Space Weather Outreach: An Informal Education Perspective

P.B. Dusenbery, J. B. Harold, B. McLain, and L. Curtis
Space Science Institute
4750 Walnut Street
Suite 205
Boulder, CO 80301

Abstract

Informal science education institutions, such as science centers, play an important role in science education. They serve millions of people, including students and teachers. Within the last decade, many have tried to improve the public's understanding of science and scientific research through informal education projects. The recent success of several space weather-related missions and research programs and the launch of the International Heliophysical Year (IHY) research and education programs make this an ideal time to inform the public about the importance and relevance of space weather to our understanding of heliophysical science. Communication efforts associated with space weather both benefit and are compromised by analogies to terrestrial weather. This paper summarizes the benefits and challenges of the terrestrial weather analogy using two exhibit evaluation studies. The paper also describes three components of the Space Science Institute's *Space Weather Outreach Program* – Space Weather Center Website, Educator Workshops, and Small Exhibits – and how they can help to achieve the education goals of IHY.

1. Introduction: The Changing World of Informal Science Education

People don't stop learning once they leave the classroom. Informal education institutions—such as museums, zoos, nature parks, planetariums, and science centers—are playing an increasingly important role in America's overall education system. They provide children and adults with opportunities to learn by doing. The Association of Science-Technology Centers (ASTC) reports that in 2005 over 96 million people visited its member institutions worldwide (ASTC, 2005). With the popularity of these institutions, it's not surprising that the line between formal and informal education is blurring. Each year, science centers offer more programs designed specifically for school children and teachers. ASTC estimates that in 2005 its members served over 24 million school children (ASTC, 2005). Many education researchers are exploring how people learn in free-choice, informal institutions and publishing their findings (e.g., Hein, 1998; Falk and Dierking, 2000). As an indication of the importance of informal education research, the National Science Foundation's (NSF's) Informal Science Education (ISE) program now requires that its funded projects include research and/or evaluation components that will produce a lasting impact on the field of informal science education. ISE seeks to contribute to the development of a diverse, internationally competitive and globally-engaged workforce of scientists, engineers, and technicians, in addition to informed citizens.

Despite the popularity of science centers and other informal learning environments, there is still a dichotomy between interest in science and knowledge of science. NSF's recently published *Science and Engineering Indicators* (NSB, 2006) shows that most Americans recognize the benefits of science and technology. Another interesting (and possibly surprising) statistic is that Americans in general have a more favorable attitude about science than do people in other developed countries. But this *interest* in science and technology does not necessarily correlate to an *understanding* of science, as is evident by the wealth of misconceptions people have about the world in which they live. For example, many college-educated adults do not know what causes seasons and many cannot light a light bulb with a battery and a wire (*A Private Universe*, 1987; *Minds of Our Own*, 1997). Within the last decade, many have tried to improve the public's understanding of science and scientific research (Chittenden et al., 2004). But their success has been mixed.

Against this backdrop, many informal educators have been re-examining the role that free-choice learning institutions, such as science centers, should play in their communities. Should they focus only on serving school children or should they also help adults understand the science behind increasingly complex public policy issues, such as climate change? Ann Mintz has written a thought-provoking article that explores the challenges facing science centers and offers some insights on how to face them (Mintz, 2005). Some centers have successfully implemented cutting-edge science and technology programs, such as the current science initiatives at the Maryland Science Center, the Boston Museum of Science, and the Science Museum of Minnesota. Another approach has been the Café Scientifique movement that started in Europe and has taken root in the U.S. and other countries (West, 2005). The concept behind this movement is simple. It is an informal forum for discussing and debating science issues outside a traditional academic context. The Café Scientifique approach offers programs for adult audiences rather than families with young children. Science centers everywhere are re-thinking their identities and missions. Though there is no single approach that will work for all museums, one common theme seems to be emerging: science centers must become vital to their communities and include a more diverse audience in their programs (Chesebrough, 2005).

2. Space Weather Research and Outreach

In the 21st century, developed countries around the world depend on space-based operations for communications, navigation, weather reporting, treaty monitoring, scientific observation, and other critical activities. As a result, we are more susceptible than ever before to dynamic processes in our Sun-Earth environment. Severe space weather events, such as bursts of radiation and magnetic storms caused by the Sun's coronal mass ejections (CMEs), could impact satellite operations, harm astronauts, and result in power outages on Earth (Carlowicz and Lopez, 2002). In our technology-dependent world, the ability to predict which CMEs will reach us and when has become increasingly important (Poppe and Jorden, 2006).

Scientists from around the world now have access to the most powerful array of ground facilities and spacecraft ever assembled for studying the space environment. Sensitive telescopes focus on the Sun's many layers, while spacecraft measure the plasma and magnetic fields of our geospace environment. A web of ground stations records the complex interaction between the Sun and our terrestrial environment, and computer models provide improved forecasting of space weather. The multi-agency National Space Weather Program (NSWP, 2000) encompasses the efforts of the U.S. research scientists who are studying Sun-Earth connections and attempting to provide timely, accurate, and reliable space environment observations and forecasts.

The recent success of several space weather-related missions and research programs makes this an ideal time to inform the public about the importance and value of space weather research. Even before the publicity surrounding the Halloween Storms of 2003, the public demonstrated an interest in space physics and aeronomy topics, as evidenced by the success of projects such as the Space Science Institute's (SSI's) *Electric Space* exhibition (Korn, 1992, Korn, 1997). Space weather offers a particularly compelling topic for both the Current Science and Café Scientifique programs mentioned above due to its visual appeal and the frequency of newsworthy events. It is of particular interest for museums, science centers, and planetaria because:

- Space weather impacts people's lives, both on the ground and in space.
- Space weather is a hot topic, even with the Sun near solar minimum.
- The general public is fascinated by space-related subjects.

Other recent space weather education projects include *SolarMax* (an IMAX film), cable TV documentaries (e.g. *Perfect Disasters: Solar Storm* by the Discovery Channel), and a number of teacher workshops and events, such as NASA's Sun-Earth Connection Education Forum's Sun-Earth Day project (which provides outreach materials to a number of informal institutions) (http://sunearthday.nasa.gov). Another indicator that space weather has had an educational impact is the role it plays in professional societies. For example, the American Geophysical Union (AGU) has included a growing number of education sessions on space weather at its meetings. AGU's Space Physics & Aeronomy Education Committee has brought together many researchers and educators in mutually beneficial partnerships. In 2007/2008, the International Heliophysical Year (IHY) will bring together scientists and educators from around the world to explore fundamental heliophysical processes and continue the legacy of the 50th anniversary of the International Geophysical Year (United Nations, 2001). The two primary objectives of IHY's education program are to inspire the next generation of space scientists and spread the knowledge of our Solar System to the people of the world. Space weather can provide a compelling hook to achieve the first objective and the wealth of good space weather education resources can help achieve the second.

3. The Space Weather Outreach Program

For the last seven years, P. Dusenbery has led an effort at SSI to bring space weather research and concepts to the American public. The project is called the Space Weather Outreach Program (SWOP) and is funded by NSF and NASA. As part of this multi-faceted science communication effort, SSI produced the *Space Weather Center* traveling exhibition (Koke, 2000; Russell, 2000; Dusenbery and Mayo, 2004; Dusenbery and Morrow, 2004; and Morrow et al., 2004) in collaboration with scientists at NASA's Goddard Space Flight Center (GSFC). After a successful three-year tour, the *Space Weather Center* is now on permanent display at GSFC. In conjunction with the exhibition, SSI conducted space weather workshops for museum educators and middle school teachers across the country; participated in Sun-Earth Day activities; and created the *Space Weather Center* (SWC) website (www.spaceweathercenter.org), which continues to evolve into one of the most-visited space weather websites and top Google hits, with new updates and innovations every year. SSI also developed the *Family Guide to the Sun* for informal learning environments (e.g. museums and community-based programs) (Morrow et al., 2004). The guide can be downloaded from the SWC website. Recently, SSI formed the *Four Corners Education Alliance* for formal and informal educators who are interested in space science topics and reach the underserved Native, Hispanic and rural audiences in the Southwest United States. And finally, SSI collaborated with the Fiske Planetarium at the University of Colorado and other partners to create a new nationally distributed planetarium show called *Space Storm.*

The components of the SWOP program are aligned with national science and math education standards (NRC, 1996; NCTM, 2000), and follow the professional development framework outlined by Loucks-Horsley (1998) and other educators. The primary audience for most SWOP projects was chosen to be upper elementary through middle-school students and their families because this is a critical time to engage learners to pursue Science, Technology, Engineering, Math (STEM)-related subjects in school and to be inspired by STEM careers. Thus, the science standards chosen are grades 5-8 and are listed in Table 1. The remaining portion of this paper will present results from two evaluation studies and discuss three major projects that SWOP is developing that can contribute to the education objectives of IHY: 1) the Space Weather Center Website, 2) Educator Workshops, and 3) Small Exhibits.

3.1 Evaluation Results

Two major evaluation studies have been conducted on the public understanding of space weather concepts: 1) Front-end evaluation for the Electric Space (ES) exhibition (Korn, 1992) and 2) Summative evaluation for the Space Weather Center (SWC) exhibition (Koke, 2000). The ES evaluation took place at the Smithsonian's National Air and Space Museum and the SWC evaluation at the Denver Museum of Nature and Science. A researcher stationed at the entrance to the SWC exhibit solicited people to complete a survey before they entered the exhibit. Ages ranged from 12-62 years with an average age of 31. As a part of the survey they were asked whether 13 terms were related to space weather, not related to space weather, or if they didn't know (see Table 2).

Common pre-visit beliefs included that clouds, thunderstorms, and El Nino are related to space weather. Although the exhibit made some progress, many people interviewed by phone after their visit continued to believe that these phenomena are related. There are also many other interesting results in Table 1 (e.g. a sizable fraction (34%) of the respondents thought that the Andromeda galaxy and space weather were related).

Once introduced, misconceptions are tenacious and difficult to dislodge without directly confronting them (*A Private Universe*, 1987). All the respondents in the SWC report replied that "solar wind" was related to space weather, but based on the ES report, their ideas of what "solar wind" means are suspect. "Solar wind" can also connote wind ON the Sun, or wind on Earth that is caused by the Sun. The term "solar storm" is used inconsistently in our communications and may introduce confusion: storm ON the Sun (like a flare or prominence), storm FROM the Sun (like a CME), storm ON EARTH caused by the Sun (like a magnetic substorm, or some also think of thunderstorms) (Morrow et al., 2005). There is a natural tendency to define a new and unfamiliar term like "space weather" or "solar wind" by using components of the term that may be familiar in another context. Anything related to space and/or weather can be construed as being related to "space weather" (Morrow et al., 2005). As another example, the ES Study reported visitor ideas about sunspots such as: "spots where the Sun hits the Earth" or "where the Sun hits you and burns you" or "areas of intense heat." A quote from the SWC report (Koke, 2000) actually suggests that we use public misconceptions about space weather as a teachable moment. "Space Weather may be a topic about which explicit discussion of erroneous assumptions actually may help teach the major points. It might be effective to face misconceptions head on and explain that clouds and thunderstorms are not related to space weather (e.g. signage that says: Guess what is NOT related to Space Weather?)"

3.2. Space Weather Center Website

Educational websites may reach the broadest informal, free-choice learning audience than all other informal institutions combined. The challenge is to connect with that audience in a meaningful way. In 1999, SSI originally launched the *Space Weather Center* website to support its 1,000-square-foot traveling exhibition of the same name. While the exhibition has since finished its national tour, the *Space Weather Center* website continues to reach hundreds of thousands of visitors. SSI recently redesigned the site and it has become one of the most comprehensive and popular space weather resources available online. Both NSF and NASA have supported SSI's ongoing efforts to develop and update the site.

The new *Space Weather Center* site has been built on experience from other SSI education projects to reach a general, web audience (i.e., the space interested public). It balances engaging activities with telling the broader story of space weather effects. The story begins with an introduction to the plasma state of matter and the Sun—the place where space weather begins. Other areas of the site continue the story, focusing on auroras and storms in Earth's magnetic field, space weather forecasting and research/modeling. The site is intended to provide multiple access points for visitors to

engage the content. For example, visitors can explore additional resources, such as a space weather FAQ, links to games, activities, and valuable online content, and a glossary space weather terms and concepts. There's even an e-card feature that allows visitors to send e-mail messages with one of thirty space weather images, such as Saturn's aurora or arcs of plasma rising from the Sun's surface. Each card includes a caption explaining the image and links to the site that discuss the card's content in more depth.

To create the site, SSI leveraged heavily from its own in-house space physics research expertise. In one case, SSI used a small NSF education/research supplement to develop online activities that used the same numerical "particle pushing" algorithms as the parent research proposal. Using game metaphors, such as "mini golf", these Web interactives guide users toward developing an intuitive feel for particle motion in electric and magnetic fields. The resulting "Magneto Mini Golf" activity has been extremely successful, with many players commenting on how surprised they were to find a game that was both fun and educational.

More recently, SSI included *The Great Escape* in the site, which is a maze activity designed as a "casual game," or one in which the rules are self-evident and appears to require little investment by the player. Inspired by the Family Guide to the Sun (which is also available on the *Space Weather Center* site), *The Great Escape* challenges visitors to play the role of a photon escaping from the Sun. The maze immediately introduces visitors to several key learning goals, including a basic understanding of the structure of the Sun and the fact that photons take tens of thousands of years to escape from its core. In addition, to successfully proceed through the maze, visitors must spell out a phrase. These phrases introduce additional content related to stellar structure and evolution. *The Great Escape* is quickly becoming one of the more popular activities on the *Space Weather Center* site.

The *Space Weather Center* currently receives over 400 visits per day with periodic spikes of several times that amount (note that "visits" describes in-depth interaction vs. "hits" which describes merely landing on the home page). Tens of thousands of people have played "mini-golf" on the site, providing them with an unusual opportunity to experience how charged particles move in magnetic fields. When someone does a Google search using the term "space weather," the *Space Weather Center* is listed fourth. Over 500 domains link to the *Space Weather Center* site, including NASA missions, schools, and sites on the aurora. SSI is continuing to innovate on providing the best possible experience for online visitors.

3.3. Workshops for Educators

SSI has created many exemplary professional development experiences for both informal and formal educators, as well as for scientists who are interested in education. Over the past ten years, SSI has conducted educator workshops in conjunction with its traveling museum exhibitions, and at various scientific and educational

conferences. SSI conducts its workshops in collaboration with other organizations, and as stand-alone events designed to reach underserved audiences.

In order to have a greater impact, SSI frequently presents its workshops through existing networks of informal educators. In addition to working with museum educators in connection with its traveling exhibits, SSI has worked with several after-school and out-of-school programs, such as 4-H, Expanding Your Horizons, MESA, YMCA, and others. In some cases, SSI workshops have led to the creation of new educator networks, such as the *Four-Corners Education Alliance*, an association of over sixty informal and formal educators from more than 25 organizations in rural areas of Arizona, Colorado, New Mexico, and Utah. This Alliance grew out of the educator workshops in the region that SSI conducted in conjunction with its *Space Weather Center* and *Destination Mars* traveling exhibitions, and an SSI-led NASA Explorer Institute Focus Group to assess the needs and overlap of the region's informal and formal educators (McLain and Koke, 2005).

The Four-Corners region includes rural and underserved areas with significant Native American and Latino communities. As such, it presents an excellent opportunity to explore the special needs of smaller museums and the educators they work with in culturally diverse and rural communities. The results of the Explorer Institute Focus Group workshop not only apply to the Four-Corners region specifically, but serve to inform efforts in other underserved regions across the nation. Workshop participants came from three groups who interact closely in their educational efforts: museums, formal educators, and leaders of informal community and after-school groups. From experience, any informal programming must recognize and acknowledge how these groups interact in order to be effective, relevant, and successful. This is especially true for small, under-funded, rural communities where such groups often need to share resources and opportunities in order to provide quality educational experiences for their young people. The workshop design encouraged rich discussion and created a sense of ownership by participants of the work to be done. It allowed them to network with each other and provided a forum for the collegial sharing of ideas – all related to NASA's educational efforts. Participants expressed the desire for more of these types of workshops (McLain and Koke, 2005). The workshop incorporated a 3-phase plan:

- A pre-assessment of informal and formal educators in the 4-Corners to reveal existing ideas, attitudes, challenges, and experiences with NASA programming
- A focus group workshop including 4-Corners museum educators and 4-Corners K-12 formal educators, to address key questions and generate specific recommendations and guidelines for NASA's informal programming
- An on-line post survey of the informal community and after school groups in the 4-Corners with which the workshop participants work

SSI recognizes the critical role that informal educators play in facilitating the public's understanding of science. For all of its workshops for educators (both formal and informal), SSI's goals are to bring high quality, space-related professional development

to those who don't often have such opportunities. Its workshops are designed using professional development standards (e.g. NRC, 1996) and conceptual frameworks (e.g. Loucks-Horsley et al., 1998). Space weather provides an ideal backdrop for addressing many space science topics that appeal to both educators and visitors. These include astronomy, space physics, earth science, technology, and even human spaceflight. For example, in late 2007, SSI will conduct a *Four-Corners Education Alliance* workshop on space weather in association with *Radiation and Human Space Flight*, an SSI/NASA project led by SSI's B. McLain. Aimed at middle and high schools students, this project will produce two documentary films and a host of hands-on educational activities. The workshop will show educators how to link up with IHY resources. SWOP will support the workshop by providing exciting space weather content and hands-on, inquiry-based experiences. The *Space Weather Center* website will disseminate radiation and human space flight resources to educators, who can use other parts of the site in their teaching. J. Harold will also develop new content (e.g. interactives) for the *Space Weather Center* site that is related to radiation and human space flight as well as IHY goals.

3.4. Small Exhibits

For over fifteen years, SSI has worked with science centers and visitor centers across the country to bring quality, hands-on learning experiences to millions of visitors. SSI is now recognized as a national leader in developing space-themed exhibitions. While most of SSI's exhibitions have been relatively large, SSI recognizes the importance of developing stand-alone, interactive components for small science centers, libraries, and community centers that are easy to ship, set up, and operate. SSI is currently developing several such components based on space-weather and Sun-Earth connection content. The development team is particularly interested in electro-mechanical devices that combine computer models and physical interfaces. Such components differ from simple computer interactives by allowing visitors to:

- Use their hands to explore a system—such as a charged particle in motion in magnetic fields—that is not otherwise accessible to that kind of inquiry.
- Manipulate objects and observe the effects while a computer performs the necessary, underlying calculations.
- Collaborate with others to successfully interact with the component. Visitor interaction is well recognized as a powerful way to stimulate learning through discussion.

Recently, SSI collaborated with six other research organizations in the Boulder, Colorado, area (the National Center for Atmospheric Research, the University of Colorado's Laboratory for Atmospheric and Space Physics and JILA, National Oceanic and Atmospheric Administration, National Institute of Standards and Technology, and the National Renewable Energy Laboratory) and the Macerich development company to create a science park in a local shopping mall. Each of the seven research organizations has an outdoor installation and computer kiosk in the mall. SSI delivers space weather and Sun-Earth connection content on its kiosk, including modified versions of activities developed for the *Space Weather Center* website.

In addition to the permanent installations, the science partners are participating in an on-going collaboration to develop science activities and education opportunities for the public and K-12 children at the mall. In October 2006, at the grand opening of the mall and science park, SSI participated in a three-day, outdoor science event that included activities for families and young children. SSI's presentations were designed to convey some basic understanding of our Solar System and the Sun-Earth connection content. Visitors could then learn about space weather on the kiosk.

The Twenty Ninth Street science partners are continuing to meet quarterly to develop more programming that takes advantage of the science park. Boulder has one of the highest concentrations of scientists and aerospace engineers of any community in the United States. The Twenty Ninth Street project has provided SSI with an opportunity to meet and collaborate regularly with other research organizations that have an interest in space weather or play an important role in space weather forecasting. Among the collaborations planned for the coming year is a Café Scientifique series planned for several of the restaurants and coffee shops in the Twenty Ninth Street mall. The science partners will take turns choosing topics and providing speakers for these informal meetings. Those who attend are invited to ask questions and discuss science issues that are both relevant to our society and timely. One of the topics that SSI plans to lead is about the risks to our current technology posed by significant space weather events and how those risks could be mitigated in the future.

4. Summary

Informal education institutions are playing an increasingly important role in America's overall education system. They provide children and adults with opportunities to learn science by doing science. The Space Science Institute (SSI) has conducted two evaluation studies on the public understanding of space weather concepts: 1) the front-end evaluation for the Electric Space exhibition and 2) the summative evaluation for the Space Weather Center exhibition. Many research programs in both the space weather and terrestrial weather realms have education & public outreach programs integrated into them. Communication efforts associated with space weather both benefit and are compromised by analogies to terrestrial weather. This paper summarized the benefits and challenges of the terrestrial weather analogy using these evaluation studies. SSI has developed an extensive science communication effort called the Space Weather Outreach Project (SWOP). SWOP includes an educational website, the *Space Weather Center*, workshops for formal and informal educators, and the development of instructional materials and small exhibits.

The new *Space Weather Center* site has been designed to reach a general, web audience (i.e., the space interested public). It balances engaging activities with telling the broader story of space weather effects and is used extensively in SSI's space weather workshops for educators. SSI has created many exemplary professional development experiences for both informal and formal educators such as the *Four-Corners Education Alliance*, an association of over sixty informal and formal educators in rural areas of Arizona, Colorado, New Mexico, and Utah. SSI is currently developing several stand-

alone, interactive components for small science centers, libraries, and community centers that are easy to ship, set up, and operate. They are based on space-weather and Sun-Earth connection content. In 2007/2008, the International Heliophysical Year (IHY) will bring together scientists and educators from around the world to explore fundamental heliophysical processes and continue the legacy of the 50th anniversary of the International Geophysical Year. The wealth of space weather outreach programs in the United States and abroad can help achieve the education goals of IHY.

5. Acknowledgements

The authors wish to acknowledge the collaboration with C. A. Morrow who has made fundamental contributions to space weather education. This work was supported by a grant from the National Science Foundation (ATM-0448883).

5.1. References

Association of Science-Technology Centers, *2005 ASTC Sourcebook of Statistics & Analysis*, Washington DC, 2005.

Carlowicz, M., Lopez, R., *Storms from the Sun: The Emerging Science of Space Weather*, Joseph Henry Press, Washington, DC, 2002.

Chesebrough, David E., *New models: The search for an improved approach to science centers and museums*, Informal Learning Review, 74, Washington, DC, 2005.

Chittenden, David, Graham Farmelo, and Bruce V. Lewenstein (Eds.), *Creating Connections: Museums and the Public Understanding of Current Research*, AltaMira Press, Walnut Creek, CA, 2004.

Dusenbery, P. B., Morrow, C. A., *Making the connection between formal and informal learning*, ASP Conference Series, Vol. 319, San Francisco, CA, 2004.

Dusenbery, P. B., Mayo, L., *Developing exhibitions through public/private partnerships: A case study of the Space Weather Center Exhibit*, ASP Conference Series, Vol. 319, San Francisco, CA, 2004.

Dusenbery, P. B., Harold, J., Morrow, C. A., *Communicating Science through Exhibitions*, 35th COSPAR Scientific Assembly, Paris, France, 2004.

Falk, J. H., and Dierking, L. D., *Learning from Museums: Visitor Experiences and the Making of Meaning.* Walnut Creek, CA: AltaMira Press, 2000.

Hein, George, *Learning in the Museum.* London, U.K. and New York, NY: Routledge, 1998.

Koke, J. *Summative Evaluation: Space Weather Center*, Space Science Institute Report, Boulder, CO, 2000.

Korn, R., *Front-end Evaluation: Electric Space*, Space Science Institute Report, Boulder, CO, 1992.

Korn, R., *Summative Evaluation: Electric Space*, Space Science Institute Report, Boulder, CO, 1997 (www.informallearning.org).

Loucks-Horsley, S., Hewson, P.W., Love, N., Stiles, K., *Designing Professional Development for Teachers of Science and Mathematics*, Corwin Press, Thousand Oaks, CA, 1998.

McLain, B., Koke, J. *NASA Listens to the Four Corners:* A Report to NASA's Informal Science Education Division, Washington, DC, 2005.

Minds of Our Own, Harvard-Smithsonian Center for Astrophysics, Science Education Department, Science Media Group, Boston, MA, 1997.

Mintz, Ann, *Science, society and science centers*, Informal Learning Review, 71, Washington, DC, 2005.

Morrow, C. A., McLain B., Wilkerson A., Garvin-Doxas K., Dyches P., *Family Guides to Timely Topics In Space Science*, 35th COSPAR Scientific Assembly, Paris, France, 2004.

Morrow, C., Edwards, C., McLain, B., Dusenbery, P., *Lessons Learned about Educational Programming Associated with Space Science Traveling Exhibits*, 35th COSPAR Scientific Assembly, Paris, 2004.

Morrow C. A., J. Harold, P. Dusenbery, *Science Communication Efforts in Space Weather: Benefits and Challenges of the "Weather" Analogy*, American Meteorological Society, 2005.

National Council of Teachers of Mathematics. *Principles and Standards for School Mathematics*, Roanoke, VA, 2000.

National Research Council. *National Science Education Standards,* National Academy Press, Washington DC, 1996.

National Science Board. *Science and Engineering Indicators 2005,* US Government Printing Office, Washington DC, 2006.

National Space Weather Program: Implementation Plan, Committee for Space Weather, Office for the Federal Coordinator for Meteorology, Washington, DC, 2000.

Poppe, B.B., Jorden, K.P. *Sentinels of the Sun: Forecasting Space Weather*, Johnson Books, Boulder, CO, 2006.

A Private Universe, Harvard-Smithsonian Center for Astrophysics, Science Education Department, Science Media Group, Boston, MA, 1987.

Russell, R.L., *Exhibit review: Look for storms, gale-force winds, and plasma blobs*, Informal Learning Review, 43, Washington, DC, 2000.

United Nations, *Putting the "I" in IHY*, Office for Outer Space Affairs, 2001.

West, R., *Café Scientifique: A huge opportunity*, The Informal Learning Review, 70, Washington, DC, 2005.

6. Tables

Table 1: National Science Content Standards Addressed in *Space Weather Outreach*

Unifying Concepts & Processes Systems, Order, & Organization Evidence, Models, & Explanation Evolution & Equilibrium	**Science as Inquiry** Abilities to do scientific inquiry	**Physical Science** Changes in Matter Motions & Forces Transfer of Energy	**Life Science** Structure & function in living systems (human exploration)
Earth & Space Science Structure of the Earth System	**Science & Technology** Understanding about Science & Technology	**Science in Personal & Social Perspectives** Natural hazards Risks & Benefits Science & Technology in Society	**History & Nature of Science** Science as a human endeavor Nature of Science History of Science

Table 2. Results from the Space Weather Center Exhibit Survey

	Related to Space Weather	Not related to Space Weather	Do not know
weather satellites	13 (59%)	8 (36%)	1 (5%)
sunspots	19 (86%)	2 (9%)	1 (5%)
Andromeda galaxy	15 (34%)	10 (23%)	19 (43%)
changing mag fields	37 (84%)	1 (2%)	6 (14%)
Aurora Borealis	19 (43%)	14 (32%)	11 (25%)
plasma	14 (32%)	15 (34%)	15 (34%)
coronal mass ejections	19 (43%)	8 (18%)	17 (39%)
power outages	9 (43%)	7 (33%)	5 (24%)

clouds	14 (64%)	5 (23%)	3 (14%)
El Nino	24 (54%)	15 (34%)	5 (11%)
thunderstorms	24 (54%)	14 (34%)	5 (11%)
sunspot cycle	18 (82%)	1 (5%)	3 (14%)
solar wind	22 (100%)	0	0