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Creating Full-Dome Experiences in the New Digital Planetarium

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Content Challenge

The last decade has brought an explosion of image and other databases describing Earth and space systems. Digital libraries archive and provide structure for the information, yet the connection with the public and schools remains fragmentary. False color images and media sound bites have little impact on an audience that remains unsure of even what causes the seasons (Schneps & Sadler 1988). Standard textbooks and even well designed videos have been shown ineffective in changing deeply rooted misconceptions (Anderson 1994, Finney 2002).

Meanwhile dynamic processes continually reshape the universe, but at scales that are challenging for humans to visualize. Either the change occurs too slowly, too infrequently, or its effect is too extensive for direct observation. Many changes are beyond the scope of direct experience because they occurred long ago, will happen in the distant future, or are only observable outside the visible spectrum. Finally there are other changes that are best understood when the situation is viewed from a vantage point that is not available to most humans – from inside a hurricane or in space watching sunlight angles change during the year. Traditionally learners have been forced to create their own mental images to understand situations that cannot be viewed directly. In many instances the result has been a misconception, which takes on a reality of its own. Baseline research described below indicates that learners who are given the opportunity to view changes and to conceptualize cause and effect from their own direct observations are more likely to form correct conceptions as is documented by the advantages attributed to hands-on instruction and laboratory experiences.

It will require more than captions on photographs to make Earth and space science discoveries meaningful and engaging. Audiences need to "experience the data," seeing with their own eyes the effects of gradual and dramatic changes. Creating these experiences requires a new kind of meta data – volumetric image bases in which the public can explore and experience the universe in motion – and a large-format playback system – a domed digital theater.

Opportunity

In the last five years, a revolution has occurred as planetariums transform into these digital theaters. No longer are planetariums confined to a starfield and pointer, plus obsolete slide projectors and laser disk players. Modern planetariums are filling their domes with pixels – creating full-dome still and moving images that put audiences inside the action – from nebulas and solar storms to changes on Earth ranging from seasonal variations to plate tectonic motions. Hubble photos are no longer flat images hanging in front of a fixed starfield. Now audiences fly through stellar birth clouds like the Orion Nebula and along the galaxy's spiral arms, journeys enabled by computer modeling of these three-dimensional structures. As an Earth science example, in a show called *Force 5*, audiences are transported inside a hurricane, tornado and, as an example of space weather, a coronal mass ejection from the Sun – with the action happening all around them.

This full-dome color moving digital imagery is created in a three-dimensional rendering package (such as 3D Studio Max, Maya, or Lightwave). Five virtual cameras (facing ahead, up, left, right and behind) capture 30 frames each second. Frames are combined using proprietary software to create "dome masters" – hemispheric polar views. In a small theater, a single fisheye lens projects the dome masters on the dome. For larger theaters, multiple projectors are required and the dome masters are sliced and edge-blended with a separate computer feeding each video projector.

Market Reach

As of this publication, there are over 25 large format digital theaters (most in planetariums) in the United States and more than 10 in other countries. Over 30 shows have been produced, either largely or totally full-dome high-resolution digital video. Creating content is expensive – perhaps a third to half-million dollars per 20-25 minute show. However, this is a tenth of the cost of an IMAX production. Several producers of large-format volumetric material are now actively seeking both content partners and funding partners. For example, the *Force 5* show was funded 67% by Earth Science and 33% by the Office of Space Science with in-kind matching funds. A commercial movie distributor is now making the show available to the domed digital theater community. As more shows are being produced, the challenge is to make the shows entertaining, engaging, and educational. Audiences of all ages will learn to expect new, exciting, and cutting-edge science – to be wowed and even inspired by their digital theater experience.

The number of digital theaters is also expanding significantly with last year's introduction of small digital theater projectors by three different companies and with this year's introduction of the portable digital theater by the authors. With these new systems, digital theaters can be installed in any small fixed dome and even in inflatable portable planetariums. Portable dome theaters can reach populations far from urban areas where IMAX theaters and major planetariums are found. The most expensive large-format digital theater production can now

be shown in the smallest portable planetarium. Unlike IMAX, the domed digital theater is scalable.

Educational Merit

In collaboration with the Houston Independent School District, Dr. Will Weber of the University of Houston undertook an independent formal research study of the fourth grade planetarium experience since the addition of the SkyVision immersive digital projection system at the Houston Museum of Natural Science. One week was selected at random in March 1999, and all HISD schools scheduled for the planetarium that week became participants in the study. The eight schools represented a population that was 85% economically disadvantaged, 66% African-American, 33% Hispanic, and 1% white. From these schools 438 students completed pre and post written multiple choice assessments. For the treatment, students received an astronomy lesson from a visiting teacher and a 45-minute planetarium program. Most classroom teachers did not provide additional astronomy instruction in the period between the classroom visit and the planetarium experience. The t-test for paired samples yielded a t (19.39) that was statistically significant (p <0.001). In addition, the analysis yielded an effect size (+1.27) that suggests that the gains made by students were both statistically significant and educationally meaningful. In a post hoc item analysis of the Planetarium instrument, researchers identified three subscales of seven items, each focusing on the educational experience of the students. Scale A represents concepts presented through words and non-moving flat projections. Scale B represents concepts presented primarily through moving videos, and scale C represents concepts introduced through immersive video experiences. Table 1 shows the results.

Scale	Presentation	Percent of Questions Answered Correctly		
		Pretest	Posttest	Gain
Scale A	words and slides	43.07%	54.60%	11.53%
Scale B	standard video	31.28%	49.02%	17.74%
Scale C	immersive full-dome video	33.22%	57.21%	23.99%

Table 1. Comparison of student gains

All three presentation techniques were mixed throughout the planetarium program and used by the same presenter. The only differences were the difficulty of the concepts, the students' initial knowledge, and the presentation format. These results strongly suggest that students achieve mastery of more difficult concepts when they can discover behaviors and relationships by observing the concept in action. Standard television video seems to be more effective than still images and immersive video is more effective that standard video. These results may also speak to the level of student attention created by immersive experiences.

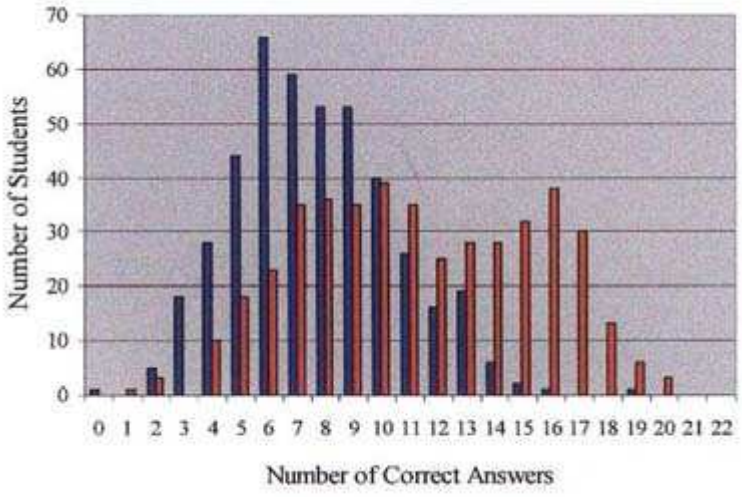

Figure 1. Comparison of correct student answers before and after the planetarium experience

Further analysis addressed information gathered through the instrument's demographic and attitudinal questions. Achievement gains were not related to the sex of the students, their interest in science or their prior experiences in the Museum. Students who indicated that they were good in science did perform slightly better than those who did not. It was also determined that the planetarium experience causes an increase in the number of students who expressed an interest in a science career and who wanted to read books about space.

In Summary

Immersive Earth and space science experiences are now possible with volumetric rendering of dynamic situations and projecting of scenes in immersive digital theaters. These new digital theaters are showing products more immersive than IMAX experiences, but for less than a tenth of the production costs and with less physical distortion of the images. These digital theaters are also well equipped to handle digital databases and can modify programs to include dynamic real-time imagery in a way that is not possible in a linear IMAX theater format. These large-format digital theaters can also deliver a range of content products, not just the astronomy topics normally associated with a planetarium. The theaters are also self-supporting, but, like IMAX theaters, need financial assistance in the development of content. Models established in the last two years indicate that once shows are developed, licensing fees and spin-off products will generate funds for the production of additional shows or clips. In summary, these theaters have the public and school audiences and scientists have the volumetric models

and databases. It's an ideal recipe for public outreach with a proven educational effect.

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