. I imagine this was because he continued to see my role as a member of the exhibit design team over my role as an observer. Also, he may have been a bit intimidated by my knowledge on the subject matter being greater than his. I suspected this and throughout the week of observations, I decreased the amount of feedback I gave the VR facilitator rapidly, until I gave none at all the last days of observation. His delivery of the newer "space stuff" modules on these final days was more confident because of this and resulted in more indicators of deep engagement from the audience such as a higher percentage of questions on the cosmological modules.

Indicators of visitor engagement increased when modules referenced some aspect of the visitors' previous knowledge on a subject. For example, the "space stuff" was very popular with many of the children, three groups indicating during their interview that the SDSS fly-through module was their favorite and all groups showed signs of engagement during the module, including reaching for the screen, asking questions, and explaining previous facts they knew about the topic. Adults especially were engaged during the seismic activity and the heart modules, asking many questions of the facilitator during those modules (often to the sadness and impatience of the children) and trying to share their engagement with the children by offering examples of relevance. One parent, in an effort to focus her child's attention on the screen and not the poster the child was playing with, called his attention to the valve in the heart model by saying "that's what used to tick on your uncle." The boy a moment later quietly explained to his

neighbor “that’s what clicked in my uncle ‘til he died,” and both remained engaged for the remainder of the module. Just as many adults and children would try to apply what they were seeing and hearing to something in their own life, many children who were not as successful at finding a matching personal instance, would blurt out the first connection they could find in an effort to participate, such as the pop culture references and non-sequiturs I described earlier. It appears that the need to make a personal connection to the exhibit’s content is universal, yet the person determines the level of relevance.

The length of time spent on a specific module had an effect on the visitor’s engagement. It appeared the regular facilitator had determined the optimum amount of time to spent on each module, as he spent an average of 2 to 3 minutes on each module, save for the Harlem Renaissance module. On the Harlem Renaissance module, the longest amount of time was spent, ranging from 11 to 29 minutes and taking up from 22% to 53% of the total viewing time of the show. This is because the facilitator would hand off the joystick to each child in the audience to give them a turn, each turn lasting an average of one minute and a half. The larger the group, the longer the time spent on that module. I noticed that, in the fifteen instances where the time spent before switching to the next module was under 2 minutes, the visitor would remain looking at the screen, but indicators of deeper engagement, such as asking questions of making physical personal connection responses would never happen. In the four instances where the amount of time spent on a specific module went over 3 minutes, it was always because of an adult asking multiple questions on the heart and lungs module or the seismic activity module. During these times, children in the audience would pay attention until about the 2-minute point and then start to show indicators of disengagement.

The age and group composition affected the visitor engagement as well. SciTech's audience caters to very young children through middle school aged children. Five groups contained children in the toddler age range. These groups were definitely affected by the presence of the young children. Parents in these groups spent a great deal of time focusing on the, often bored, younger children who were asking to leave or fidgeting in their seats. Adult visitors, whether chaperoning a group or the only ones in the audience, were the most engaged in every audience, save for those tending to smaller children. They would ask questions throughout the presentations, prod their children for answers and engagement during the presentation and were quite vocal in the post-interviews. I noticed the parents would often prod their oldest child for answers to questions. When an oldest child wasn't obvious, such as in Boy Scout groups or in one case where a mother watched with her triplets, the more charismatic child or children would be prodded.

The presentation content varied greatly between the different modules and affected the engagement level according to the visitor's personal investment in the topic. We developed the "space stuff" modules, and the stories associated with them, with middle school aged children, grades 3-8, in mind, yet the content was just above the American Association for the Advancement of Science educational standards[28] corresponding to grade 8, mainly with the introduction of galactic scale and the universe that exists outside our galaxy. When I asked the children if they had ever gone over any of the astronomy information in school and, if not, what grade they expected this info, all but one group of children stated they had gone over the astronomy related information in school previously. What seemed to matter more to the children was the general topic of "space" that that modules covered, not the storyline or the facts given.

[28] AAAS educational benchmarks. Found at: http://www.project2061.org/tools/benchol/ch4/ch4.htm#Universe. Last accessed May 7, 2004.

In contrast, modules with instantly recognizable content, such as the carpenter ant, the Wright brothers' plane and the heart and lungs modules, brought on instant engagement from the audience. Whether or not the visitor began displaying deeper indicators depended on the presence of other factors, such as age, group composition and dynamism of the facilitator.

One factor that would always maintain engagement or reengage viewers was motion of the model on the screen. Even if the child were not listening to the facilitator, which could be inferred from some children mouthing or saying other words to his/herself while looking at the screen, their gaze would remain on the screen longer if the model was being moved in some way. The type of movement was important, though, too. Their gaze would be longer if the movement was purposeful or directed, such as locating a certain point on a globe, or walking a certain path with a destination, than if the movement was continuous, such as a globe rotating. On the APO telescope walk-through, two of the facilitators would walk through the VE as they discussed the fats about the telescope site. This directed movement, including climbing stairs and panning the VE for perspective, resulted in longer periods of visitor engagement and signs of deeper engagement. I hypothesize that if the joystick was given to the visitors during this module, the deep engagement indicators would become even more prevalent.

The parents would continually try to engage the children by asking questions or echoing facts given by the facilitator. Another tactic used by many parents to assumingly promote engagement was admonishing their children for their disengagement. On three occasions, a parent would scold a child for chatting off topic to a neighbor or for purposely distracting other viewers. I expected these etiquette-breaking disciplinary actions, which are common to most public outings with children. What was unexpected was when a parent would reprimand their child for offering playful answers to facilitator's questions, for the "testing" I mentioned earlier

or for asking, what they felt, were too many questions. The parents seemed to feel the VR presentation was more revered and therefore required a certain level of composure and respect from the audience. This was especially prevalent during the more content heavy presentations, such as the SDSS fly-through, the heart and lungs model and seismic activity globe, but appeared in other modules as well. After scolding, the children would regain passive engagement, but none of the children in these instances displayed deeper engagement indicators for the remainder of that particular show.

The module that commanded the highest level of engagement was the Harlem Renaissance module. There are many reasons for this, the most important being that this module has many factors that cause increased engagement for the visitor, therefore allowing more chance to a specific factor to affect a particular visitor and to display characteristics of deeper engagement. The length of time spent on the module was the longest for the Harlem Renaissance module which was always the final module showed, so therefore it was first module the children commented on in 62% of the interviews. Comments on other modules in these interviews came with further probing. This module also uses the factor of visitor prior knowledge, assuming that the visitor is familiar with and enjoys video games. All but one of the references to video games were made during the Harlem Renaissance module.

The largest factor causing visitors to display deep engagement indicators was a high level of interactivity and collaboration in the module. Once the joystick controller was handed to a visitor during the Harlem Renaissance module, in every case, everyone in the room remained engaged or became re-engaged, especially the visitor controlling the movement, and many would offer their navigational help. In every case, the adults would attempt to navigate the "driver," or the child with the joystick, to specific locations, such as the Cotton Club, or, in the three

instances where the module content was not explained, they would at least advise the driver walk on the sidewalk. The children would prefer to navigate the driver to crash into building walls and get hit by cars in the module. The desire for more violence occurred frequently once the video game analogy was introduced. The train of thought would usually be verbalized as 'This is like a video game. My favorite video game is [X]. We should be able to [do some violent act]' or 'Go try to [do some violent act].' Most of the experimentation with the Harlem module included trying reckless acts and acts not allowed in reality, like walking off the edge of the VE.

There were factors I watched for to see if they affected the level of engagement, but had little or no effect that I could observe. Gender was not a large component in visitor experience, from what I observed. Roughly a third of the child visitors were female and any indication of non-engagement with the presentation, on any of the modules or in any of the groups, was more due to their age, rather than their gender. With the adults, there were far more women than men (22 compared to 4) and, as I stated above, they were almost always engaged in the presentation. Time of day that the visitor viewed the show did not seem to factor into their experience, and when it did, it was more a function of the facilitator and any fatigue he or she was feeling. The size of the group had an affect on the amount of verbal feedback the audience gave, but not necessarily on the level of engagement from individual visitors during the show. This is possibly due to the difference in magnitude and the fact that there was more likely to be one gregarious child in a larger group than in a smaller group. I did note that if there was one markedly vocal child in the group, there was more likely to be feedback from the other children in the group, even those who appeared less engaged with the presentation, but this is common in any group of children.

Unfortunately, I noted that the facilitator giving misinformation did not discourage engagement from the visitor. As the facilitator of the VR presentation is navigating the visitor through the various models and giving them corresponding information, the facilitator takes on the role of a teacher and sometimes even an expert. It is a natural assumption for the visitor, that since the facilitator is giving gross amounts of information and answering their questions, the facilitator knows the subjects they are talking about explicitly. While this actually was mostly the case in the shows I observed, there were points in the presentation where distinct misinformation was given to a visitor, five times in the normal script the facilitator followed, six times as an answer to a visitor question. Also, at no showing of the Harlem module did the facilitator explain the significance of the module or the purpose for its development, yet this did not affect the visitor's engagement. In one instance, when he was asked the relevance of the Harlem Renaissance module pointedly, he responded that the programmers "just wanted to do historical-type neighborhoods." The facilitator would go into extreme detail about the technological aspects of development for the module for the adults and to the apparent oblivion of the children who were completely focused on the navigation for the driver. Yet, as I stated before, the Harlem Renaissance module remained the module with the highest interactivity, even without depth of content.

Recommendations for the Future

As I imagined, in a study as exploratory in nature as this was, it seemed to open up more avenues for future research than were originally expected. The following are some of the areas that I could foresee as potential opportunities of investigation.

Drawing on the contextual learning model I referred to earlier, one of the factors important to a learning experience is the physical environment. Because of this, modifications to

the VR room at SciTech would be quite beneficial. In fact, based on the successful anecdotal feedback they have received from the VR room visitors, SciTech has plans to move their room from the basement, to the main level of the museum as well as to increase the capacity that the room can hold. They see the VR room as a success and want to increase visibility and capacity. I anticipate these changes will be positive and look forward to their results. Another change I would recommend is an observational area for future visitor studies. My being visible to the viewers during the entire presentation acted as a distraction on many occasions. If a researcher was able to observe from an unobtrusive place, I believe a different type of data and insight could be collected. If this room is created and the general VR audience volume is increased, an observation room could be a useful site for future VR research.

The VR room at SciTech is advertised to visitors primarily based on the VR technology and not on the content the technology displays. It would be interesting to see the effect that an exhibit not marketing the VR technology specifically would have on visitor experience. Would they focus more on the content or have the same reaction? A focused study to determine how the marketing of the VR room and its content affects the meaning a visitor makes and their levels of engagement would almost certainly yield interesting results.

As a possible short term resolution to the SciTech presentations possible misinformation and complete lack of visitor interactivity, our group had decided to begin working on pre-recorded portions of the module, followed by opportunities for visitor interactivity. While many visitors expressed positive feedback about the presentations, when probed, they felt that more interactivity in most of the modules would help with their learning and engagement. This also may reduce the extreme connection to video games that many of the children had when using the joystick controller. Once the initial acclimation and usability period is completed with the

joystick controller, it is possible that the visitor can then get more of the benefit of the interactivity and benefit from a constructivist pedagogy.

Because a proper gauge of all audience prior knowledge and interest in a given subject area is extremely difficult to collect and process for each showing, the method of showing a large number of models seems to work best in the SciTech environment. It gives different viewers a broad catalog of information to which they can relate. It would still be informative to see just how prior knowledge affects a particular visitor's experience with a particular module. Future investigation into methods of gathering this information in unobtrusive ways is needed in the general visitor studies literature and would help on a microcosm level as well.

Another VR exhibit specific observation that begs further study was comparing the attention parents require of their children during different exhibits are needed and how it affects the child's level of engagement between exhibits. As I mentioned previously, in the VR room, many parents would continually admonish their children for lack of attention to the screen or playful answers to facilitator's questions. I hypothesize this is not the case with many of the other very informal exhibits at the museum. Surveying the parents to determine exact why their reactions are different with the different media would be very helpful.

Conclusion

As with most of the research in VR being used as an educational tool, this study is quite case specific and therefore cannot be intended to speak for the universe of VR applications in museums. While it cannot completely answer the questions I originally posed as guides, some insight has been gained into new directions to explore. There are definite indicators of visitor engagement that reoccurred with many of the groups, implying they are possibly general measures. There are also factors that affect a visitor's engagement level and therefore their

affective and cognitive experiences. The VR technology, itself, acted as a draw for many visitors. Without a comparison to a similar, non-VR exhibit, I am not able to estimate whether it increased the amount of engagement a visitor has with an exhibit, though. Visitors seemed engaged in the content, partially due to the medium. Whether they are inspired to learn more on the given content, or even science in general, is not possible to track with the methodology I used. I believe that Lewin's five aspects model would be of tremendous use with a more experimental design, holding various factors outlined in this study constant at different times. Hopefully, this study can act as a springboard for future projects utilizing VR in museums and other informal learning settings, some of which I have recommended, and add more to the small but growing body of research on how visitors make meaning in museums, specifically with exhibits using VR technology.

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Appendix A: Consent and Assent Scripts

Script for Parental Verbal Informed Consent

My name is Joi Podgorny and I am a graduate student in Social Science at the University of Chicago. I am here to conduct a study that will look at museum experiences with virtual reality exhibits.

Before we begin, I would like to take a minute to explain why I am inviting you and your child to participate and what I will be doing with the information you both provide to me. Please stop me at any time if you have any questions. After I've told you a bit more about my project, you can decide whether or not you would like to participate.

I am doing this research as part of my studies in the Department of Social Science at the University of Chicago. I plan to observe and interview 30 museum visitors after they view a virtual reality exhibit and will use this information as the basis for my Masters Thesis. I may also use this information in articles that might be published, as well as in academic presentations and with researchers in the virtual reality field.

Participation should take about ten minutes and is on a purely voluntary basis. You and your child will be asked to explain your experience watching the virtual reality exhibit. The exhibit is still in a development phase, so any information I collect will go toward improving upon the exhibit for other museum visitors. I will not be asking personally identifiable information from either of you. I may wish to quote from this interview either in the presentations or articles resulting from this work. A pseudonym will be used in order to protect your identities, unless you specifically request that you be identified by your true names. Aside from giving me your time, there are no risks to you or your child participating in this survey.

If at any time and for any reason, you or your child would prefer not to answer any questions, please feel free not to. If at any time you or your child would like to stop participating, please tell me. We can take a break, stop and continue at a later date, or stop altogether. You will not be penalized in any way for deciding to stop participation at any time.

If you or your child has questions, you are free to ask them now. If you have questions later, you may contact me, Joi Podgorny at joi@uchicago.edu or 773.665.1572, or via SciTech's employees Ronen Mir, Carina Eizmendi or Sammy Landers.

If you have any questions about you our your child's rights as a participant in this research, you can contact the following office at the University of Chicago:

Social & Behavioral Sciences Institutional Review Board
University of Chicago
5835 South Kimbark - Judd 122
Chicago, IL 60637
Phone: (773) 834-5805
Fax: (773) 834-8700
Email: sbsirb@ura.uchicago.edu

Are you interested in participating in this study?

Script for Child's Verbal Informed Assent

My name is Joi Podgorny and I am a college student at University of Chicago. I am studying virtual reality museum exhibits and what people who watch them think of them.

What you are about to watch is not the final version of the exhibit. I plan on taking visitors' comments and ideas back to the people who made it to see if we can make it even better.

What I am doing is watching people watch the virtual reality show you just saw. After they are finished, I see if they wouldn't mind answering some questions about what they thought of the exhibit with me for about ten minutes.

After you watch the exhibit, I would like to ask you some questions about the exhibit. You do not have to answer any questions if you don't want to. If you want to stop at any point, just tell me, and we will.

If you have any questions, I am giving your parent my information so they can get a hold of me.

Are you interested in participating in this study?

Appendix B: Survey Interview Question Guide[29]

First, I would like to ask a couple of questions about you.

- Why did you come to this museum today?
- What about this exhibit interested you?
- How did you choose to see this exhibit?
- Before you came today, did you know anything about Astronomy?
- Did you know anything about telescopes?
- Did you know anything about other topics from the exhibit? Which ones?
- Have you been interested in Astronomy before?
- Would you say Astronomy is:
    - A major interest of yours?
    - Interesting but not a major interest?
    - Something you are not really interested in?
- Did you look at any other exhibits today about Astronomy?
- Did you ever study Astronomy in school?
- In what grade did you study topics like you saw in this exhibit?
- What grade do you think they would go over the topics you just watched?

Now I would like to talk about the exhibit you just watched.

- What did you think about it?
- What was it about?
- Why do you think it was made?
- Did you enjoy it?
- What parts did you enjoy?
- What was the best part?
- What was the worst part?
- Do you think you learned anything from it?
- What did you learn?

[29] This guide was developed before observations of visitors viewing the exhibit. Actual questions posed were similar, but situation dependant and organic to the progression of the interview.

The people who made the exhibit want it to be the best it can be. I would like to talk to you now about what you think the people who made the exhibit should know.

- How could it have been better?
- Was there anything too easy?
- Was there anything too difficult?

(Here I would press for more specific information about their opinions about the exhibit such as comments about:

- The technology
- The sound
- The lighting
- The space
- The delivery of the information
- Too much/little information
- Length of exhibit)

I want to give you a chance to tell me anything else on your mind.

- Was there anything that we haven't talked about that you would like to talk about now?

Is there anything you want the people who made the exhibit to know?

Appendix C: 2D Screen Shots of APO walk through module

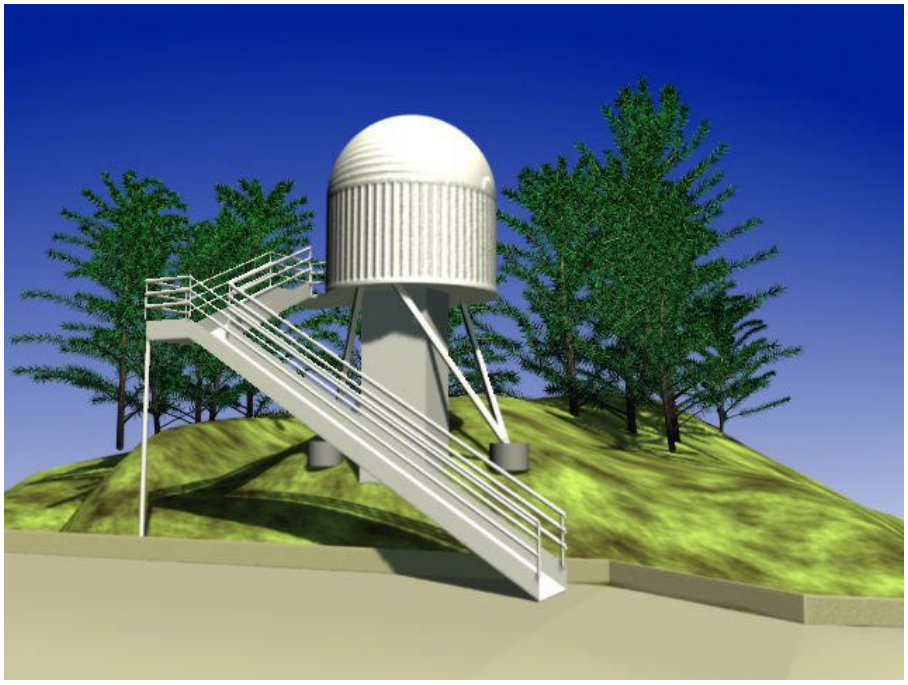

Figure 1: 3D Model of the 2.5 meter telescope at Apache Point Observatory.

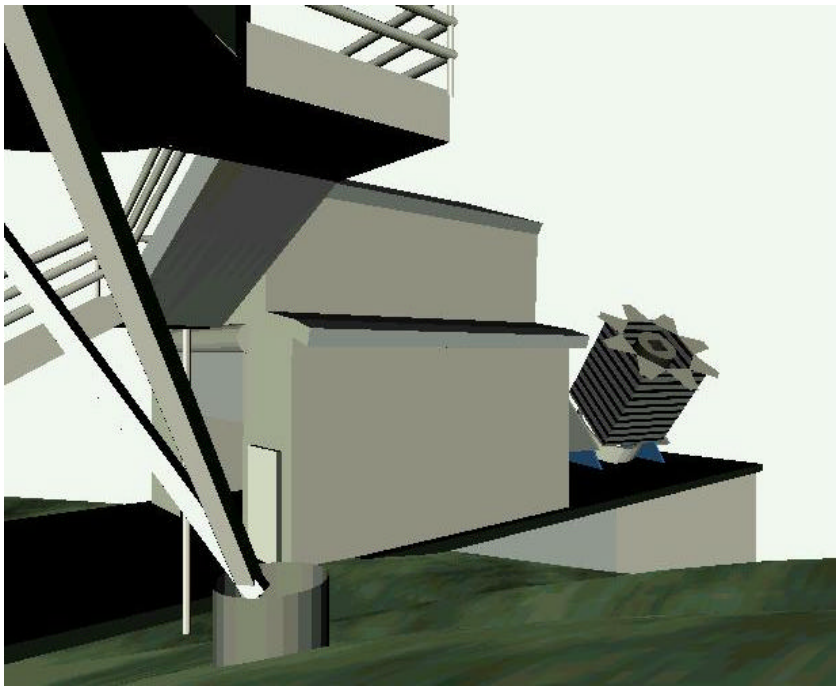

Figure 2: A 3D model of the base of the 2.5 meter telescope,
with the SDSS telescope in the distance.

Appendix D: 2D Screen Shots of SDSS fly through module

Figure 1: “Flying by” various clusters of galaxies.

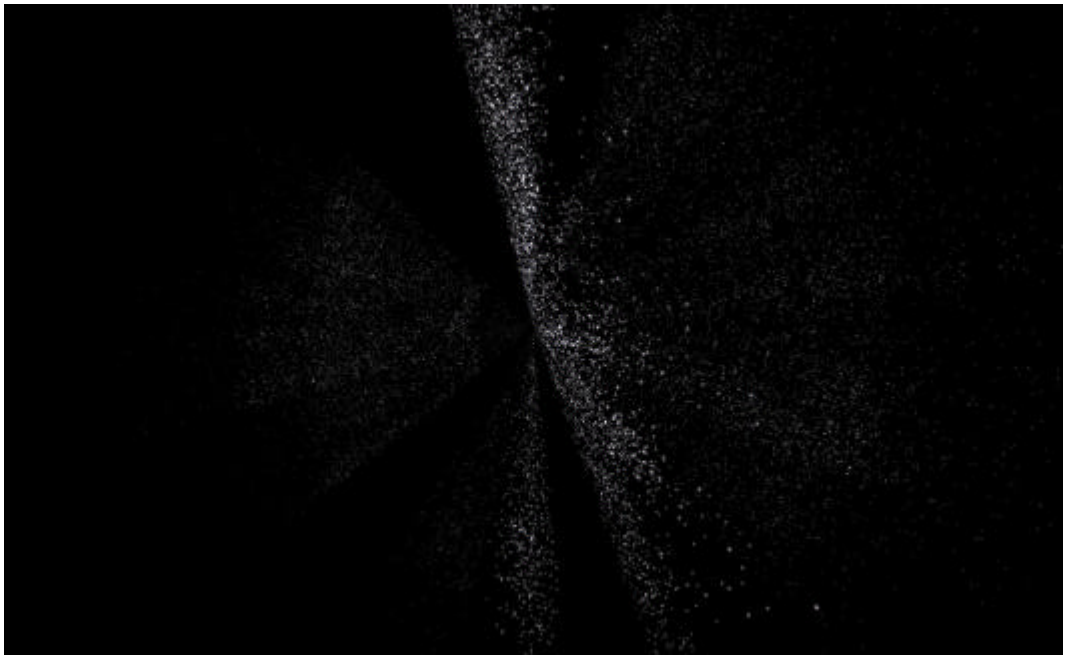

Figure 2: More distance view of the data, shows the fans they are collected in. Each point represents a galaxy in the universe.