

The Worldviews Network: Digital Earth for Ecological and Resilience Education

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Abstract. The Worldviews Network uses Digital Earth technology to engage public audiences across the United States on issues of global environmental change at a bioregional level. Worldviews content uses digital planetarium technology to immerse audiences in tours of Earth and space, following storylines that emphasize the interplay of physical and biological systems. Museum and planetarium staff join the Worldviews Network team and external advisers to produce programs that span cosmic, global, and bioregional scales, capitalizing on museum environments to engage in science-based discussions. Each program employs a “See, Know, Do” transformative learning model. Dialogues and further interaction with audiences highlight ways in which they can remain engaged in the bioregional topic.

1. Introduction

The original purpose of Digital Earth was to make sense of the enormous amount of geospatially-referenced data available today about Earth’s physical, biological, and social systems [1,2]. Although there is discussion about how much progress has been made in realizing this original vision, most has focused on technical goals such as infrastructure for spatial databases, geobrowser tools, geospatial libraries, and support for simulation features [4-6]. Less work has focused on dealing with the capacity of Digital Earth tools for solving specific problems, such as the opportunity to clarify the context for interconnected global challenges. For example, mitigating the effects of global climate change will have to move beyond simply tabulating emissions, to creating a “shared understanding of the problem and possible solutions” [7]. In this paper, we describe the Worldviews Network, a project that uses informal science institutions (e.g., science centers and museums) and Digital Earth technologies now found in many digital planetariums to engage members of the public in dialogues about resilience and

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sustainability using a bioregional perspective. We collected evaluation data from attendees following audience engagements and have initial findings on public response to these presentations.

2. Planetariums for scaling up Digital Earth

Planetarium simulation software systems are increasingly adopting features of dedicated geobrowsers, such as Google Earth. A planetarium's intrinsic geometry allows it to present views of Earth via an immersive display that can captivate audience members, who often describe presentations more as an "experience" than a lecture [8]. Furthermore, planetarium presentations often adopt a navigational paradigm of seamless flight from one place or time to another within the virtual simulation [9]. Using "Powers of Ten" transitions through exponential changes in scale, complex relationships and interactions between Earth's cosmic environment and the planetary biosphere become intuitively linked—from whole Earth to regional perspectives. Audience members have self-reported such nesting of data and concepts as an important way in which they understand local phenomena in the context of broader global frames of reference [10]. Visualizations of phenomena in spectral bands beyond the range of unaided human perception can provide insights into how scientific observations reveal otherwise imperceptible ecological interactions. These capabilities provide a necessary context within which to introduce concepts of "planetary boundaries" [11]: how ecosystem services are often taken for granted and, more urgently, have become destabilized due to modern human activities.

Most digital planetariums also serve as theater spaces that accommodate audiences for lectures. The dome projection systems can have extremely high resolutions, with the largest theaters using multiple edge-blended projectors tiling the display with tens of millions of pixels. These enable large-scale visualizations and animations of time-series geospatial data, similar to R. Buckminster Fuller's vision of a *Geoscope* [1]. Domes are also highly immersive, echoing Al Gore's original vision of a Digital Earth being experienced through virtual reality [2]. A realistic depiction of Earth in a dome theater may trigger the "Overview Effect," an affective response and shift in perspective reported by astronauts after viewing Earth from orbit [12]. A modern digital planetarium may provide the most effective environment for large audiences to experience a digital globe intuitively and viscerally.

3. The Worldviews Network

Taking advantage of the capabilities of digital dome theaters, the Denver Museum of Nature & Science (DMNS) in Denver, Colorado, the California Academy of Sciences (Academy) in San Francisco, NOVA/WGBH in Boston, design/engineering firm The Elumenati in Asheville, North Carolina, and affiliates of the National Oceanic and Atmospheric Administration (NOAA) have joined to form the Worldviews Network (www.worldviews.net) through a three-year Environmental Literacy Grant from NOAA's Office of Education. The network's mission is to place Earth within its cosmic context to encourage participants to explore connections between social and ecological issues in their backyards. The network launched with informal science institution (ISI) partners across the United States, including the American Museum of Natural History (AMNH), New York, New York; the Perot Museum of Nature and Science, Dallas, Texas; the Journey Museum, Rapid City, South Dakota; the Bell Museum of Natural History, Minneapolis, Minnesota; the University of Michigan Natural History Museum, Ann Arbor, Michigan; and the National Environmental Modeling and Analysis Center (NEMAC), Asheville, North Carolina.

3.1. Bioregional Community Dialogue strategies

The project links ISIs, researchers, and community-based organizations to create interactive planetarium programs for promoting ecological literacy through "Bioregional Community Dialogues" (BCDs). Using online collaboration tools and teleconference calls, the Worldviews Network team and partners identify a global change issue that has local impacts and then build a coalition of highly motivated individuals involved in that issue. This blended internal/external team co-constructs a narrative that spans cosmic, global, and local perspectives. Content layers from a wide range of observed and modeled datasets are created to tell stories about Earth's coupled human-natural systems.

Delivering this storyline, the team connects its own target audience with opportunities to engage with issues at the nexus of science and society. We have adopted a number of specific strategies in designing BCDs, outlined below.

3.1.1. See, Know, Do. We use a “See, Know, Do” framework to design the events [3]. “Seeing” involves the creation, presentation, and experience of viewing immersive visualizations within the planetarium to engage visitors’ visual and spatial intelligence. For “Knowing,” the narratives are constructed to help visitors understand the web of physical-ecological-social systems that interact on Earth. The “Doing” component emerges from interaction among participants: for example, researchers and non-governmental organizations help audience members conceive of their own relationship to the highlighted issue and ways they may remain involved in systemically addressing problems the audience identifies.

3.1.2. Maximizing visual impact. Immersive dome theaters require presentation styles distinct from a flat screen. Instead of merely viewing images through a frame, viewers feel that what they see on-screen is happening to them. Since such immersion can limit options for camera movements and editing [13], we follow tested and effective techniques for structuring immersive storytelling. We also follow best practices based on audience responses to data visualizations [14-19].

3.1.3. Storytelling (local to global). Educators face challenges in assisting individuals and communities to establish personal connections to complex issues such as climate change. The magnitude of climate change, its perceived remoteness, and the apparent inadequacy of an individual’s response have been identified as obstacles to pro-environmental behavior [19,20]. The adage “think globally, act locally” suggests the scale at which most of us can become actively engaged. Our existing Worldviews Network partners have developed stories by selecting a local issue relevant to their own communities and created a narrative that makes connections from local to systemic issues, and regional to continental to global scales. Grounding environmental education within a local perspective can help to “develop a sensitivity to and knowledge of the bioregion in which one is living” [21]. Addressing ecological interactions from this perspective can connect individuals to potentially abstract issues both cognitively and affectively. Perhaps most importantly, it can help participants more readily see ways in which their own decisions and actions can impact Earth systems.

3.1.4. Framing global environmental change. Our presentations demonstrate the complex linkages between Earth’s physical and biological systems and their relationship to human health, agriculture, infrastructure, water resources, and energy. We have focused on critical thresholds, such as freshwater use, biodiversity loss, land use change, and anthropogenic changes to the nitrogen and phosphorus cycles. We have been guided by environmental literacy principle documents [22-25] to help ISIs and their audiences understand that humans drive current trends in coupled human-natural systems—and that humans could choose to play an important role in reversing these trends.

3.1.5. Resilience of coupled human-natural systems. Given the scale and scope of anthropogenic global changes, we have found it essential to provide inspiring examples of how small groups and individuals address complex challenges using the theme of resilience of human and natural communities. Humanity has entered a time in which anthropogenically-induced global change is the new normal. Resilient communities can anticipate and prepare for change, can recognize the need to adapt to new conditions, and through intentional design, can absorb and respond proactively to change. We educate our ISI collaborators about resilience science practices by highlighting examples, such as those catalogued within the Buckminster Fuller Institute’s Idea Index (www.ideaindex.org). We demonstrate how organizations around the world are developing and implementing innovative strategies to comprehensively address humanity’s most pressing problems. Such examples provide a

positive heuristic for audiences to gravitate toward as they deepen their awareness of the complexity of the challenges we face on the planet today.

3.1.6. Traditional and indigenous knowledge. Traditional ecological knowledge, derived from situational and place-based experiences of indigenous cultures over many generations, plays a critical role in creating resilient land- and seascapes. Indigenous knowledge can offer an improved understanding of historical baselines and new ecological perspectives, provide models for sustainable resource management, and inform conservation planning and environmental assessment [26]. We have incorporated traditional ecological knowledge with scientific knowledge in two of our BCD events.

3.1.7. Involving local external experts as advisors. We identify scientific advisors at both local and national levels to augment Worldviews Network team knowledge of the research field. Additionally, ISI partners are encouraged to find local experts, including researchers and representatives from businesses, educational groups, non-profit organizations, NGOs, and community-based organizations with expertise on the chosen issue. In previous BCDs, these external partners typically co-develop narratives, assist with identifying content assets, review scripts and check for accuracy, and sometimes participate in the live public presentations, by describing solutions implemented at the local level.

4. Encouraging Dialogue

Given the varying sizes of venues, events have served dozens to hundreds of people at a given time. External groups provide unique viewpoints to propel discussions and lend expert credibility for audience members. For example, after the DMNS “A Global Water Story” dome presentation, 40 audience members moved from the Gates Planetarium to a classroom where the director of a Colorado water education organization led a group discussion. Participants shared perspectives with one another about what they had heard, discussed how it related to their own work and lives, and conferred on strategies for addressing water issues. Such dialogues help audiences remain engaged with network partners and the issues they highlight long after each event.

A private group of over 200 persons, representing policy makers, local tribes, NGOs, educators, and scientists attended our BCD at the California Academy of Sciences entitled “Valley Oaks: An Ecological Journey Through Time,” an exploration of historical, ecological relationships between people and one of California’s iconic species, Valley Oaks. After the presentation, the Worldviews Network team moderated a dialogue among stakeholders to determine strategies for “re-oaking” throughout a range of urban and suburban landscapes in Northern California.

5. Preliminary Evaluation

Written questionnaire data have been collected from 391 audience members at five different BCD events at four ISIs (AMNH, $N=50$; Academy, $N=124$ and $N=113$; DMNS, $N=67$; RENCI, $N=37$) that took place from 2011 to 2013. Participants filled out the questionnaires after the dome presentation (and before any additional engagement opportunities). The questionnaire was modified from an interview instrument developed for NOAA’s *Science On a Sphere*[®] programs, where visualizations are projected onto a sphere rather than a dome [27]. The intent of the BCDs was not only to increase audience understanding of ecology, environmental, and resilience issues, but also to introduce audience members to locally-relevant solutions to local and regional problems. Thus, the goals for each BCD event matched the “See, Know, Do” model:

- Increase awareness of core ecological content (environmental literacy)
- Understand new relationship(s) between interconnected social-ecological problems within the context of larger systems
- Have a positive affective (emotional) response—awe, inspiration, amazement
- Identify opportunities/roles that they can engage in or initiate solutions
- Gain awareness of a community resource working to address the identified problem

5.1. Evaluation Results

5.1.1. Knowledge/understanding outcomes. Overall, responses showed strong achievement of goals for the audience to learn about ecological issues. Approximately half of respondents across events reported learning something new about Earth ecology. Others described an enhanced understanding about relationships between humans and Earth systems—from human-influenced ecological changes to the relationships around human use of natural systems, each referenced by about one-quarter of respondents. The data also offered some indication of increased awareness about addressing ecological challenges, although it was not a common takeaway by attendees. This may reflect variation in the degree to which solution-oriented content was specifically addressed during an event (as opposed to a focus on ecological concepts and data). In a different measure, audience members selected these three statements most frequently as reflecting what they got out of their experience, highlighting connection with the core principles of the Worldviews Network:

- Thinking about complex interrelationships in Earth systems
- Visualizing concepts of time and scale
- Feeling a sense of how small Earth is in the universe.

5.1.2. Affective outcomes. Throughout the dataset, there was a stream of comments and responses that highlighted the potential of BCD events for achieving an affective outcome, although such responses were not always dominant in data collected to date. Specifically:

- 10% of attendees indicated the dome presentation helped them understand content through its promotion of an affective response, primarily expressed as *inspiration*, *caring*, and *personal relationship*.
- When asked to pick statements that aligned with their reaction to the event, fewer audience members chose the emotion-based statements. However, of those who did, a higher proportion tended to rank them as their strongest experience than respondents selecting other non-affective statements:
 - Feeling the need to take care of Earth
 - Feeling a sense of the sacred in regards to Earth
 - Amazement at the beauty of what was shown.

5.1.3. Intent to increase stewardship behavior. Relative to the other outcomes, fewer participants reported gained awareness of engagement opportunities, and even fewer who mentioned specific ways in which they could or intended to engage in solution-focused activities. As this was not always a key focus of every presentation, this finding was not entirely surprising.

6. Discussion

The Worldviews Network has pioneered a novel use of immersive Digital Earth technology for connecting public audiences with ecological and global change issues at multiple scales. Evaluation results have pointed to the value of its combination of technological and pedagogical approaches, combined with its ecological content, to create audience engagement. Questionnaires showed that the vast majority (81%) of respondents indicated that the Digital Earth dome presentation helped change their understanding of the content, with most citing that it gave them new perspective, helped them visualize, and generally helped them understand content. When describing what they liked most about the presentation, respondents highlighted both the pedagogical approaches and technological tools about equally (around 40% of those responding); with aspects of the ecological content receiving a smaller proportion of comments (17%). Similarly, comments about what made the presentation easy to understand tended to reference presentation style or visuals and technology. The positive responses to these fundamental aspects of the Worldviews Network presentation model—combining immersive visualizations with live presentations—are identified as relevant by all audience members. These and previously discussed results show that Digital Earth tools can provide a powerful way to educate the

public about complex Earth systems, to help them understand bioregional effects of global environmental change, and in some participants, to trigger a strong affective response. Engendering such reactions from the public will become more important as we move from simply documenting global change to the challenge of designing adaptive solutions.

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