Media-Based Learning Science in Informal Environments

Commissioned Paper

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The media are the most pervasive disseminators of informal science education in this country. Watching commercial and non-commercial television will provide you with information on alligators or zygotes, bio-fuels or stem cells, polar bears or hurricanes. Radio, too, provides discussions of genetics and global warming and birds and stars. Often radio and television will cover science issues with a contextual overlay of politics or morality, so viewers and listeners can sense how they and their community relate to it. But for excitement, going to the theater to see an IMAX movie will take you deep below the surface of the ocean or up into the stratosphere or into a volcano or the eye of a storm. And if you want more, a planetarium show will even reveal our current understanding of cosmology and black holes and dark matter. The topics seem endless, and they are.

Collectively, these media reach millions of people each week with information and ideas about a range of sciences (and by the word *sciences*, I include the array of content captured by NSF's use of the acronym STEM, standing for science, technology, engineering, and mathematics). Most of the time they reach you in your home or in your car, sometimes you have to go to a theater in a museum or in a multiplex. Increasingly, they can be seen or heard as podcasts or directly streamed from websites, further broadening their reach to new audiences and making it easier for traditional audiences to access programming when and where they choose to do so.

A substantial amount of funding goes into ISE media, and it has been a staple of PBS for generations; NPR and the Discovery Channels are also frequent purveyors of science content. Among the funders of these ISE media presentations are national, governmental organizations (NSF, NOAA, NASA), numerous corporate and foundation interests, as well as, according to the underwriting credits, the viewers of PBS and listeners of NPR.

This paper explores the nature of adult science learning from media as part of informal science education initiatives and brings together the research studies and evaluations (mainly evaluations) that have sought to identify the outcomes of these programs. It is an integration and analysis of ISE evaluations and research and an exploration of how this knowledge intersects with the policy issues that emerge in the discussions of how to leverage our large investment and incredible resources in science media designed for the general population.

Specifically we address the following questions:

- What is the nature and quality of the evidence on media as a tool for learning science?
- What are the defining characteristics of learning from media? Are they different across the types of media? Are they different across audiences?
- To what extent have traditional theories of learning informed the design and evaluation of media in informal science environments?
- How can theories of learning be brought to bear on media design and evaluation?
- What are the methodological challenges in conducting studies on the impact of media on learning? What methodologies have been most effective?

OUR FRAMEWORK

We will begin with a framework for defining media, adult learning, and the factors that influence each and then turn our attention to a summary of evaluation findings related to informal science learning through media.

The Media

There are many modes of delivery for informal science education content, but for the purposes of this paper, we have focused on the following forms of media: television, radio/audio (including podcasts and streamed audio and video files via the Internet), film, giant screen film (e.g., IMAX), and planetarium shows. Where necessary, we have also addressed variance in outcomes based on modes of distribution, for example, the difference between hearing an audio program on the radio versus downloading it in a digital format from the Web or viewing a television program at home rather than watching a video program in a public setting such as a museum or theater.

One of the most common and most pervasive modes of ISE media dissemination is via public broadcasting. Regular full-length programs devoted to science, e.g., NOVA and Scientific American Frontiers, accompany science inserts in other programming, e.g. the Science Units broadcast on The NewsHour with Jim Lehrer, and insterstitial programming such as Stargazer. Since most of the research and evaluation of informal science education via media has been tied to funded ISE media programs and most funded programs have traditionally aired on public broadcast channels, most of our subsequent knowledge is generated from studies of ISE on public channels.

Somewhat less is known about the amount and nature of science programming on commercial broadcast channels, however, research suggests that topics such as genetics, disease and diet are fairly common fare for health segments on local and national news programs. On commercial television, CNN and the various Discovery Channels also have science programs as specials or as regularly scheduled series, as do the four major broadcast networks; but less is known about their audience or impact.

Google lists 26 science-focused talk radio shows, many of them with national distribution. A number of them have received NSF support over the years, and are found on public radio, such as Living on Earth, StarDate, Earth& Sky, and Science Friday. Other audio programs are accessible online as streaming audio or as podcasts. On commercial radio stations, AAAS's Science Update, 60-second interstitials cover a wide range of current science content, including answering questions submitted by listeners. They now use podcasts to distribute a week's worth of programs at a time. Also Science and Society, a brief set of audio materials, funded by the Chemical Heritage Foundation, is available for download via the Internet. Talk Radio Network (with such talk stalwarts as Michael Savage and Laura Ingraham) have regular science commentators and often feature current science topics as issues in their programs.

There is less formal research on streamed or downloadable video and audio files on the internet, but many science resources are now being made available in these formats on a variety of formal and informal science education websites. Popular science and science-related websites frequently contain video or audio clips (either short sound clips or longer podcasts) that can be streamed or downloaded. For example, the NOVA site on PBS.org feature video clips while the Health and Science page on NPR.org features an ability to "hear all stories." Video clips, and links to more, are also prominently featured on the Discovery.com homepage and full-length video programs are available to purchase and download for $1.99. Science.com offers a "multimedia" link on its homepage that links to a variety of streaming video offerings as well as other interactive presentations and slide shows. The homepage for NationalGeographic.com prominently displays an image and link that take visitors to the "Featured Video." The dramatically changing landscape of Web-based materials suggests that more resources will be made available in a variety of formats and available to the public.

IMAX and other giant screen presentations are prevalent in both commercial movie complexes and in museums, planetariums, zoos and marine centers around the country. There are 289 IMAX theaters and most of them show some form of science programming periodically. Many of the programs have been developed in collaboration with organizations such as NASA, the Smithsonian, National Geographic, WGBH/NOVA, and Discovery Channel. To give a sense of the range of science topics covered, some of the recent IMAX-type movies include: Tropical Rainforests, Roving Mars, Dolphins, and The Science of Risk.

Accessibility Continuum In addition to considering the range of ISE media, it is also important to consider how people come to have access to ISE programming. Informal Science Education content can be obtained in a variety of, often redundant, ways through the array of accessible media. Accessibility has an impact not only on types of viewers and listeners, but also on the total audience size and frequency of their viewing and listening.

Figure 1: Accessibility Continuum

Highly Accessible	Broadcast Media	Internet	Home Video Distribution	Location-Based	**Limited Accessibility**

Broadcast Media Broadcast media are among the most accessible with the lowest barriers to viewing/listening. Because they are among the most-readily accessible, broadcast media therefore have the most extensive reach in terms of actual and potential audience members. Science content comes directly into viewers' and listeners' homes, workplace, and cars, and little needs be done to receive the programming except tuning in at the appropriate time on the appropriate channel. New technologies, such as Digital Video Recording systems (e.g., TiVo) or Digital Audio Recording systems (e.g. RadioShark) further help to streamline the process of finding ISE programs and allowing audiences to access them at more convenient times.

Internet There are an estimated 233 million people in North America (69.7% of the population) as of early 2007 able to access the Internet (source: http://www.internetworldstats.com/stats.htm). Streamed or downloadable audio and video programs, accessible via the Internet, are therefore available to large number of potential viewers and listeners. However, lack of Internet access—and the lack of broadband access—can be a barrier for some (especially populations that have been traditionally underserved by other forms of Informal Science Education). However, the need for audience members to be proactive in seeking out internet-based programming is a more pervasive and substantial limitation, in comparison to broadcast media. New technologies, such as RSS feeds or podcast subscription services make it easier to push content to audience members who have indicated a preference for seeing or hearing more—thus eliminating one of the potential barriers to access.

Home Video Distribution There is a limited market for providing programs to viewers directly via DVD or VHS. Most video sales and rental services include modest listings of science titles—many of which have been previously broadcast or shown in theaters as giant screen programs. Direct-to-home sales and rental services provide opportunities for people to see programming they may have missed, or gain access to programming that may not have been available via other broadcast or internet-based sources. This mode of distribution allows viewers to access programming in the comfort and convenience of their own homes. Thanks to services like Netflix and mail-order giants like Amazon.com, would-be viewers need not even leave their homes to visit stores or rental centers; but they do require viewers to be proactive in selecting titles of interest to them. In its "Science and Nature Documentary" category, Netflix lists 145 videos, including recent National Geographic Specials and programs and other programs that have aired on the Discovery Channel or PBS.

Location-Based Programming The last mode of ISE distribution on the Accessibility Continuum is location-based programming. These are programs that require viewers and listeners to be physically present in locations where they can be seen or heard. IMAX and planetarium shows require viewers to go to special theaters that are equipped to show giant screen or dome-format videos/films. This category can also include shorter educational videos that are designed for use in museum, park, or zoo installations and the new types of short-range broadcasts or audio-guides that enable guests of museums, parks, and zoos to access a range of audio and video content during their visits.

The Audience

Our work focuses on adults who interact and engage with media outside of formal instructional settings. We also assume a general adult audience as the target for our research and reporting in this paper, one that may contain some professionals who work in the field of science, but is not exclusive to those who have science training beyond the high school or basic college level. Much evaluation work has also been done for informal science education programs that target youth, but our paper will focus more on the unique characteristics of adult learning, making comparisons and contrasts where appropriate.

PBS Viewers PBS viewers tend to be more educated and more wealthy than the American population at large. According to PBS, "Its viewers are 44 percent more likely than the average Joe to have a household income over $150,000; 39 percent more likely to have a graduate degree; and 177 percent more likely to have investments of $150,000 and up.” (source: http://www.cpb.org/ombudsmen/display.php?id=7)

It is interesting to note that PBS viewers often have consistent content preferences and viewing patterns: some watch more news shows, others tend to go for the arts and film, and still others favor science programming. Over the past several years, the Corporation for Public Broadcasting (CPB) has been studying the audience for public television and its analyses divide the audience of adults, eighteen and older, into eight descriptive, psychographic categories (CPB 2006a, 2006b) Two of these audience segments have a clear interest in, and regularly view, science programs on PBS.

Discerning & Dedicated The most committed audience segment, called Discerning & Dedicated, are more likely to be members of their local PBS station and spend much of their television time with PBS, an average of eleven hours a week. They comprise 8% of the PBS audience, and are interested in many topics, and include science among them. They report watching *Nature* and NOVA with some regularity. This group is older, affluent and well-educated and somewhat liberal. They are civic-minded and most philanthropic of PBS-viewers, and they are empty nesters.

Innovating & Inclined The Innovating & Inclined, about 13% of the adult audience, have a positive attitude towards public broadcasting, but watch only two and a half hours a week. These viewers find PBS programs more interesting than most other television and are more likely than other audience segments to agree that “PBS programs have changed their lives or their way of looking at the world.” They tend to watch science programs, naming NOVA and *Nature*, and would like to see more of these kinds of programs on the air. They also watch the Discovery Channel and HBO. These Innovating & Inclined are a bit younger than other groups (mean age of 41) and often have children in the house. They are the most affluent of all viewer segments and well-educated. They get out of the house and go to zoos and science museums, and tend to be civically active, attending PTA meetings and writing letters to public officials. They are also philanthropically-minded and heavy NPR listeners. They see themselves as neither liberal nor conservative. In its strategic plan for the past year, CPB has included a focus on the Innovating & Inclined, based on the perceived interest of this group in science programming and activities.

These audiences seem to influence the content of PBS science programming, too. Consider the language levels required to comprehend the science content, the background knowledge needed to enter into the dialogue, or to access of enriching materials given access to broadband networks. The programs are made for those who are likely to watch them (older, more educated, and wealthier), and those who watch are looking for modestly challenging programming that will give them something to talk about with others at work or at the bridge table and provide them with sufficient information to follow up with a reading or a visit to a museum.

NPR Listeners NPR radio programming tends to be heard by younger listeners. (Recent audience research about NPR listeners indicates that Gen Xers (age 28-41) are just as likely to be NPR listeners as baby boomers. (*Current*, January 22, 2007) Research suggests that NPR listenership has been growing over the course of the past few decades. For example there was an increase from 10.2 to 13.8 million listeners from 1986 to 1991, representing a 35% total increase in listenership (Crane 1994). From 1999 to 2004 there was an additional 66% increase in listenership, and in 2003 NPR boasted an estimated weekly listenership of 20 million (source: http://en.wikipedia.org/wiki/NPR). Public radio listeners are comparable in many ways to public television viewers in terms of demographics. The average listener is white, 50 years old, and earning an average annual income around $78,000 (source: http://en.wikipedia.org/wiki/NPR); they are better educated, more politically active, and more active consumers (Crane 1994).

Internet Users Use and popularity of the internet are at an all-time high. According to one recent study by the Pew Internet and American Life Project, "40 million Americans rely on the internet as their primary source for news and information about science." The study goes on to report that use of television and use of the internet (by those with broadband connections in their homes) are roughly equivalent as sources for science news and information, especially among younger users.

In a recent study of communications and technology users, the Pew Internet & American Life Project developed a typology of users (Pew, 2007).They note that 24% of radio listeners have listened to music or radio shows on something other than a home or car radio and 13% have watched TV shows or news programs on something other than a TV set at home (e.g., computer, cell phone, iPod). Much of this listening and viewing is likely to be music and video games, but the potential for a large portion of the population to receive informal science media in non-traditional ways seems to be expanding. http://www.pewinternet.org/pdfs/PIP_ICT_Typology.pdf

IMAX/Planetarium and Web Audiences IMAX theaters tend to attract a slightly younger audience, since many adults take their children to the sites where these theaters are located. IMAX and similar types of giant screen film shows are more likely to go for excitement and delight, rather than in-depth, issue-oriented science concepts. While there are educational materials associated with many of the IMAX presentations, these are focused on reaching school groups rather than the general audience. Planetariums often tend to attract more foreign-born visitors, especially in large cities, and have slightly younger audience members that those associated with PBS and NPR programming.

What Do We Know about Adult Learning and the Media?

Implicit in the question above are a set of distinctions, i.e., to understand what is known about adults' informal science learning via media it is essential to recognize the underlying assumptions that:

- There are differences between adult learning and youth learning;
- There are differences between formal and informal learning; and,
- Learning from media is different than learning in non-mediated formats.

Differences between adult learning and youth learning Children's brains are wired to learn. Scientific studies have identified differences in the ways that children acquire information and process the world around them—differences based on the physical and chemical makeup of the brain at different states during the developmental process. Adults, on the other hand, have the advantage of being able to draw upon more extensive prior knowledge, and because they have been learners for longer periods of time, have more strategies and skills for organizing that knowledge (e.g., metacognitive strategies) (National Research Council, 2000).

For instance, an adult viewing a program about the underlying physical properties that make roller coasters work would likely bring some recollections of personal roller coaster-riding experiences to the viewing experience, along with a basic understanding of some of the physical properties being discussed. Both things provide a springboard from which new knowledge acquisition can be more effectively launched.

Furthermore there are distinctions between many of the science programs developed for children and those for adult audiences. Children's television and radio programs are often created as a series in the hope that, with a consistent schedule, children will become regular listeners and viewers. A once-a-week series, if successful in attracting an audience or critical attention, will receive further funding and may, over time, develop sufficient numbers of programs to be broadcast as a daily strip.

Children's prosocial/educational programs are carefully designed to cover a well-defined curriculum; they are educational without requiring the mediation of a teacher. In development, producers usually engage both scientists and science educators to ensure that both the science and the educational strategies are correct and designed appropriately for the target audience. The design is likely to incorporate repetition and iterative strategies of incremental information presentation that builds on earlier information to more fully engage children in learning new concepts. An idea introduced in one program will also appear, perhaps slightly modified, in a later program. For example, concepts in *Cyberchase,* an animated show produced by Thirteen/WNET that highlights mathematical concepts for 'tweens, are closely aligned with math standards and curriculum frameworks, and the program attempts to build—both on-the-air and online—a collection of concepts and strategies for solving math problems. *DragonflyTV,* produced by Twin Cities Public Television, features different children doing different scientific investigations each week—the themes, children and specific inquiry methods differ from program to program but the underlying focus on scientific method and general approaches to scientific inquiry are constants.

Because of this design strategy, children's television series often find a substantial, secondary audience within the formal school structure. The primary expectation of the development team is that a home audience will emerge, but they recognize that many children may see one or more of their programs in school. Most producers encourage this by developing teacher manuals to accompany their products.

In contrast, adult science programming often exists as stand-alone events even within a series. Recent topics on NOVA, for example, include a program about dogs, followed by one on the 2004 Indian Ocean tsunami, followed by one on a design for a submarine with panoramic views. *Nature*, as well, is also more a science variety series than a focused opportunity to learn a set of science ideas over a prescribed set of programs. These, and similar series, are episodic and, because they may include programs developed by different producers, may have a different look-and-feel, further distancing them from a coherent set of common ideas about science.

Science programming for a general adult audience on television and frequently on radio is often packaged within other programming. Because of their packaging within news programs, shows like *National Geographic Expeditions* on NPR's *Morning Edition* and science segments on *The NewsHour with Jim Lehrer*, can cover more political and policy issues and, because they appear more as news, often get away with it more critical and analytical pieces. For example, a series of Science Reports on *The NewsHour with Jim Lehrer* aired in the spring of 2007, featured content related to the politically-charged topic of global climate change and included political as well as scientific perspectives. Radio series, such as *The DNA Chronicles* and *Science Friday*, are part of a news and information block and can also incorporate more controversial issues that inform the audience members.

None of this is meant to minimize the quality and value of these programs, only to contrast them with the design of children's television series with a well-formed curriculum and a different mission. Adult science programming is responsive to the need to be current and aware of happenings in science, but not designed to influence knowledge and skills the way that children's programs are. From a design perspective it can be said that adult science programming, in contrast to children's programming, lacks a specific curriculum and an organizational structure that helps viewers scaffold information and ideas from program to program. Children's science series, by design, are much more likely to lead to substantive and significant outcomes than science programming aimed at adults. However, adult science programming can still have a significant impact, it just comes about in different ways and over longer periods of time (Miller, 2001). Also, the attributes that engage older viewers are not substantially different from those that capture younger ones. Among the motivating factors are: social relationships, external expectations, social welfare (big picture), personal advancement, escape/stimulation, and cognitive interests, (learning merely for the sake of learning).

Differences between formal and informal learning Two key areas where differences are likely to exist between formal and informal learning are the context for learning and the potential or desired learning outcomes. The context for learning can vary in terms of when and why the learning is taking place. There may also be differences in the locus of responsibility for learning (i.e., teacher-directed vs. learner-directed). Greenfield and Lave (1982) suggest that one of the key differences between formal and informal learning is the extent to which the learning activities are embedded within the learner's day-to-day life. Formal learning is typically set apart from the activities of day-to-day life whereas informal learning can enable a greater connection between learning and day-to-day life. Furthermore, Maarschalk (1988) suggests that formal learning tends to be planned in a more concrete way whereas informal learning can occur in less concrete, more varied, and more spontaneous ways. Informal science media programming (for adults) is essentially pedagogy-free: the information is presented, with a moderator or explainer mediating the information, and it is essentially up to adults to make sense of it however they best see fit. There is no teacher on hand to break things down, foster discussion, or answer questions.

Rennie and Johnston (2004) present a model for research that engages three characteristics: that learning is personal, that learning is contextualized, and that learning takes time. In that learning always takes place in a context, there are fundamental differences in the context for formal learning and informal learning. In informal education, content creators have the desire for a widely-shared cognition that can be contextualized, rather than mastery of a theory. Instead of being set apart from everyday life, the goal of informal science education is enabling the ideas and information to be integrated more fully into ways of thinking or ways of behaving.

Informal science education has an implicit rather than explicit pedagogy and curriculum and the individual learner owns more responsibility for learning, unlike formal education where the responsibility is often shared with an educator. In a formal educational setting a teacher is sometimes held accountable when students fail to learn, but we don't usually hold the producer responsible when viewers fail to learn from informal science education media productions.

Psychological grounding for non-formal and informal learning In this section, we review theories of motivation, cognition, and metacognition as they pertain to informal learning in general and adult learning from media in particular. These theories overlap in that motivation influences engagement and cognitive/metacognitive activity, which in turn determines an individual's level of expertise in a topic. In terms of motivation, we see interest and engagement as central constructs that mediate learning. In formal education the context for learning is well-defined. Learners are primed for learning even if they may not be intrinsically motivated to engage with the subject matter being taught or studied. In informal educational contexts, however, motivation for learning and interest in a particular topic are important factors that have a great impact on what is ultimately learned. Interest in turn leads to more sustained and deeper cognitive engagement in ideas though interest alone is not enough to sustain learning (Pintrich, Marx & Boyle, 1993).

High vs. Low Interest/Motivation Adults with low interest or motivation to learn (either in general or about specific topics) are more likely to approach educational programming, if they choose to attend to it at all, with less focused attention and interest—causing less thorough processing and therefore diminished ability to use and apply what, if anything, is learned. On the other hand, adults with greater motivation to learn (again, either in general or about specific topics) allocate more cognitive resources to attending to and processing the information that is presented leading to more thoroughly processed messages and allowing more connections to be made with prior knowledge. The salience of the content area to the audience member's daily activities may contribute to interest and motivation. So, scuba divers may have greater interest in ocean pollution than in Mayan science and would choose to engage one program rather than another. Consequently, from the producer's perspective, program content that appeals to the interests of a wider audience can capture a larger viewer/listener base. However, a deeper look at a narrow topic may get a greater portion of those with an interest in the area and still meet the producer's goals.

Novice vs. Expert The cognitive outcomes for adult learning can also be expressed in how novice and expert learners are different. The novice-expert paradigm purports that the nature of subject-matter expertise can be described in terms of four general cognitive activities (e.g., Chi, Glaser, & Farr, 1988). Experts with meaningfully organized knowledge display: (a) coherent *problem representations* based on the underlying features of the topic they are studying, (b) organized, goal-oriented *strategies* which they can apply flexibly to a given problem, (c) a variety of techniques to *monitor* progress (e.g., problem recognition, rechecking work), and (d) *explanations* that demonstrate a deep understanding of the scientific principles driving their work. This last aspect of expertise is of particular interest from an adult informal learning perspective. Learning outcomes can be described on a continuum from limited understandings of a factoid (cf., explanatoid: short fragments of explanations, Crowley & Galco, 2001) and explanations of increasingly larger concepts or constructs. These outcomes are themselves dependent on the prior knowledge a viewer brings to a media presentation, and that viewer's motivation for learning more.

Furthermore, there is also a meta-level of awareness that is required in order to learn from science media. Learners need an awareness of how knowledge is created, and how the methods vary by scientific field (Zimmerman, 2000). We suggest that the people who are most able to reconcile contradictory information from science media and create deeper more coherent explanations of phenomena, are those who best understand the nature of scientific research. For instance, a media-savvy learner is able to distinguish between preliminary, breaking news in a magazine and information in a textbook that reflects a broader consensus from scientists. A learner should also understand that a study's data collection methods and sample affect the generalizability of findings. Finally, a learner should understand how to locate additional resources before making any decisions based on a single news story (Zimmerman, 2000).

In sum, learning depends upon a combination of motivation, prior knowledge, and metacognition that leads to differences in learning gains. In this section we have theorized that there are particular aspects of motivation and metacognition that influence adult learning from media and may be of value when reviewing studies of learning.

Differences between learning from media and non-mediated formats Researchers have argued that there are not fundamental differences in the actual learning processes that takes place: at least on a cognitive level, learning is learning and all of the psycho-physiological processes that must take place in order for learning to occur are taking place whether or not the content or stimuli from which people learn is mediated or non-mediated. Clark (1983) in his classic article on learning from media states the case that *...media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition.* (p. 445).

However, research has also supported the belief that there are fundamental differences in the nature of media stimuli, triggering and facilitating the learning process in different ways than non-mediated stimuli, therefore having the potential to impact learning outcomes in unique ways (Kozma,1991). Kozma argues for unique media effects that vary with the medium, characteristics that interact with the viewer and his or her motivation for engaging the media, characteristics that influence the *structure, formation, and modification of mental models*. For example, the self-directed style of learning that mediated content often tends to promote may foster deeper processing and therefore greater understanding of the concepts presented. Pacing is another characteristic of media that influences impact. As described above, viewers use prior knowledge to process the information presented. Those with greater knowledge of subject matter and science processes can process the information at the pace it is presented, because they can use their long-term memories to supplement the information in the program. Those with less familiarity may have difficulty with the presentation and, since it is transient, can't review it and capture the ideas. They may choose to quit viewing, since the program is making less sense the more they watch it. As Kozma notes,

> *With books, the reader sets his or her own cognitive pace (i.e., words per unit of time) to accommodate personal requirements for comprehension. With video, the pace is set by someone other than the learner, and the presentation (i.e., words or visual elements per unit of time) progresses without regard to individuals' cognitive requirements.*

Theories of learning suggest that there are opportunities and constraints when media are used to engage and inform adults. Unfortunately, there seems to be no consistent and universally-supported theory that offers a clear strategy and guidance for producers of informal science materials. Nevertheless, it may be useful to consider and build off of research to inform the design of programming.

SUMMARY OF EVALUATION FINDINGS RELATED TO INFORMAL SCIENCE LEARNING THROUGH MEDIA

To better understand the current state of knowledge about science learning through media we did an informal meta-analysis of twenty-three informal science education evaluation reports and articles. The pieces used for our analysis were pulled from the evaluation report archives on the Informal Science website, funded by NSF (http://www.informalscience.org) and, by request, from others doing work in science education media evaluation.

Table 1 presents a framework that drives our analysis. It is based upon a combination of literature and speculation, and was not intended to be a definitive model of learning, but rather a set of ideas directing what we might find in the literature. For instance, the column “media production context” describes the kind of information relevant to understanding the nature of the media piece and the features that might influence learning. This is followed by an inputs column that describes the qualities an individual brings to a production. The outcomes column speculates on several timeframes for cognitive and behavioral changes that ultimately lead to a scientifically-savvy populace. Our analysis pays particular attention the outcomes of media learning, as none of the studies surveyed articulated a theory for how or why adults were expected to learn from the material.

Figure 2. Framework for Adult Learning from Media

<table>
<tr><th rowspan="2">Media Production Context</th><th rowspan="2">Inputs within an Individual</th><th rowspan="2">Activities</th><th colspan="3">Outcomes</th></tr>
<tr><th>Short-term
(i.e., immediately leaving the experience)</th><th>Mid-term
(i.e., days or weeks after)</th><th>Longer-term
(i.e., lifelong, accumulated learning)</th></tr>
<tr>
<td>• topic
• production quality
• dissemination strategy (PBS vs. Discovery vs. freestanding documentary)
• supplemental materials
• gatekeepers</td>
<td>Antecedent knowledge, attitudes and behavior
• Prior knowledge
• Motivation (interest, efficacy, goals)
• Metacognition (i.e., media literacy, knowledge of how media is created, how scientific knowledge is created)</td>
<td>• Initial media experience
• Enjoyment/ engagement with the media</td>
<td>• Initial learning, most likely knowledge gain with some connections with prior knowledge (a-ha! moments)
• Attitude change
• Behaviors/ opportunities for action
• Seek supplemental activities or materials
• Discuss with others
• Concrete, immediate action steps (e.g., beach cleanup, replace light bulbs)</td>
<td>Outcomes from additive elements
Re-exploration or reinforcement
• Repeated and varied exposure to science topics (e.g., DNA, global warming, obesity)
• Deeper learning that reconciles multiple experiences or sources of information into a single explanatory, actionable framework
• Increased ability to seek out and identify opportunities to act on learning or gain new experiences
• Awareness of the process of doing science
• Meta-awareness of how to make sense of science in the media, which is itself dependent on knowing how scientific knowledge is created</td>
<td>Educated citizenry who make informed decisions about
• politics
• health
• crime (e.g., in juries)
• consumer actions (e.g., buying a Prius, taking vitamins)
• education & policy (e.g., influencing the curriculum)</td>
</tr>
<tr>
<td colspan="2">Program goals
• Design intentions of media – what do they want people to learn? This varies, but is generally less well-defined for adults
• Edu- or info-tainment</td>
<td colspan="4">External influences
• Who makes media
• Who funds media
• Who is the predetermined audience for adult media
• Moving targets of developments in technology – by the time how you've figured out how to do podcasts effectively, there's something new
• Interests or hooks are dependent on current events, that require acceleration of production.</td>
</tr>
</table>

Research Methods

From our own files, from colleagues, and with the assistance of the NAS staff, we have aggregated research and evaluation reports on science media programs that considered adults as their primary audience. We collected approximately fifty research and evaluation reports on informal science media project, about half of which were targeted at the adult audience and half designed for children and youth. The list of evaluation papers that met this criteria and our analysis of their characteristics are included in the appendix to this paper.

The reports cover programs broadcast over a seven-year period from 1999 to 2006 and included both formative and summative evaluations, as well as a handful of published summary articles. In some cases we were able to obtain copies of both the formative and summative evaluation reports for a specific program but, given our charge to assess learning from adult science media, we sought more summative evaluation reports to include in our review. Much of this material is fugitive literature, and requests to producers and distributors—and even to some researchers—did not always yield a response. For many of our queries, respondents (both producers and researchers) were unsure as to whether their reports were public documents and therefore able to be shared without permission. Almost all of the reports we obtained were funded by the National Science Foundation. We were not able to obtain research reports on science programming found on commercial radio and television.

Among the programs whose evaluation reports we reviewed were Discoveries and Breakthroughs Inside Science, ScienCentral, and NewsHour (television news format programs), Strange Days on Planet Earth, Pulse of the Planet: Science Diaries and Einstein's Big Idea (longer format television programs), Earth and Sky, Science Friday and The Weather notebook (radio segments/shows), Cosmic Collisions and Search for Life (planetarium shows), and a handful of IMAX movies. We found that most studies focused on individual interventions such as a single television or radio program. In addition, reports from recent years suggest a trend in providing programming content through multiple media, especially via the Internet.

The reports we gathered were organized into four categories based on the media focus of projects being evaluated: Television, Radio, Film/IMAX and Web. In some cases, there was an overlap, with projects using multiple media formats to help reach adult audiences with ideas about science. Two researchers read and recorded information on methods and outcomes for each report. Information was summarized using the following analysis construct:

Figure 3. Data Analysis Strategy

Product Information		
Program/Product Name	Evaluator/Report Author	Program Content Area
Report/Article Name	Program Funding Source	Primary Intended Audience
Year of Report	Program Format	Secondary Intended Audience
Program Creator	Program Length	Delivery Method
Research Design		**Findings**
Research Methods	Number of Media Exposures	Related to Learning
Overall Study Design	Research Participant	Related to Engagement and
Research Questions	Demographics	Enjoyment
Study Timeframe	Instruments	Related to Attitude Change
Duration of Study	Data Collection Methods	Related to Behavior Change
	Analysis Techniques	

Research Methodology and Challenges

Methods and instruments We found an abundance of traditional, descriptive evaluation methods (e.g., surveys, focus groups, interviews, etc.) being used to assess the impact of the media materials. Surveys and questionnaires were, by far, the most common method used by evaluators to gain information from program audiences; interviews and focus groups were used less frequently but were still quite common. Surveys were tailored to the content of the particular media presentation and often used combinations of Likert-scaled items and open-ended questions. Given the choice of methods, the findings of these studies primarily focused on self-reported knowledge gain and attitude change, as will be described further in the next section.

Sampling Most often researchers used a convenience sample, easily obtained by recruiting viewers and listeners, or by intercepting patrons of an IMAX-type presentation. Sometimes, based on the target audience proposed by the producer, an evaluation used a quota sample, so that specific demographic characteristics were included in the research. Basic breakouts by demographic groups were the only results presented, however, usually because of small sample size and limited expectation for the reach of the research.

Timing of research We found most evaluation efforts to be relatively short-term, e.g., studies that assessed exposure immediately following the presentation and then followed up with viewers/listeners after a short period of time had passed, normally two weeks to one month. For location-based media settings (planetariums and IMAX-type theaters), intercepting visitors before and after the presentation is likely to be the only time a researcher would have access. Follow-up telephone calls or email contacts permit assessment of more delayed impacts. For broadcast media, the respondents can be viewing/listening at the time of broadcast, and then complete a questionnaire or be interviewed in the days and weeks that follow. Or, the audience members can receive DVDs and CDs to view/hear at a time convenient to them, within a given time period. Evaluators of *Einstein's Big Idea*, for instance, used a combination of these two approaches. They recruited participants from an existing database of PBS viewers, asked participants to watch the broadcast of the program and provided DVDs to those who were unable to do so.

Research Findings

Based on our understanding of how adults learn and the context for interacting with informal science education media, we examined the research reports on science media programs. Our basic analysis seemed to elicit four traditional categories of evaluation outcomes: learning, engagement/enjoyment, attitudes, and behavior. Each project seemed to tackle one or more of these evaluation outcome categories based on the goals established for the media products by the producer and were selected for study at the time of the proposal.

Learning Efforts to measure learning from the science media materials were the most frequently noted outcome studied in the evaluations we reviewed. However, the way that "learning" was addressed varied from study to study and, for the most part, was not a well-defined construct. Researchers took different perspectives of how to best measure the learning outcomes for each project:

1) Self-rated level of learning
2) Subjects answer questions related to content learning
3) Observable learning outcomes (applied knowledge)

Most studies focused only on viewers'/listeners' ability to recall information from the program itself. Participants' ability to recall that they had seen the program under study days or weeks after the event was typically greater than their recall of actual content or information from that show. Unlike research on children's programming—often conducted in school where assessments are a normal part of the day—adult viewers and listeners were not likely to take or complete a pre- and posttest on their knowledge of the subject matter and few of the questions asked by the researchers sought to explore specific knowledge that was based on the program content. However, some evaluators made an effort to compare recall between control and treatment groups. This was the case in recent evaluations of *Discoveries and Breakthroughs Inside Science*, and to a more limited extent in the evaluation of *ScienCentral* where recall among more frequent viewers was compared to that of less frequent viewers.

We found even less focus on assessing people's ability to apply what they had learned and/or to take action based on the contents of the informal science media programs. A few evaluators made an effort to infer learning outcomes based on observations of the participants, but it was more common for evaluators to draw conclusions about learning from self-report data about what or how much was learned in the most general sense. We did not find any transfer tasks that would let the researcher see if the knowledge acquired through viewing or listening could be applied in different settings.

Since our focus was on impacts of ISE media efforts and we looked primarily at summative evaluation studies, we did not find much information on the formal features or production and presentation elements that influenced learning outcomes differentially. Some of this may be found in formative evaluation studies and have informed the productions that were later studied for audience impacts. Even so, from the few formative evaluation studies we examined, formal features was not a major concern; most formative studies explored appeal and comprehension and did not link well-defined production features to audience responses.

Engagement/Enjoyment (Affective Response) Engagement can be associated with attention to the program, but attention measures, time-sampled observations, and instrumentation to assess enjoyment during the program were rarely used with adults in the studies we have seen. Most often, attention and appeal are self-reported attributes marked on a scale. Some evaluations explored the reasons why members of the audience felt more (or less) engaged by the program (e.g., personal interest in the subject, age/point in life, etc.) and why some content was more (or less) engaging (e.g., style of program, level/newness of content, etc.). Several evaluators found covariance in participants' preference for a program/frequency of viewing or listening and self-reported levels of engagement and enjoyment; higher levels of enjoyment were commonly reported among more frequent listeners/viewers. For example, a paper published in *Informal Learning Review* about evaluation findings for the short-format science radio series *Earth & Sky* reported that program appeal and engagement were highest among regular listeners. Similar results were found in the evaluation for *Science Friday*; interest in listening was found to be higher among those with higher interest in science and increased listening correlated to more enjoyment of the program. Whether more frequent listening was the by-product of engagement/enjoyment or vice versa was not explored in any of the studies that we reviewed.

Interactions with program-associated websites can be more tangibly measured by using Web metrics to capture how long a user spent on a site, how many links were clicked, how many parts or features of the site were explored, and what was downloaded from the site. This operational definition of engagement doesn't transfer easily to television or radio programs, but it does provide an indication of the appeal and value attached to the content and/or the qualities of the Web site. Website evaluations also included a fair amount of self-reported data, for example, in the evaluation of *Strange Days on Planet Earth*, evaluators asked visitors to indicate how much they liked the website on a scale of 1 to 7 (the resulting mean was 6.3), and were also asked to comment on how interesting the found the content to be (mean, 6.3), and how visually exciting they found the site to be (mean rating, 6.2).

For both website and the associated broadcast media, producers often try to balance the needs of different parts of their projected audience in order to appeal to the many. Evaluators reported whether the materials were perceived as too difficult or too simple, but often did not establish an anchor point for what is easy or hard, so it was difficult to assess how initial perceptions of relative levels of difficulty influenced viewers and listeners.

Attitude Change A commonly-used outcome measure is the attitude scale or a series of questions asking for the participant's attitude towards science in general and/or the science content in the program. Several evaluators found evidence of attitude change among the participants included in their program evaluations. Attitudes toward science were more favorable after exposure to many informal science education media programs/products. An evaluation of Science Units aired as part of *The NewsHour with Jim Lehrer* revealed that interest in science topics, and science in general, increased among viewers. Evaluations also revealed that in some cases people were more likely to believe that science played a positive change-making role in our world and came to be more aware of the part that science played in helping to advance technology, health care and general quality of living. For example, an evaluation of *Discovery and Breakthroughs Inside Science* found that, as a result of exposure to the program, audience members believe they could understand science and math, and led people to alter previously-held beliefs that science does more harm than good. Evaluation participants in other studies reported greater appreciation for science in the world around them, a finding applicable to the natural sciences, physical sciences and biological sciences (e.g., viewers had a greater appreciate of the natural world in an evaluation done for *Earth & Sky*). Conversely, some evaluations showed changes in people's attitudes about how much we, as humans, have contributed to environmental problems, as reported an evaluation for *Strange Days on Planet Earth*. People were also found to have more positive attitudes about their ability to understand scientific concepts. However, only a handful of the studies we reviewed made an attempt to distinguish between the attitudes of viewers/listeners/users and non-viewers/listeners/users (e.g., as was the case in evaluations we reviewed for *Earth & Sky*, and *Science Friday)*.

Behavior Change Many, but not all, of the programs whose evaluations we examined sought to change, not only the audience's attitudes, their knowledge, and their enthusiasm, but also their actions. The options ranged from further exploration of the content on associated websites to going on field trips to sharing their opinions with others. Most studies only measured behavioral changes in terms of very basic self-reported follow-up activities (intended or actual). Among those, the most common were talking with others and seeking additional information about topics through other resources (including other media sources). Depth of internalization of information as evidenced by reported conversations with others varied quite a bit. In some instances, audience members reported casual conversations with friends and families, others reported or demonstrated an ability to engage in more meaningful dialogs, and occasionally debates, about topics. For example, evaluations of *Discovery and Breakthroughs in Science* found that people were using more scientific terms in follow-up discussions with others and that more STEM-related conversations were taking place in general. There were only a handful of instances where evaluators sought to learn more about specific and targeted changes in behaviors, e.g., greater stewardship of our natural environment. In the evaluation of *Earth & Sky*, evaluators explored specific actions by listeners following exposure to the program and found that 14% spontaneously reported doing some science-related activity including looking at sky, discussing the program with others, and reading and searching for additional information on the Internet. When given a checklist, 74% said they discussed the show or did other related activities. Understandably, action in response to the program was greatest among more frequent listeners. Two-thirds of *Science Friday* listeners reported discussing topics with others and half had read related material in other sources. Similarly, half of all *Weather Notebook* listeners reported that they had told family or friends about the show and what they had learned.

Gatekeepers A few studies commented on importance of broadcasters as part of the process of getting program to audiences. While almost every producer of science media wants prime time exposure on PBS or NPR to reach the widest audience possible with their products, not all are able to achieve this goal. The importance of gatekeepers in science media projects, including the marketing efforts for giant screen film, is critical in getting the material out for consumption. While most evaluations have pursued the audience, a few studies have looked at the responses of broadcasters and editors to assess their view of the products (e.g. a survey or radio programmers and interviews with newspaper editors done as part of evaluations for *The Weather Notebook*). These handful of studies targeting broadcasters/editors, researchers came to better understand the limitations and constraints associated with airing science programming as well as programming characteristics (e.g., length and relative appeal of program titles) that influenced the decision-making process.

IMPLICATIONS AND DIRECTIONS FOR FUTURE RESEARCH

It is surprising how little we know from the research on science media intended for the adult general audience. There have been several decades of media creation and for much of that time, NSF—the major funder of many ISE media products—has required formative and summative evaluation and occasionally funded efforts to identify effective research. Nevertheless, as they say in the production business: The money needs to be on the screen.

Formative evaluation and impact research appear to have served very different functions for the production groups who designed and produced new media materials. For many, but certainly not all, production teams, formative evaluation was a useful intervention in the life of the creative process; if helped identify weaknesses that could be corrected and informed the development of associated websites and outreach. However, research on impacts and outcomes was often not as valuable as good reviews and reasonable ratings for getting to the next production effort. Impact research was more for the funder, and consequently was often seen as "a necessary evil," a luxury more than a necessity to see whether they had created had the intended effects. Mere presence of an outcome study met the requirements of the grant or contract. Formative evaluation had proven worth, as producers were able to see how the information would help evolve their products. Summative or impact evaluation came too late in the process to have any effect on the materials in distribution.

Among the studies we reviewed, the rigor of the research methodology, its atheoretical position, and the selection of outcomes to assess, may be a function of both the major funders who, until recently, have not been particularly demanding, and the production groups who are not prepared to interpret the methods and findings of more sophisticated studies nor allocate the funding necessary to conduct them. Researchers are dependent on self-report as an efficient way to obtain information about the audience's reaction to the program. The additional cost and effort to conduct more rigorous research—identifying valid and reliable measures of science learning, using validated observational strategies and protocols, obtaining larger and more carefully-drawn samples of participants, and applying more powerful research designs—are the factors that constrain the findings we have seen.

That is not to say that individual efforts have not been more rigorous, just that the preponderance of studies have failed to find significant, consistent, and meaningful impacts of the treatments they have studied. Much may be excused, because the treatments are so modest; rarely is a person's life changed dramatically because of a 48-

minute film. But more powerful research strategies might yield more information to share with producers and funders. Single variable analyses, such as comparisons of *Science Friday* listeners vs. non-listeners on sources of science news is an illustration of a more thoughtful and thorough approach. We saw little effort to conduct multivariate analyses using, say, attitude variables as a predictor for follow-up behaviors (e.g., are people with positive attitudes toward science more likely to discuss shows with others?). Again, given what one would expect as the modest treatment of individual programs, researchers may be forgiven for their reticence and unwillingness to push harder. Without the support of the funders, this effort is not likely to move towards greater rigor.

In recent years, federal and foundation funders of informal science media materials have begun receiving pressures to justify their spending and, subsequently, have begun to press grant and contract recipients to increase their efforts to understand impact. After a review of recent and current science education RFPs from NSF, IES and NIH, discussions with groups proposing ISE media development, and conversations with researchers and evaluators who often work on these projects, it is clear that there has been a shift in the demand for greater rigor in seeking answers to questions about impact. Accountability and findings of impact were increasingly important to those who supported the development and dissemination of informal science media materials. Over the past two years, evaluation, and especially outcome studies, have been funded at higher rates. Program directors are encouraging more rigorous evaluation and research, seeking greater confidence in findings, and insisting that project directors allocate more resources for impact studies. Increasing demand for more rigorous evaluations and more complex research questions also means a greater variety of research methods and perspectives might be applied.

This new support for outcome and impact studies points to the weaknesses of past efforts. To suggest actions and strategies for future evaluation and research, we need to build on our understanding of the limitations noted in earlier studies. So, what's missing . . . and what can be done.

<u>*Assessments of depth of understanding or behavior*</u> While modest treatments and limited resources do constrain the impacts that evaluators have chosen to study, there do seem to be many opportunities to be taken. By using fewer subjects and spending more time with them, researchers could explore standard outcomes in greater depth. Does "discussion with others" mean mentioning a few factoids at the water cooler, or engaging in parlor chats about the nature of science? What are the content elements shared with others? Are they core to the program's message or particularly salient to the individual? When people read information on a website, are they looking for basic science information or its

applications to their lives? What are people learning and how, precisely, do they follow through on what they've learned?

Evaluations have mastered studies of the surface features, tapping into outcomes that are easy to capture. By using more innovative strategies and more powerful methodologies and going deeper into core outcome issues, we may find out more about impact and what leads to it.

There are some hypotheses or goals about what people are expected to learn in the reports we have seen, but no theories articulated in these evaluations about how people are expected to learn, or why the delivery method (e.g., radio broadcasts) would be expected to have an impact (e.g., greater attention through the immediacy and authenticity of the message). Some research plans have implicit theories about the nature of the interaction with media and possible outcomes, but none of these are stated as theoretical propositions or bases for the research. It is possible that information on approaches to learning can be found in the production proposals themselves. Using a framework, like the one we used in our analysis, might help both production teams and evaluators identify and clarify the elements in the project that can be efficiently studied and build the research more carefully around them.

We also encourage further speculation on what the production of science media might look like if it was based more explicitly in psychological theory. We would expect greater attention would be paid to production aspects that would make people savvy about the media such as consistent themes, attention to prior knowledge, and awareness of process of scientific discovery. These are difficulty to achieve in one-offs where learners may enter and exit the experience with different degrees of knowledge. In such programs there is no overall curriculum plan and consistency in goals of what they should take away from the program—a stark contrast to the serialized content of children's science media.

Further attention should also be given to understanding the process of adult learning from media and the characteristics of productions that facilitate or impede this process. The sources of such understanding may emerge from an integration of theory and research from several fields, including mass communications studies, social psychology, and cognitive science. The framework we presented on adult learning from media could be a starting point for articulating the process, identifying alternative models or model components, and generating measures and methods to test those models. Work such as Miller and colleagues' path analyses of the factors influencing learning from science media (Miller, 2001; Miller, Augenbraun, Schulhof, & Kimmel, 2006) provide examples of how theoretical, psychological research on informal science learning could be pursued.

Cumulative, long-term studies of multiple influences on science learning.
Miller (2001) notes that:

> *constructing a measure of free-choice science-education resource use indicates the value and necessity of viewing free-choice learning broadly rather than viewing its components singly. The literature illustrates that single free-choice science education activities – museum visits, science television viewing, science magazine reading – have few significant effects. But recognizing that individuals select from these resources as if they were a smorgasbord and tailor their menus to their own interests and needs provides an important analytic and programming insight into free-choice science education.* (112)

One strategy is designing research studies that use the individual rather than the intervention as the object of study. It is the accumulation of learning opportunities over time, such as multiple visits to museums (Falk and Dierking, 2000) that may lead to greater understanding of science concepts; repeated visits may lead to familiarity with exhibits and greater liking of that which is familiar. But does the accumulation of science learning from NOVA or other series of disconnected programs lead to greater concept mastery or science-related activity? How is this learning mediated by opportunities to act on or apply this knowledge? A research agenda focused on cumulative learning from media could contribute greatly to the fields of communications and cognition. Children's expertise on self-selected topics such as dinosaurs and trains is well-documented (Chi, 1978, Crowley & Jacobs, 2002). Those children grow up to be adults with similar capacities, and at times identical interests. Studies of adults' developing scientific expertise, and the media that influence learning, would enrich the studies of their younger counterparts.

Furthermore, data collection proximate to the event seems to be standard practice, regardless of whether the goals of the program are short term or have a longer perspective. While a longer-term evaluation might be possible and sometimes even quite desirable, the researcher is not driving the project or its timeline, the producer is. Once the program is completed and broadcast/distributed, the producer is likely to want to close the books and move on to the next project. The outreach and website support are likely to be passed on to others rather than remaining with the production company. A proposal to extend the research effort for another six months or a year, might not be well received, since it means that the findings would be delivered to team members already deployed to other projects, that a budget that they had hoped to close out and a final report that now needs to be prepared to finish the project for the funding agency. Reality has trumped desirable research, time and time again.

Recent pressure on traditionally "low-cost, low-yield" evaluations to incorporate more quasi-experimental designs in hopes of getting better outcome data have yet to pay off—and probably won't until the available resources are increased and project reporting deadlines are extended.

Group observations or assessments Except for those reports that included focus group studies, most research and evaluation studies used individuals as the unit of analysis. There's no sense of how knowledge is co-constructed by dyads or groups of individuals, and no sociocultural theories underlying the evaluations. In contrast, there is a growing body of research on knowledge construction in museums by both adults (Leinhardt, Crowley, and Knutson, 2002) and parents and children (Crowley & Galco, 1999). We recommend that greater attention be given to the ways in which adults process information from media in groups, whether they be discussions between commercials, the coffee klatches discussing the latest NPR science segment, or the online discussions on a science website. Cocktail conversations are more than outcome events to be counted, they are opportunities to study the sociocultural processing of informal science media presentations. Researchers should be noting more than the event and explore the contents of the discussions more fully.

Multivariate analyses that link attitudinal changes to behavior The reports we examined presented few analyses of individual differences in learning from media, save for those who presented variance data or t-tests on impact differences by gender or age. Multivariate analyses, along the lines of Miller, et al's (2006) study of learning from science newscasts would cast a wider lens on the interaction of demographic and psychological factors that influence various learning and behavioral outcomes. Such analyses—when constrained not only to measures that are valid and reliable but also that are also grounded in theory and observed practice—could help identify when and where media has the strongest influence on changing attitudes and influencing behavior. As audience studies further differentiate the viewing audience, multivariate analyses can lead to more predictive outcomes based on media and audience characteristics.

Measures that replicate or leverage assessment and accountability in formal settings
For decades there has been movement in the formal education literature for "authentic" instruction and assessment (Archbald & Newman, 1988). The terms may be ill-defined, but the goals are worthy: connecting what is being taught and learned with applications likely to be encountered in the real world. Arguably, in-school and out-of-school settings are different enough that it may take significant effort to use methods developed for in-school use for studies in the adult work and home environments (Bass, 2005). Many of the research methods used to studying informal science learning are traditional school and higher education data collection strategies, such as surveys and interviews. It is

possible that these traditionally constructed methods don't tap into the ways people actually learn in informal settings. Assessment and accountability are not well-defined, so it's hard to identify any methods that could even be leveraged.

How does one assess learning from science media? During the design and pre-production period—perhaps even at the proposal stage—the project team needs to operationalize the outcomes that they think the program will elicit. And those outcomes need to be more precise than "Improves attitudes towards science" because the operationalized outcomes become the basis for the impact study. Once learning outcomes have been identified, researchers can better tailor their instruments to capture it, incorporate more rigor in their instrumentation and hence, collect better data. Perhaps grantors, if an outcome study is important to the grant, need to insist on a sign-off for both the producers and the evaluators prior to funding.

Sample selection strategies that capture a broader swath of the likely audience members
A concern across the studies reviewed is the likelihood of selection bias from participants. Those who don't watch are not likely to participate in studies; it is much more of an opt-in strategy than a sample selection procedure. As a result, feedback and improvements may adjust the programs for the specific audience members reviewed, thus potentially narrowing the niche market for media materials. Research subjects need to be recruited from a range of sources beyond the station membership lists in order to obtain feedback from a wider sample that more closely resembles the potential audience for the event.

Weak sampling strategies limit the generalizability of the findings, but greater efforts to recruit a more acceptable sample may be beyond the budget of many projects. It is more difficult and costly to undertake multiple recruiting strategies to reach a more comprehensive sample of likely viewers/listeners. There are many instances where it would be nearly impossible to find a good sized sample of people who have seen particular programs on their own. Often a PBS broadcast of a science program might reach one to three percent of the total TV viewing audience. Reaching a sample of that one percent of viewers would be a daunting and costly task at best.

To make it possible to reach a large number of audience members efficiently, many studies "seed" copies of the program on DVD or CD to those who are willing to view or listen at home prior to completing a questionnaire or participating in a focus group. These "audiences" may not be representative of the actually audience for the program, but at least some of their demographic data are likely to be available. Seeded viewing is artificial, and outcomes may ultimately differ from those that occur as a result of natural/non-seeded viewing, but it is often more effective to provide participants with program materials to review rather than trying to find participants who have viewed or heard the program on their own—the later can turn out to be the evaluation equivalent of finding a needle in a haystack.

Finding viewers of giant screen films and planetarium shows is less difficult: Intercepting patrons as they are coming or going from IMAX theaters or planetariums is a common practice. There are challenges, however, in recruiting participants who are reluctant to give up time to participate in research activities since they have made a special effort to be where they are and doing what they are doing; taking time out for research is not a high priority in this context.

RECOMMENDATIONS FOR MOVING FORWARD

By acknowledging the limitations of existing research and the barriers to improving it, we can consider strategies to move the effort ahead. What is required is a joint effort of the funders of ISE media projects, the producers of the media materials, and the researchers who will study it.

Policy and Practice and Research Learning about learning from informal science media is not a research issue alone. Development, production, and funding strategies favor formative evaluation over summative studies, because the former can help immediately improve the product. In the media business, the preponderance of funds have to go to creating the engaging and informative products that audiences will come to see and hear. In many ways, producers are the gatekeepers for the research effort and need to be educated and enticed to take the next steps. Research to improve the product is immediately valuable; that to build generalizable knowledge of the general audience and how they learn is valuable only in the long term.

Media projects tend to be content driven with a focus on production and the potential to reach an audience. Theories about learning or engagement are not often a concern or of interest to production people; theories about learning may get in the way of telling a story or generating interest by recasting the direction to content rather than narrative. Unlike many programs in the Department of Education or other parts of NSF, Informal Science Education doesn't encourage consideration of theory-based efforts. That does not mean that the programs are developed without some implicit belief about how to design content that will engage and inform audience members.

Because the most powerful readers in funding panels are producers of science programs, and because most production and budget detail is about the media aspects of the proposed project, discussions rarely engage issues of theory and why this program, if funded, will or will not have an impact. Theory is not explicit and project development does not rely on organized learning or media theory to drive content and narrative. Academic researchers, as well as evaluators, should have a say about linking theory to practice.

We suggest the following ideas for consideration:

- Proposals for new media projects should reflect current knowledge about learning and those with knowledge of how people learn from the media should be among the readers. This happens to some degree, now, with NSF. However, there is still some discontinuity between the producers of science media and the evaluators of NSF proposals. The former have skills in communication, and the latter have expertise in learning theory. More efforts are needed to encourage productive collaborations that build capacity for the media producers.

- Science media should focus more on science as a process than providing information on an interesting phenomenon or fact. Public understanding of science and science literacy may depend more on people learning that science is a complex activity, building on past learning and being willing to change based on new information. We also need to take advantage of science as news and science as theory building. Science news—in newspapers, on the radio and television, and through the internet—are often portraying preliminary findings, incomplete information, and sensational conclusions. They can engage and encourage curiosity and further exploration, but they need to be understood for what they are. Science documentaries have different attributes and can provide historical perspective, the notion of how scientific understanding has changed over time, and the extent to which findings can be interpreted and generalized. The audience needs to understand how to evaluate contradictory information and take action on real probabilities rather than subjective ones.

- Can we build a knowledge base of effective production features from the accumulation of formative evaluation findings? The data may be particular to the individual program, but a continuing collection of the formal features of various productions that capture attention and may lead to knowledge or behavior linked to the program. In children's series, producers are willing to explore variations in presentation form, following the model established by *Sesame Street*. That children's series had an enormous amount of material to create and program. A one-hour special does not have the variety of content to explore nor the ability to become as granular with the narrative as a tightly-scripted, multi-episodic children's program.

- While it may run against the grain of producers, we can gain value from conducting studies comparing one program with another. Is there a difference in audience reaction from one program about sharks to another? What are the features of one show that captures more attention than another show might? Which generates more knowledge gain or stimulates more follow-up activities? And what are the characteristics of programs that motivate an audience to engage some action? These kinds of comparisons can help us learn more about how to design a show that leads to more understanding of science, more follow-on actions, more water-cooler discussion.

- Longitudinal studies have a great deal to contribute. They have no immediate value to production teams, so the opportunity has to be taken at the institutional level. Is there a difference in reactions from an occasional viewer of a program on nature or one who never misses a science show on PBS? Can we learn about adult learning with a longitudinal sample of adult viewers/listeners? Do ideas about how science works accumulate for regular viewers? Researchers need an opportunity, free from a single program (but perhaps taking advantage of a series like NOVA), to study the impact of consistent viewing of or listening to science media. Does watching Discovery Science create scientifically-literate adults? Or do scientifically literate adults tend to view Discovery Science?

- Building on our knowledge of children's informal science media, can funders encourage producers to build in common elements to their products—elements that are repetitive and foster a greater understanding of science among viewers and listeners. Perhaps a theme for a year's funding cycle would lead to building a body of experience for the audience. Examples of these elements include: how our understanding of the phenomenon has changed over the years based on the process of science, what evidence was necessary to arrive at our current understanding of it, what might the next research steps be to enhance our understanding or modify it further, and how the ideas can engage citizens. Science literacy is crucial to an informed electorate, and citizens need to understand both facts and process to make informed decisions.

- Funding levels for research and evaluation need to enhanced and summative studies may need to be funded on a separate track from the production efforts, perhaps matched from a different funding pot. Along with further funding should come a demand for more rigorous and powerful research methodologies. Studies need not be only Random Clinical Trials (RCTs) and matched-control group efforts; media may call for different kinds of studies that fall outside of traditional research paradigms. For instance, producers may want to use authentic assessments that assess how effective a program is in getting its messages applied in the real world. Not every program is *An Inconvenient Truth*, but more modest actions might be identified after viewing a natural history program or one that deals with the environment.

- We can learn much by going deeper into modest outcomes, such as exploring the content of water-cooler discussions, or asking why people bought the book accompanying the program, or following-up on what happens to the downloads from the accompanying website. The trade-off may be fewer research subjects, but the ability to delve further into their reactions and responses to informal science media may have greater pay-offs. Deeper studies also means different methodologies, so RCTs may be put aside for more qualitative efforts and descriptive reports. But these, too, will yield useful information about the impact of informal science media projects.

- NSF may need to create incentives for programs that move the needle, perhaps more funding for dissemination or outreach. Right now, whether the program has any impact is less important than that it finds a reasonably large audience, wins awards and critical acclaim, or meets high production standards. While we're not suggesting a "What Works Clearinghouse" for ISE media projects, some recognition of what is effective would be an incentive for those planning to go back for further funding of new projects. Given a broad definition of impact that is based on rigorous qualitative or quantitative research, producers may find benefits in supporting summative research.

- We can also broaden the notion of where the audience is obtaining ISE media products. While there is no "science" or "math" category on YouTube.com, searching for science videos get more than 30,000 results. One search yielded: Highspeed vibration of cornstarch solution, followed by JunkScience: Global Warming Myth Busted, followed by Ali G "talks to some geezers about science and technology." I also quickly saw some National Geographic excerpts and an interview with Richard Dawkins. Math got me 11,300 hits, beginning with vedic multiplication and a lot of stuff on the Qur'an and math and even a Tom Lehrer song about the New Math from 50 years ago. The numbers and topics are likely to change daily, but the range of "science" and "math" topics is likely to be broad and certainly not vetted by scientists and mathematicians. Is there a strategy that will get better materials to show up on YouTube searches or through Google or other search engines? How do we resolve our struggles with rights issues, with vetting procedures, and with search strategies? If a new generation of adults is being raised on access to easily shared information, how do we ensure that they are information literate? If we can reach them through our existing channels of science media, or should we be trying to extend our traditional approach through synergies between radio and television to more interactive and more valued venues? Funders of science media will have to engage this issue over the coming years.

- There will be new media emerging that can help us learn more about how adults learn. Gaming may have a lot to offer at the moment, because so much of it is for a younger audience than this paper is seeking to cover. Male gamers continue into their late 20s, and can pick up incidental science content as part of games. The culture and ability to learn from games (see Gee, 2003; Prensky, 2000) can affect STEM learning within the context of formal education, but is too haphazard to easily impact serious gaming and the larger population of adults. Understanding how to manage a nuclear plant without it exploding might inform the player about nuclear energy. But the expense of creating sophisticated games, especially serious games, might limit the ability to reach a wide audience with this medium.

The delight and engagement that many of us find in watching or listening to informal science education media may be a sufficient outcome. But our investment has to produce more than sufficiency. Our country needs citizens knowledgeable about the sciences and their impact on our society and our environment. To reach this end, our efforts to create media that have an ability to entertain, to inform, and to create enough discomfort to stimulate action must be informed by research. Without greater understanding of what works, and how it works, and why it works, we cannot create the best science media we need. To know so little after so many years is disheartening; that we know how to learn more is the hope we have to develop an informed citizenry.

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