**LOCAL ID**   |
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTHOR</td>
</tr>
<tr>
<td>TITLE</td>
</tr>
<tr>
<td>IMPRINT</td>
</tr>
<tr>
<td>ISBN</td>
</tr>
<tr>
<td>SERIES NOTE</td>
</tr>
</tbody>
</table>

**ARTICLE AUTHOR**  |
| Yu, Ka Chun; Champlin, David M.; Goldsworth, Deirdre A.; Reynolds, Robert G.; Dechesne,|
| ARTICLE TITLE   |
| Long-Term Audience Impacts of Live Fulldome Planetarium Lectures for Earth Science and |
| FORMAT         |
| EDITION        |
| VOLUME         |
| NUMBER         |
| DATE           |
| PAGES          |

**DECLARATION**  

**AUTHOR** Earth and space science : making connections in education and public outreach /
**ISBN** 9781583817667
**SERIES NOTE** Astronomical Society of the Pacific conference series ; v. 443.

**DECLARATION**  

**AUTHOR** Long-Term Audience Impacts of Live Fulldome Planetarium Lectures for Earth Science and
**IMPRINT** Book
**EDITION** 2011
**FORMAT** 2011
**PAGES** 187-
NOTICE - Warning Concerning Copyright Restrictions.

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of Copyright Law.
Long-Term Audience Impacts of Live Fulldome Planetarium Lectures for Earth Science and Global Change Education

Ka Chun Yu, David M. Champlin, Deirdre A. Goldsworth, Robert G. Raynolds, and Marieke Dechesne

Denver Museum of Nature & Science, 2001 Colorado Blvd, Denver, Colorado 80205, USA

Abstract. Digital Earth visualization technologies, from ArcGIS to Google Earth, have allowed for the integration of complex, disparate data sets to produce visually rich and compelling three-dimensional models of subsurface and surface resource distribution patterns. The rendering of these models allows the public to quickly understand complicated geospatial relationships that would otherwise take much longer to explain using traditional media. At the Denver Museum of Nature & Science (DMNS), we have used such visualization technologies, including real-time virtual reality software running in the immersive digital “fulldome” Gates Planetarium, to impact the community through topical policy presentations. DMNS public lectures have covered regional issues like water resources, as well as global topics such as earthquakes, tsunamis, and resource depletion. The Gates Planetarium allows an audience to have an immersive experience—similar to virtual reality “CAVE” environments found in academia—that would otherwise not be available to the general public. Public lectures in the dome allow audiences of over 100 people to comprehend dynamically changing geospatial datasets in an exciting and engaging fashion. Surveys and interviews show that these talks are effective in heightening visitor interest in the subjects weeks or months after the presentation. Many visitors take additional steps to learn more, while one was so inspired that she actively worked to bring the same programming to her children’s school. These preliminary findings suggest that fulldome real-time visualizations can have a substantial long-term impact on an audience’s engagement and interest in science topics.

The digital planetarium industry has grown explosively (Lantz 2006) with nearly 700 theaters in operation worldwide since the start of the decade (Neafus et al. 2005). For this expanding market, multiple vendors now sell astronomy simulation software which re-creates not just a traditional planetarium’s night sky, but also the rest of the known universe, including high fidelity views of the surface of the Earth. The geospatial features of the digital universe programs lag behind more well-known digital globes like Google Earth, mainly because the focus of planetariums remain away from the Earth’s surface. Yet digital planetariums offer their audiences unique benefits. Their status as theater spaces means large groups can listen to a lecture or participate in a discussion. They can have extremely high resolutions: the largest theaters have multiple edge-blended projectors which tile the domed display with tens of millions of pixels. They are also completely immersive: instead of viewing data representations through the narrow window of a computer monitor, the audience member is surrounded by the data inside the dome. A video fulldome planetarium may be the best way for a large audience to intuitively experience a digital globe. In this paper, we present the
impact that immersive digital Earth visualizations have had on audiences at the Denver Museum of Nature & Science (DMNS).

1. Digital Earth in the Gates Planetarium

The Gates Planetarium at DMNS is a uni-directional full-dome theater, with a dome tilt of 25°, and seating to accommodate 120 visitors (Neafus & Yu 2007). Renovations in 2007 have resulted in a current projection system consisting of six Projection Design F30 SXGA+ (1400 x 1050 resolution) projectors, which together tile the surface of the hemispherical dome with about nine million visible pixels. Visual content is provided by three separate visualization computer clusters which make up the imaging back-end.

DMNS’ Digital Earth lectures are made possible with SCISS AB’s real-time Univer view visualization platform. Although its primary function is to simulate a virtual universe, populated with catalogs of objects based on three-dimensional astrophysical databases, Univer can also generate highly realistic depictions of the surfaces of the Earth and other planets. Detailed high resolution satellite imagery are pulled from remote Web Map Service (WMS) servers and then mapped onto topography of the surface created from digital elevation maps. Using physics-based renderings of the atmosphere that include Rayleigh scattering, Univer can give a visually rich and realistic depiction of the Earth as viewed from the air as well as deep space.

Because loading externally created three-dimensional geological models was difficult in Univer, the Digital Earth talks focused not on such subsurface models, but instead on visible surface features that highlight geological principles. External WMS servers, including NASA’s Near Earth Observatory (NEO) and OnEarth were accessed to stream composite imagery from Landsat 7, the General Bathymetric Chart of the Oceans (GEBCO), and MODIS imagery from the Aqua and Terra satellites. Additional global geospatial datasets were loaded via Univer’s KML support feature.

Appearing at roughly bi-monthly intervals, the lectures started in 2008 and have continued to the present. The main topics have been primarily geology, geography, and global change, and their direct and indirect impacts on human populations. The itinerary for each 60+ minute long lecture was planned in advance, with stops at specific locales around the Earth designed to highlight points of the topic for that evening. However, because the tour in Univer was piloted in real-time, there was flexibility in how the talk was actually presented. Co-author and lecturer Raynolds could spend more or less time at each location, deviate from the original plan to take side jaunts, and take questions and requests from audience members.

2. Visitor Reactions

Analyses of the written visitor evaluations from the Digital Earth series is covered by Yu (2009). From the 28 October, 2008, lecture onwards, we also began to contact visitors over the phone for short oral interviews. One goal of these interviews would be to assess whether the planetarium presentations were able to increase a visitor’s interest in and motivation to learn more about the topics discussed.

Positive effects from informal museum programs may occur long after the original experience by a visitor (Anderson et al. 2007). In our attempts to begin to understand whether our live digital planetarium lectures can have such longer term effects, tele-
phone interviews were intentionally undertaken many weeks, and sometimes months, after the occurrence of the original lecture: roughly three weeks after the lecture for the attendees of the 28 October 2008 presentation; 8 weeks later for the 11 November 2008 presentation; 20 weeks for the 13 January 2009 presentation; 11 weeks for the 10 March 2009 presentation; and 6 months for the 7 July 2009 presentation.

Forty-six visitors constitute the total sample. The final group of adult participants contained a broad mix of ages and genders. Because we initially wanted an idea of how visitors who were unfamiliar with the fulldome technology would react to their experiences, we initially chose those who had stated on their written evaluations that they had not previously seen any live planetarium lectures that utilized Uniview. For the July 2009 group, however, we decided to remove that restriction, and hence were able to obtain feedback from those who returned and had a continuing interest for the lecture series. The interviewees were contacted by phone or email the week before to make sure the visitor still agreed to the interview and to set up a time and date to be contacted by telephone. Each interview lasted five to ten minutes.

2.1. Remembering the Lecture

As would be expected for the question, “What do you remember learning from the lecture?” answers from respondents who had seen the lecture recently were more detailed than those separated by months from the experience. Participants who attended the 28 October 2008 talk (on natural hazards such as volcanoes, earthquakes, and tsunamis) were interviewed 23 days after the talk and were able to remember specific locations that were flown over during the lecture:

Really one of the things that stands out that was incredibly useful to understand was the way Java and Sumatra were shown in an oblique perspective; and the volcanoes; and the way the islands were juxtaposed with the western coast of America. [The geology of the plate movements were contrasted between Indonesia and North America in the lecture.]

Volcanoes in many places on the Earth, [the] Pacific Tsunami, Africa, Alaska West coast from Canada down through United States, South America. [Interviewer: Anything else?] Cities, populations developed around areas vulnerable to having earthquakes, mountains that were going to go ‘pop goes the weasel.’ It was very frightening.

Even when the visitor could not explicitly remember individual place names, the content of the lecture could still be vivid:

Hmmm.... I can’t remember what country we were looking at, but I was surprised by the number of volcanoes. And with the amount of population around them. That was the major thing: that there were so many people living around those volcanoes.

As should be expected, the recollections for the presentations separated by a month or more were less distinct and more vague. Sometimes the interviewee could remember some details about the general topic (in these cases about different challenges people around the world have in finding fresh water, faults and earthquakes, and rivers):

I think I remember it was a tour of Africa and the features; what caused the features, like climate change, how it affects tributaries, the water supply and the ecosystem. [59 days after lecture]
Information about the tectonic plates and the different names for different types of geological movement–those were the basic points. And that he decided to tell the story of highest [and] lowest points of each of the continents. [81 days after lecture]

I remember we... followed the Amazon through the rainforest, through Brazil and how it came out of the highlands. ... We also looked at the rivers over the Nile, the Blue Nile, and the White Nile, and how those rivers came together. [6 months after lecture]

Even when the main subject or the details of the talk were not recalled, the visitors tend to have strong impressions of the event based on what they had seen (as opposed to any specific piece of information that they had heard in the talk):

I think what most impressed me was that it gave me a sense of connectedness and breadth of geography that we saw in our fly-over, particularly of North Africa. To get a sense of the expanse was more important than any one bit of info. The topics were interesting and helpful and the identifications too, but the breadth [was most important]. Got a real visual sense of the geography; of where it was desert or where there were populations.

2.2. Visitor Interest in Lecture Topics

We wanted to gauge visitor interest in the topics discussed in the talks: “Did you become more interested in any of the topics covered in the lecture as a result of the talk?” For visitors who did become more interested, we also wanted to know, “Have you done anything to learn more about these topics since the lecture?” Those visitors who tried to learn more about a topic did so with the resources available to them. This included hardcopy atlases and encyclopedias, but also Google Earth and online resources:

Yes, I came home and looked over all the National Geographic atlases to see the places that were talked about. Yes, I actually started reading a bunch of earth science books–like encyclopedias and things–that we have at home.

I’m a Google Earth fanatic ... revisited those places from different perspectives on Google Earth. Had conversations with other friends to let them know about the show ... invited people to the shows. We [he and a friend who also attended] reflected on it as we climbed Mt. Democrat day before the election. While atop Republican peak, looking at the landscape, having a good view, reflected back on that evening and talked about the points the geologist talked about.

Online, [Google] ... I’m interested in active [volcanoes] in Hawaii and the possibility of the super volcano in Yellowstone, Wyoming. I’m just fascinated by Yellowstone. I didn’t know that there was the possibility of volcanoes there.

In one case, not only did the talk leave a strong impression on a visitor based on how much she remembered (when interviewed 59 days after the talk), but it also fostered a personal behavioral change:
The Sahara—how it had changed and the desertification. Iran and Iraq are supposed to be lush, and you could see the canals that they used [for transport] and now they are no longer able to use them; they’re silted in and the soil going out—that’s happening now because of the way the we’re killing the soil . . . the method of farming, the soil is turned over, the wind takes it away. We do more and more to get a crop and do more and more damage. It’s defeating. . . . Actually, we’re recycling more.

However, the visitor that we have discovered with arguably the most impact from the Digital Earth lectures was Beth (not her real name). After seeing multiple lectures, she later signed up to a DMNS-sponsored geology field trip in summer 2009 by canoe that was also led by lecturer Raynolds. After getting to know Raynolds, Beth invited him to lecture to her children’s elementary school classes. This was followed up by organizing two field trips for classes at the school to visit the Gates Planetarium during the school day and experience special daytime Digital Earth lectures hosted by the co-authors. Author Yu did not even learn that the inspiration to bring Digital Earth style content to her children’s elementary school was rooted in past evening Digital Earth presentations until Beth was randomly selected to be interviewed, and she revealed all of this information to the interviewer.

2.3. Comparisons to Google Earth

The attendees of the July 2009 lecture were asked a set of additional questions about Google Earth in their interviews. Google Earth is likely the one application the audience would be familiar with which is similar what they had seen in the dome. Given that Google Earth can be freely downloaded and installed on a computer and experienced in the comfort of one’s home, how does it compare to a planetarium lecture that requires a fee to attend, as well as time and effort to travel to?

Of the ten visitors asked about Google Earth, all responded that they were familiar with the software. When asked, “What do you like about the planetarium presentation better than Google Earth,” the following response was typical:

[Having] a guided tour, with a theme, by a knowledgeable person who could kind of help us interpret what we were seeing, was able to take us from one side of the planet to the other . . . So he was able to make it more informative and understandable than me just looking at Google Earth by myself.

For the visitors, a guided tour like Digital Earth was universally seen as being more educationally valuable—more “informative and understandable”—than attempting to explore Google Earth by themselves. When they were asked, “What do you like about Google Earth better,” a typical reply was that Google Earth had better imagery (“I was expecting some more high-resolution pictures on Digital Earth because of my experience with Google”), or its ability to handle current events (“Google Earth does wonderful work with maps on the news, and you know, like, in the event like the Haiti earthquake, Google Earth just had wonderful information.”)

3. Conclusions and Future Work

The telephone interviews tend to affirm the potent combination of fulldome planetariums and digital globe software for public education. Self-reporting by visitors on the
written evaluations showed that their interest in the topics was increased significantly after the lecture compared to their interest before (Yu 2009). Interviews revealed that attendees of the lectures did remember specific details of the talk. For instance, five (out of nine) participants could cite specific locales visited and facts presented more than three weeks after the 28 October 2008 lecture. The number of participants who tried to actively learn more after the lecture was in the minority, but significant (20 out of 46 interviewed, or 43%). However, these few participants were still engaged enough by the lectures that they sought out further information of their volition and without being encouraged to by the speaker. One participant was affected enough to engage in changes in her personal behavior. Answers to follow-up questions about the value of the fulldome planetarium tended to re-iterate the responses seen from the written evaluations: the large immersive display of the venue added value to the presentation. Based on the substantial visitor survey data reviewed for this paper (300 written evaluations and 46 follow-up oral interviews), live lectures with digital globe software in a digital planetarium appear to be powerful tools for teaching and engaging the public about complex topics that involve a global focus.

Topics related to climate change can be controversial for U.S. audiences, since there is a perception among Americans that global warming is still controversial among climate researchers (Krosnick et al. 2006). We see this reflected in the negative comments seen in two out of the 37 total written comments in the evaluations for a lecture that touched on this topic (“...a bit less politics;” “the political bias was overwhelming”). It is our intent in the future to explore how digital fulldome planetariums can be used to engage audiences in politically charged topics like climate and global change. Other informal education experiences have been shown to not only motivate people to learn more about science, but to lead to long-term attitudinal changes (National Research Council 2002). Whether large-scale immersive visualizations of digital globe data in digital planetariums can affect similar modifications to visitor attitudes and behaviors with regards to climate change is as yet an unanswered question.

Acknowledgments. We thank Julia Spaulding and Margaret Hester from DMNS’ Adult Programs division for help with distributing and collating the written evaluations; Greg Mancari for assistance with the interviews; and Katherine Honda for library research.

References

Lantz, E. 2006, LF Examiner, 9, 12
Neafus, D., & Yu, K.C. 2007, Planetarian, 26, 6
Yu, K.C. 2009, Planetarian, 36, 6