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Impact of Technology on Informal Learning

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Abstract

Diverse forms of educational technology facilitate and serve as resources for informal learning in a variety of out-of-school settings, including science museums and the home. This chapter examines studies of technology-based exhibits, mobile technology, and web sites, emphasizing those experiences designed for learning within the science museum context. It also addresses studies of narrative media, such as television and large-format film. Studies in these areas face greater challenges than those carried out in the classroom, and they are relatively limited in number. Nevertheless, they indicate the potential of educational technology in these contexts, which emphasize a learner focus, the role of motivation, social interaction, and just-in-time learning.

Introduction

The intent of this chapter is to provide an overview of educational technologies used for informal learning in science, technology, engineering, and math (STEM) in out-of-school settings. Because readers of this volume may be less familiar with this context, the chapter begins with a brief overview of informal STEM learning, followed by discussions of the various roles played by technology. The chapter concludes with a review of issues raised by the use of technology for informal learning, and directions for further study.

Informal Science Learning Environments

Rather than being guided by a teacher and a standards-based curriculum, informal learning is voluntary and self-directed, driven by intrinsic motivation based on widely varying personal interests. Informal learning is episodic, typically involving activities of relatively short duration, often mediated within a family or other social group. It can be considered the primary way in which most people learn most of the time, since the hours spent in school represent less than 10% of the average person's life (Jackson, 1968; Sosniack, 2001; U.S. Dept. of Education, 1991).

In content areas related to STEM, informal learning is facilitated by institutions established for that purpose, notably science-technology centers or science museums broadly defined (e.g., science centers, natural history museums, planetariums, zoos, aquariums, botanical gardens, arboreta, nature centers, and science-rich children's museums). They provide rich environments that offer visitors the impact and multidimensionality of tangible objects, multisensory experiences, and reality-based learning situations (Sweeney & Lynds, 2001), along with opportunities for social interaction. Some 75 million children and adults visit more than 300 U.S. science museums annually, primarily as family groups (ASTC, 2005). In addition to these institutions, libraries, community-based organizations, and diverse forms of media, including the Web, provide informal education in aspects of STEM along with other content areas to form a loosely interconnected informal science learning infrastructure (Lewenstein, 2001; St. John & Perry, 1996). Recent technology-based vehicles for learning enable organizations within this infrastructure to design virtual experiences that can overcome geographic, physical, and time constraints, enabling these institutions to reach an even greater portion of the public.

In many respects, the term “informal” is unfortunate because it is based on a contrast with “formal” classroom learning. This distinction is fuzzy, somewhat arbitrary, and at times incorrect; exceptions are common. For example, teachers in many classrooms employ the hands-on activities typical of informal learning, and formal instruction often takes place within informal learning institutions that have hidden curricula (Vallence, 1995). Nevertheless, at least in the case of museums, informal education can be differentiated in general from formal education by the nature of the stimuli, physical environment, overt behaviors, social contacts, and learning consequences (Bitgood, 2002). As encapsulated in the often-repeated quote by the former physics professor and teacher who founded the Exploratorium, “no-one ever flunks a museum” (Oppenheimer, 1975, p. 11).

The term “informal” has been applied to indicate the setting (outside of school), the process (without an instructor or self-directed), and the audience (other than students). In response to this lack of specificity, some prefer to use the term “free-choice learning,” emphasizing a characteristic of the learning (Falk & Dierking, 2002, p. 6). Others create a distinction between informal and non-formal. Also defined in various ways, “non-formal” is often associated with organized learning outside the formal educational system (Carlson & Maxa, 1997). Related terms include lifelong learning (Chapman & Aspin, 2000), out-of-school learning (Rennie, Feher, Dierking, & Falk, 2003), recreational learning (Ucko, 1998), and experiential (Kolb, Boyatzis, & Mainemelis, 2000) or experience-based learning (Andresen, Boud, & Cohen, 2000). Some authors make distinctions between learning that is intentional versus learning that occurs "in the wild" in everyday settings, which may be considered accidental, incidental, or implicit (Bransford et. al., 2006). The Learning in Informal and Formal Environments (LIFE) Science of Learning Center, for example, places emphasis on "emergent occasions of learning that occur in homes, on playgrounds, among peers, and in other situations where a planned educational agenda is not authoritatively sustained over time" (Bransford et. al., 2006, p. 216). Intentional and incidental learning can reinforce one another, however, as in the co-construction of "islands of expertise" through family activities that build on individual interests over time (Crowley & Jacobs, 2002, p. 333).

For the purposes of this chapter, "informal" learning will be broadly considered to encompass learning experiences facilitated by science museums and similar institutions, as well as other forms of self-directed learning that occur outside of school, such as in the home. The focus will be on those experiences that have been specifically designed for informal learners.

Studies on Informal Learning

In addition to the difficulties of sharply defining its domain, informal learning outside the classroom is typically more challenging to study than formal. The number of independent variables is considerably greater as a result of the many factors that influence an individual's personal, socio-cultural, and physical context (Falk & Dierking, 2000). As an example, preliminary studies within the museum setting indicate that certain variables—prior visitor knowledge, motivation, expectations, within group social interaction, advance organizers, and exhibition design—appear to play the most significant roles; other factors that influence museum learning include prior visitor experience, prior interest, choice and control, between group social interaction, orientation, and architecture (Falk & Storksdieck, 2005). Even focusing on a single concern such as making appropriate use of learning progressions, an area of active research for developing classroom science curricula (Grandy & Duschl, 2005), is far more daunting when applied to heterogeneous audiences of informal learners.

The scope of learning outcomes is considerably broader than the conceptual learning and cognitive gains traditionally assessed in the classroom, an emphasis accentuated by mandatory large-scale testing. Informal learning may have its greatest impact on attitudinal or behavioral change and the affective domain, stimulating an individual's interest in additional exploration and further learning (Meredith, Fortner, & Mullins, 1997). Yet affective state information is notably much more difficult to measure than cognition (Picard et al., 2004).

In addition, there are methodological obstacles to conducting research on "non-captive" audiences, whether museum visitors, television viewers, or web users. Studies often focus disproportionately on concerns related to usability, such as navigation. This emphasis contributes to the ease with which users can access learning resources, but it obscures larger, more critical issues. For example, understanding how, why, and to what end people use science museum web sites would help designers better select, organize, and present learning resources and activities. Understanding the impact of such experiences can also provide insight into how best to position this virtual resource in relationship to the physical science museum, other museum web sites, and complementary aspects of the learning infrastructure (e.g., books, magazines, television).

For these and other reasons, research and evaluation studies on informal learning are far fewer than those conducted in the classroom, and the fields are less well established. However, this situation is improving. Evaluations of informal learning practice, more common than research *per se* (although the two are sometimes conflated), are being carried out in greater number. The requirement that all projects funded by NSF's Informal Science Education (ISE) program include at least formative and summative evaluations (NSF, 2006) has been a driver over the past decade; most projects also involve front-end studies of target audiences and may include remedial evaluations as well. Beginning in 2004, the ISE program solicitation explicitly asked proposers to demonstrate how projects build on the results of prior work. To facilitate that outcome and enhance knowledge accumulation, the program requires grantees to post summative evaluations at the web site www.informalscience.org and has funded the Association of Science-Technology Centers (ASTC) to develop an ISE Resource Center (DRL-0638981) to disseminate research and practice further (www.insci.org).

Research and evaluation efforts have been supported by an increasing professional presence in the field. The Visitor Studies Association (www.visitorstudies.org) was founded in 1988, and the American Association of Museums formally established the Committee on Audience Research and Evaluation (CARE) two years later. The National Association for Research in Science Teaching has had an informal science learning strand since 1995. The Informal Learning Environments Special Interest Group (ILER-SIG) was established within the American Education Research Association in 1997. That same year, the first annual international conference on Museums and the Web (www.archimuse.com/conferences/mw.html) was held.

Although published informal learning research still represents a small niche within the literature of educational research, especially in the museum setting, these studies have increased in number over the past decade (Dierking, Ellenbogen, & Falk, 2004). The growth is reflected in the increasing frequency of special issues of educational research journals dedicated to informal science education in the last 15 years. They include the *International Journal of Science*

Education (1991), *Science Education* (1997), *Journal of Research in Science Teaching* (2003), and most recently a supplemental issue of *Science Education* (2004) published as part of an NSF-funded initiative designed to coalesce the last decade of research on learning in museums into frameworks for practitioners.

The increase of professional organizations and publication outlets indicate the growth of a field that historically has been characterized by extreme diversity in educational training and professional affiliations. As a result, research findings have been splintered into a wide array of publications or left unpublished. Consequently, in the view of one observer, "the result is a set of individual research case studies, which are difficult to compare and from which it is almost impossible to generalize" (Falk, Dierking, & Storksdieck, 2005, p. 5). The National Research Council's Board on Science Education received NSF funding (DRL-0545947) to conduct a consensus study that will attempt to draw together the disparate informal science literatures, synthesize the state of knowledge, and articulate a common framework for the next generation of research on informal STEM learning. This chapter will employ the lens of educational technology to help bring focus to a portion of the research literature.

Role of Technology in Informal Learning

As a result of developments in technology and their applications in museums, the home, and other settings over the past decade, technology-based proposals have been the fastest growing category of proposals to NSF's ISE program relative to proposals for museum/exhibit, television/radio, and community/youth projects. The field of informal STEM education has embraced technology for a variety of reasons. One strong impetus has been the desire to engage visitors through "hands-on" experiences, a hallmark of science museums today. Such activities are consistent with inquiry-based learning (Olson & Loucks-Horsley, 2000), constructivist (e.g., Anderson, Lucas & Ginns, 2003; Hein, 1995), and sociocultural learning theories (e.g., Leinhardt & Knutson, 2004; Ellenbogen, 2003), which provide underlying educational frameworks for learner-centered engagement with exhibits and related interactive activities. Another derives from the necessity to offer enjoyable learning experiences that cannot be readily duplicated at home or in school. This need is especially great for science museums, which must continually attract new and repeat visitors to their facilities to generate revenue.

Not surprisingly, there is overlap in the use of certain educational technologies within and outside the classroom, such as computer- and video-based programming. This chapter will emphasize studies based on those technologies and applications most commonly employed in informal settings in a way that is distinct from their classroom-based applications. They can be sorted more or less within existing taxonomies for educational technology, including those developed primarily to encompass formal learning applications. For example, most fit within the categories of "Learning Tools" [II.A.2 Educational Media and II.6 Interactive Learning Media] (ETRAC, 2002) or correspond to "Media for Inquiry" (Bruce & Levin, 1997, p.6). More closely aligned is the taxonomy of digital technologies developed for museum learning opportunities (Hawkey, 2004), which separates those offered on-site and online. Although these taxonomies provide overall frameworks, they are necessarily arbitrary and provide a classification system based on a particular set of criteria; alternative classification schemes could be derived from the learning environment, degree of interaction, or other aspects of the technology. For the purposes of this chapter, technology in informal science learning environments will be discussed in the following categories: technology-based exhibits, mobile technology, websites, and narrative media, such as television and large format films. Science museum applications will be emphasized over other settings because they have received more attention, especially compared to research on educational technology in the home (Kafai, Fishman, Bruckman, & Rockman, 2002).

Technology-Based Exhibits

Permanent and traveling exhibitions are the primary means by which most science museums engage their visitors with aspects of STEM content. These exhibitions contain exhibit elements, or exhibits, that typically involve technology-based interactive devices or “interactives,” which may be mechanical, electronic, or multimedia-based. They can range from simple low-tech devices, such as direct manipulation of a simple phenomenon, to those that are complex and high-tech, such as scientific instrumentation. Historically, science museums have pioneered the use of technology, such as computers, for public use. As an example, a major permanent exhibition was developed in the early 1980s using then state-of-the-art Texas Instrument TI-99/4A personal computers on which visitors registered views on the impact of technology on their lives (Ucko, 1983).

Interactive exhibits offer visitors the opportunity to explore real (and sometimes simulated) scientific phenomena, as well as aspects of historic and state-of-the-art technology. Interactives based on classical physics tend to be the most widespread because the phenomena lend themselves readily to direct visitor manipulation, although exhibits based on biology (e.g., Colson, 2005) and chemistry (e.g., Ucko, Schreiner, & Shakhashiri, 1986) also have been developed. Because the term “interactive” encompasses an extremely wide range of experiences, from simple and individual to complex and collaborative (Heath & vom Lehn, 2003), it is challenging to generalize findings about learning derived from use of these devices. In any event, one would do well to keep in mind, as these authors point out, that it is the learner who is interactive.

Science museums have begun to explore the use of newer technologies to create augmented and virtual environments (Roussou, 2000). Research on their impact, like other areas of technology in informal learning environments, is dominated by usability studies. An exception is a series of studies by Roussou and her colleagues (e.g., Roussou et al., 1999) that has demonstrated that collaboration in Virtual Reality (VR) settings, where users interact with a computer-simulated environment, increases the learning experience; much of this work, however, was conducted in the laboratory or in classrooms. More recently her work has demonstrated the critical role of interactivity for learning in VR experiences in museums and other informal learning environments (Roussou, 2004). The worlds of VR and augmented reality pose particular problems for integrating interactivity. How can people who visit a museum in a group together share the same VR experience? What distinctions are made between mere navigational interaction and control over the VR environment? These two problems weaken many of the existing efforts to measure learning in VR environments. Participants report a high level of engagement and enjoyment, but few qualitative or quantitative measures have demonstrated conceptual learning. In a study on the effects of learning at a virtual reality exhibit, de Strulle (2004) discusses an exhibit developed by the Reuben H. Fleet Science Center in San Diego with multiple kiosks that enable learners to enter a shared VR experience as personalized avatars. Within this interactive virtual environment, de Strulle found an array of critical design and instructional issues shown to facilitate and detract from learning in virtual spaces with implications for the development of future VR exhibits. Further work will be needed to demonstrate that this type of interactivity effectively mediates learning along with serving as an attractor.

Technology holds great potential to support inquiry practices in museums (Ansbacher, 1997). It has proven to be an effective scaffolding tool that helps learners engage in domain-specific inquiry (Lin, Davis, & Bell, 2004). Embedding supports for discipline-specific thinking into object- and phenomenon-based experiences changes learners' experiences by allowing them to participate in disciplined inquiry. Technology-based tools can supplement and assist, but do not necessarily have to replace, direct experiences in a museum. Rather, they make objects and phenomenon a central component of an inquiry, and then can further support learners as they extend their investigations beyond simply reading exhibit labels or even beyond a one-time visit.

Visitors tend to use technology-based exhibits more frequently, for a longer period of time (Serrell & Raphling, 1992). One of the explanations for this longer hold time, which is a measure of visitor attention, is "technological novelty" (Sandifer, 2003). In this study, technological novelty was defined when an exhibit either contains visible state-of-the-art devices or illustrates, through the use of technology, phenomena that would otherwise be impossible or laborious for visitors to explore on their own.

A concern sometimes raised is that technology-based exhibits may reduce visitors' interactions with other exhibits or objects in the museum, or worse, replace authentic experiences. In the case of object-based exhibits, technology appears not to compete but to engage users in a different kind of learning (Eberbach & Crowley, 2005). There are also concerns that technology may decrease social interaction that is a hallmark of informal learning experiences. The interfaces on technology-based exhibits, such as touch screens or joysticks, are often designed for one person (Flagg, 1994). Unless social interaction is prioritized in the design of technology-based exhibits, people will continue to be hampered in their efforts to use technology-based exhibits in social groups (Heath, vom Lehn, & Osborne, 2005).

Mobile Technology in Museum Exhibitions

Hand-held personal data assistants and data probes have been used to extend science learning beyond the classroom for years. These devices are ideal for just-in-time learning (Bransford, Brown, & Cocking, 2000) and field research (e.g., Soloway et al., 1999). Many of these projects occupy an overlapping space that falls between informal and formal learning environments, and hold potential for linking these environments across the educational infrastructure.

Personal or mobile devices are perhaps the most rapidly growing category of technology for informal learning environments. Mobile devices such as cellular phones, Personal Digital Assistants (PDAs), and portable digital media players (e.g., iPod) offer the potential to support self-directed and customized learning anytime and anyplace. An example of a project underway is "Science Now, Science Everywhere" (DRL-0610352) at the Liberty Science Center in New Jersey, where mobile phones are being used to expand exhibit learning. Podcasts and vodcasts (video podcasts) are becoming increasingly available on web sites of educational radio and television and programs. As noted in a recent review (Scanlon, Jones, & Waycott, 2005), emphasis should be placed on the mobility of the learner rather than the specific nature of the mobile technology, whose unique affordances include accessibility and immediacy, in addition to portability.

Museums have been relative early adopters of mobile technology in an effort to customize or to supplement existing exhibit labels and interactive components. Audio tour technology has long been used to supplement and enhance exhibitions. Mobile technology can now serve as highly personalized guides. For example, the Exploratorium, in partnership with Hewlett-Packard Laboratories and The Concord Consortium, developed the Electronic Guidebook, a portable device that allows the museum to communicate with its visitors in a customized manner (Fleck et al., 2002a; Hsi, 2003). Visitors are given a PDA, which serves as a tool for informing, suggesting, and remembering that they can carry with them in the museum. These Electronic Guidebooks provide information by creating what is essentially a homepage for each exhibit that can be accessed on the PDA; they also function as electronic scrapbooks by allowing visitors to bookmark webpages. Findings led the researchers to focus on more streamlined experiences. Fleck and colleagues (2002b) tested a simpler version that focused only on the remembering or scrapbook function. Following up several weeks later, the researchers found that most of the test subjects revisited the webpages that were bookmarked during their museum visit.

In addition to this kind of handheld device, Radio Frequency Identification (RFID) tags or transponders, small and inexpensive enough to be integrated into almost anything, can be used to personalize the visitor experience. In the *NetWorld* exhibition at the Museum of Science and Industry, Chicago, for example, RFID technology offers a central means of interacting with the exhibits by allowing visitors to create personal avatars. At The Tech Museum of Innovation in San Jose, CA, visitors to *Genetics: Technology with a Twist* can grow bacteria in a wet lab, using RFID-based Tech Tags to post results at their very own website, allowing them to track their experiment's progress online days later. A study showed that less than half intended to follow up and see the customized webpage (Eberbach, 2006). These findings contrast with those of a national study of museum website users that found that more than half were likely or very likely to visit a museum's website after visiting the physical location (Marty, 2005), raising questions for further research on these applications of technology.

Use of mobile technology in museums presents great challenges. In the Tech Tags study, visitors reacted very positively to the concept of being able to use technology to customize their museum visit, but at the same time, noted frequent technical complaints. The discrepancy between ideal and practical uses of mobile and ubiquitous computing will need to be addressed directly as they become more common. In an institution filled with hands-on exhibits, the devices compete for attention, along with the museum visitor's hands, eyes, and ears. Thus, there is a danger of the mobile device displacing the exhibit (vom Lehn, Heath, & Hindmarsh, 2005). In addition, the device typically prioritizes the individual user over the group. To overcome this limitation on social interaction, visitors sometimes group together in an attempt to synchronize experiences, pressing the "start" button at the same time or connecting multiple headphones to the same device. They may also divide tasks and share information, with one person attending to the mobile device and the other attending to the exhibit.

The challenges of integrating mobile technology into the museum experience are being addressed in numerous projects that are keeping pace with new developments in hardware and software (e.g., cell phone capabilities), as well as new uses for technology (e.g., podcasting). Less is known, however, about the learning impacts of these devices. One proposed rubric for analyzing the impact of handheld technologies is the extent to which they embody the characteristics of portable vs. static and personal vs. shared (Naismith, Lonsdale, Vavaoula, & Sharples, 2005). Sharples (2003) proposes that the most important requirements for successful mobile technology are portability, adaptability, availability, and usability. The focus, for now, remains on usability as museums explore not only new technology, but also metaphors to help visitors understand the function of the technology, privacy statements to assuage concerns, and even public orientation and training sessions (Hsi & Fait, 2005).

Museum Websites and Web-Based Museum Experiences

Websites have become a well-established technology used to supplement and scaffold museum exhibits. Science museums employ websites as an opportunity to expand their audience and activities by providing not only highlights of their exhibits or programs, but also synergistic content and programming. The Internet offers tremendous potential for self-directed learning, whether accessed at home, in a museum, or in a library. It has been called “one of the most powerful and important self-directed learning tools in existence” (Gray, 1999, p. 120). Characteristics that promote informal learning include providing independent access to information and resources, self-directed and self-paced use, and capability to build on prior knowledge.

Museums now use the web for such diverse purposes as webcasts, online exhibits, and virtual tours (Spadaccini, 2006). For collecting institutions, such as natural history museums, computers have provided the public with virtual access to at least portions of the artifacts held in storage. In addition, the web provides access to educational media, games, simulations, and scientific visualization. Some museums have created a presence on the web that rivals their physical institution. The Exploratorium (www.exploratorium.edu) and Franklin Institute Science Museum (www.fi.edu) host sites that attract millions of users annually. Allison-Bunnell and Schaller (2005) argue that any movement toward a virtual museum will require the field to reconceptualize the online science exhibit experience. For example, an object-based exhibit can become part of an online reference resource, or an exhibit that demonstrates phenomena can be transformed online to explain the underlying principle.

Not surprisingly, people are able to visit museum websites more frequently than a physical museum. A recent national study of museum website users (Marty, 2005) shows that visits to science museum websites are more frequent (weekly vs. quarterly), but significantly shorter than physical visits. The average museum website visit is generally under 12 minutes, while the average visit to science museums lasts approximately 2 hours (Semper, Wanner, Jackson, & Bazley, 2000). Half of all visitors who arrive at a home page leave after viewing only the home page, suggesting that either the person was quickly able to get the needed information or instead was uninterested, unsatisfied, or overwhelmed (Jensen, 1999).

There is limited research on the ways in which visits to museum websites influence or compare to visits to museums. The previously cited study of a website linked to exhibits through RFID technology (Eberbach, 2006) revealed that people who had access to the website were able to recall, on average, only one more exhibit than people who had not had access to the website. Preliminary research suggests that the motivations for visits to museum websites differ significantly from motivations for visits to physical science museums (Haley, Goldman, & Schaller, 2004). Typical motivations for science museum visits include entertainment or recreation, social activity, education, a life cycle event ("My mother always took me here, so now I take my children"), place ("We have to go to the Smithsonian while we're in Washington DC"), content interest, and practical reasons ("It's too cold to take the children to the park") (Moussouri, 1997; Rosenfeld, 1980). On the other hand, Haley, Goldman, and Schaller reviewed the research on website visit motivations to identify a different set of primary drivers: gathering information for an upcoming visit to the physical site, engaging in very casual browsing, and seeking specific content information as either self-motivated or assigned research.

These motivations make sense when situated in the larger context of how people in the US use the Internet. The Pew Internet and American Life Project (Fallows, 2006) shows that 40 million Americans surf the Internet just for fun or to pass the time per day in a typical month. Surfing for fun only falls behind using e-mail, using a search engine, or getting online news. The web has rapidly become the predominant source (52% of those surveyed) when information is sought by the public about *specific* personally-relevant science-based issues (National Science

Board, 2006). These numbers reveal that the motivations of the general web user are the same as the virtual museum-goers—entertainment and seeking information.

Web casts and virtual field trips that are broadcast online add a new dimension to museum programming. A webcast is generally a live online broadcast that allows people to participate in a tour or demonstration. Some science museums have developed webcasts with both asynchronous and real-time communication between staff and visitors. The Darwin Centre in London, for example, offers participants the ability to communicate with staff *via* e-mail both before and during the actual webcast, and then archives past webcasts for later viewing.

Museums are also creating alternatives to museum visits through virtual field trips. Typically a museum staff member or a scientist provides a tour of a specific research site or other facility to a geographically distant school group. The program allows two-way communication so students are able to ask questions of the museum staff. In the Jason Project, which originally started in 1989 using satellite technology, students are able to observe and communicate with scientists in diverse environments, such as rainforests and wetlands. Alternatively, students visit a webcast site at the museum where they link to an otherwise inaccessible site, such as the Liberty Science Centers' *Live From: Cardiac Classroom* and the Museum of Science and Industry's *Live at the Heart* project. In these programs, students view live, open-heart surgery. They are able to examine medical instruments used during the surgery and ask questions of the medical staff.

Another interesting web-based application is "citizen science," in which the public makes local observations that they transmit by means of the Internet to researchers who collect and analyze the resulting data. The Cornell Laboratory of Ornithology has pioneered this type of activity, which involves the public in scientific investigations (www.ebird.org); other citizen science projects involve observation of spiders, butterflies, and weather data (e.g., http://www.cocorahs.org). These projects are based on the principle that the web allows ordinary citizens to become involved in and contribute to ongoing scientific research. Programs such as the Great Backyard Bird Count draw as many as 50,000 people submitting data during a week (Bonney, 2005). This program represents an excellent web-based example of informal science learning that is based on three key elements: real science, real learning, and real partnerships (Barstow, 2005). These citizen science projects also engender a critical feature of web-based informal learning experience by allowing people to interact with each other rather than an organization (Bandelli, 2005). These programs, therefore, are situated between the highly-designed and mediated experiences of science museums and the less-mediated home-based experiences.

Narrative Media

Narrative media, such as film and television, employ diverse forms of technology for informal learning experiences. Large-format film or "giant screen" theaters, located in approximately one-third of science museums as well as other venues, show science-based documentaries along with other films. (The technology typically involves 15-perforation/70 mm film projected onto a very large slightly-curved rectangular screen or a dome.) According to one survey, more than one in three Americans annually see a giant-screen film, although not all are educational (Opinion Dynamics Corp., 2005). Because of the large frame size and extremely high resolution of the film, this technology immerses viewers into the projected image, whether photographed with special cameras or computer-generated. Planetariums employ optical or digital projection systems to create shows that incorporate images of the sky, space, and occasionally other scientific subjects. A recent article makes the case for digital full dome systems as a powerful tool for learning astronomy and calls for research studies on the best ways to use this technology (Yu, 2005). Laser projection systems, including 3-D versions, have been used in both planetarium and theater settings.

There are few studies on these technologies. Notable exceptions (e.g., Fischer, 1997) have focused on programming characteristics, such as humor, that have the potential to impact learning or impact specific audiences, such as school groups (e.g., Storksdieck, 2005). The most comprehensive study to date is a review of summative evaluations on 10 giant-screen film projects, including their supporting materials (Flagg, 2005). The evaluators typically measured changes in verbal knowledge and perceptions of scientists. All 10 of the studies showed a significant impact on viewers' verbal knowledge. Three of the ten measured perceptions of researchers and found that half or more of the viewers felt they learned something new about the lives and work of scientists and researchers. The studies were less likely to examine the impact of the film on viewers' interests and attitudes. Half (five of the ten) measured change in interest level, and only two of those five studies found a significant positive impact. These two films (*Stormchasers* and *Dolphins*) increased interest in learning more about related topics. Less is known about changes in viewers' attitudes. A study of one film, *Tropical Rainforests,* found that adult, youth, and child viewers had a significantly more positive attitude towards rainforests after viewing it.

Shifting from museums and theaters to the home, television becomes an important potential element within the informal learning infrastructure. It is the primary source in the US (41% of those surveyed) for *general* information about science and technology (National Science Board, 2006). Science- and math-based television and radio programs reach some 100 million children and adults each year. Educational science programming on television, once primarily the domain of the Public Broadcasting System (PBS), can now also be found on several Discovery Channels, National Geographic Channel, The Learning Channel (TLC), NASA TV, and others. Top-rated educational programming currently includes *Zoom* (WGBH, ages 5 to 11); *Cyberchase* (WNET, ages 8 to 12); *Dragonfly TV* (TPT, ages 9 to 12); and *PEEP and the Big Wild World* (WGBH/TLC & Discovery Kids, pre-K). *NOVA* (WGBH) is the most widely-viewed science program for adult audiences. Each of these programs also offers ancillary activities on the web, making www.pbs.org one of the most popular .org sites and informal learning resources worldwide.

Science programming has been part of television from its earliest days with such shows as *Watch Mr. Wizard* in the 1950s. Shows for young audiences in particular were spurred by the strengthening in 1996 of The Children's Television Act of 1990, requiring that networks broadcast three hours per week of educational programming for children. Others point to the increase of the child-related economic market (Fisch,2004a). Data on the impact of the earliest television shows is largely anecdotal (Newsom, 1952) but more recently, the study of science-related television has been extensive and more rigorous (e.g., Fisch, 2004b; Flagg, 1994; Rockman et al, 1996).

What sort of learning occurs as a result of science-related television? Fisch (2004b) characterizes three critical outcomes: (1) attitudes towards science, (2) exploration and experimentation, and (3) knowledge of science. Comparative studies of the impact of science and non-science television have demonstrated that viewers of science shows (e.g., *Cro* television program) were more likely to be interested in learning more science or doing science activities. Television with less of a narrative element, such as *Bill Nye the Science Guy* had less impact on viewers' attitudes. However, control group studies of the impact of *Bill Nye the Science Guy* found that viewers were significantly more capable of making observations and comparisons than non-viewers (Rockman et al, 1996). Thus, television can successfully model scientific processes for viewers. Some research results are not surprising, for example that older children tend to show greater gains in content knowledge. Other results, however, demonstrate the distinct impacts of this technology, such as effects that are strongest for girls, an audience typically underserved by technology.

Comparative study of the treatment of science across television genres (the narrative style of *Cro* versus the documentary style of *3-2-1 Contact*) found several significant differences (Fisch, 2004b). In the narrative format, scientific explanations were broken up and spread among multiple characters in contrast to the direct approach of the documentary format. Content was constrained in different ways. In the narrative format, content had to fit the setting (e.g., the *Ice Age*), but could be addressed on a scale that was impossible in the documentary format (e.g., *Giant Catapults*). The documentary format had the freedom to address a wider variety of content in more real-life contexts. A critical final distinction was the marketability of the narrative format television. These shows have been able to move beyond the more limited PBS audience to a larger and more diverse audience of Saturday morning cartoons, for example.

Although children benefit from viewing television by themselves, the benefits are generally said to improve if parents and children watch together (e.g., Reiser, Williamson, & Suzuki, 1988). These findings are similar to those based on family use of interactive exhibits in science museums. Using an exhibit or watching a television program alone provide accessible experiences to the child, but adult interaction can enrich or extend them (Fisch, 2004; Gleason & Schauble, 2000).

Finally, an enabling feature of the technology of television is its ease of use. Unlike the other technologies discussed in this chapter, children can watch television from an early age. Usability issues endemic to interactive websites, software, and exhibits do not apply to television technology in the same way (Fisch, 2004a).

Classroom Implications

Research studies on technologies for informal learning can benefit classroom instruction in a variety of ways. After all, "what's considered fun, good learning in informal settings could and should also be the norm in formal learning. Formal education could benefit from the emphases on personal involvement with ideas, open-style learning environments, and broad diversity among collaborating learners" (Strohecker & Butler, 2004, p. 151). Work in informal domain can help demonstrate for formal educators the importance of a learner focus, motivation, and non-cognitive learning outcomes, as well as the value of inquiry-based and constructivist learning approaches. The "emergence of rich constructivist environments can be facilitated by the emergence of powerful technology tools" (Karagiorgi & Symeou, 2005, p. 24), which are more likely to be applied first in informal learning environments.

"Technology transfer" from informal to formal settings may involve modification of the technology or conversion into suitable formats. For example, StarLab (www.starlab.com), a small-scale inflatable version of a planetarium, can be used to support the Planetarium Activities for Student Success (PASS) program developed by the Lawrence Hall of Science (www.lhs.berkeley.edu/PASS/) and other activities tied to the curriculum. Web-based informal programs, such as citizen science, where volunteers carry out research-related tasks, may be transported, as in the case of Cornell Laboratory of Ornithology's *Classroom FeederWatch* (www.birds.cornell.edu/schoolyard/). Existing materials may be repurposed as enhancements to instruction. For example, teachers can record or purchase copies of Cyberchase television episodes on topics in math. The companion web site offers teachers follow-up activities, interactive challenges, and video clips that connect the math topics to student interests and to National Council of Teachers of Mathematics (NCTM) standards. Similar educator support is provided for *Zoom, Dragonfly TV, NOVA*, and other educational television programs; many of these materials are accessible through PBS TeacherSource (www.pbs.org/teachersource/sci_tech.htm).

Science museums, schools and community-based organizations have employed various forms of technology to enhance after-school programs, which take advantage of a range of computer and web-based software applications (e.g., www.kineticcity.com), wireless and mobile communication devices, Geographic Information Systems (GIS), and Global Positioning Systems (GPS), for example. Development in this area has been stimulated by NSF's Information Technology Experiences for Students and Teachers (ITEST) program (see www2.edc.org/itestlrc for examples).

Challenges to the Field

Because technology plays such a key role in most forms of informal learning, the question "how we *should* use technology—as opposed to how we *can* use it" (Parkes, 2004, p. 35, emphasis in the original) assumes great importance for science museums and the diverse panoply of technologies employed in other settings. Similarly, "the story of digital technologies in educational contexts has often been one of a solution in search of a problem" (Hawkey, 2004, p. 39). The limited but growing body of evidence from research and evaluation studies can help guide appropriate applications of technology based on the intended audience, content, and setting, as well as the design of the software or programming.

Educational research and evaluation involving technology must grapple with additional complexity beyond the general challenges faced by studies on informal learning mentioned earlier. The impact of the educational technology must be separated from other independent variables in settings that may not readily lend themselves to control groups or otherwise generalizable research. Furthermore, the interrelationship of hardware and software must be unraveled across a wide range of possibilities. The hardware may serve as the primary learning vehicle, as in a physically interactive exhibit, or it may be nearly invisible to the learner, as in a giant-screen theater. Similarly, software may be the primary driver of interaction, as on the web, or it may be essentially absent, in the case of direct physical interaction. Also, the role played by the interface, the means by which visitors or users experience the technology, whether or not mediated by software, may be underestimated (Parkes, 2004). In each case, it is design that shapes the interaction of the technology with the user. That design may be guided by best practices (e.g., McLean & McEver, 2004) and by models of informal learning (e.g., Falk & Dierking, 2000). However, a much more comprehensive body of educational research is needed in general to provide an evidence-based foundation for the creative design and application of informal learning technologies. Furthermore, this body of knowledge will need to be translated into forms that can guide practitioners.

Further study is needed in many areas. For example, what is impact of the physical and social environment in mobile learning? How can the design of learning experiences best encourage social interactions that facilitate learning conversations? This issue is especially important for personalization technologies that may isolate the user, inhibiting social interaction, unless the experience is designed for collaboration or sharing. One possible direction is offered by findings from study of “smart toys,” which show a potential for encouraging increased social interaction among children, along with providing rich learning interactions. (Plowman & Luckin, 2004) Another area that warrants further study is the role of gender and cultural differences in the use and impact of various informal learning technologies. Initial work indicates that girls and boys tend to prefer different types of online activities (Schaller, Allison-Bunnell, & Borun, 2005).

As the work cited here demonstrates, technology is no panacea for informal STEM education, and like all tools, has significant limitations. When the latest technology is employed for its ability to attract users, the technology itself may overshadow the educational application. Certainly users may still learn something about the technology itself, which can be of value, but not necessarily the intended outcome. In addition, an excess of technological novelty may lead to “cognitive overload” as visitors attempt to make sense of each new device (Allen, 2004). Of course, the simple act of using the technology does not necessarily lead to learning, which requires “minds-on” as well as “hands-on” interaction (Gregory, 1989). Especially if "high-tech," the technology may be complex to use and to understand. Its impact may be limited to "those already engaged in inquiry and who have sufficient prior experience to interpret the results of the technology" (Ansbacher, 1997, p. 3). From a practical standpoint, it is also challenging for institutions to introduce new technologies continually as a means for learner engagement as the pace of development and application to consumer products increases. If cutting-edge, or worse, "bleeding-edge,” the technology itself may be prone to breakdown and require frequent maintenance, confounding attempts to study visitor interaction and behavior.

Opportunities

Despite these types of challenges, informal learning technologies offer great potential that further research will only help to develop. Technologies increasingly enable personalization and customization, such as through visitor RFIDs in science museums. Portable and wireless devices bring mobility and remove place-based limitations, such as through web browsing with cell phones or PDAs, allowing "just in time" learning (Bransford, Brown, & Cocking, 2000). Similarly, the shift from broadcast to interactive media and "narrowcasting" makes possible highly targeted programming and information on demand at any time, such as via podcasts. These continuing trends will make possible greater connections across learning that occurs by different modes in different places at different times.

In response, place-based institutions must seek new strategic niches, which in turn can be facilitated by educational technologies. It has been suggested "the museum is the perfect place in which to produce a true physical hypermedia system" (Jones, 2002, p. 5). This direction is bolstered by the recommendation from a MacArthur Foundation-funded planning grant on Digital Learning and Play for further research and development related to "new hybrid spaces that blend physical and virtual environments and digital tools," (Hsi, 2005, p. 4). These combinations of learning resources must support interactive social group learning experiences, as well as authentic experiences augmented by appropriate technologies. In this way, "the integration of real and virtual will provide further powerful learning opportunities" (Hawkey, 2004, p. 38), creating places for sharing personalized learning experiences.

Furthermore, emerging network-based technological applications also offer great potential for informal STEM learning. They will likely be influenced by the "nascent revolution" arising from the advanced networking and distributed scientific knowledge environments of the evolving cyberinfrastructure (NSF, 2003, p.9). The NSF-supported Cyberinfrastructure for Education and Learning for the Future (CELF) initiative presents a vision of cyber-enabled learning that "will take place in the context of computationally augmented real-world environments, online communities of practice, interactive virtual environments, games, simulations, models, and audio/video/IM/SMS communications—not just in classrooms" (Computing Research Association, p. 9). The CELF vision also includes the intriguing notion of a Lifelong Learning Chronicle (LLC) that would take advantage of digital technology to provide a qualitative and quantitative record of learning over time. In these ways, "informal learning may harness ubiquitous computing environments of the future by providing 'learning services' to people in formal, non-formal, and informal settings, and by helping people to manage their personal learning goals, projects, and informal learning activities" (Roberts et al., 2005, p. 10).

More educational research also will be needed to understand the impact of aggregation of learning experiences that combine various informal modes, whether they occur in hybrid forms at one time and place, such as augmented reality, or as asynchronous experiences across multiple platforms, such as the combination of *Cyberchase* TV shows and an associated web site or *ZOOM* TV programs and *ZOOMzone* museum exhibits. These latter approaches take a step towards creating learning communities that cut across the institutional borders of museums, libraries, television, and other informal learning resources, as well as the formation of an "ecology of learning" in which various types of organizations serve complementary niches. Studying the interaction of the learner with the associated informal technologies in a particular environment, along with learner-to-learner interaction, adds additional layers of complexity, but will be essential for maximizing educational impact. The potential for embedded monitoring within interactive technology may be assist such studies, assuming that privacy issues can be addressed.

Conclusion

Learning technologies in informal settings can provide enrichment and extension experiences through such means as museum field trips, after-school programs, and home-based Web and television that are complementary to classroom instruction in schools, which are "just part of a broader learning ecosystem. In the digital age, learning can and must become a daylong and lifelong experience" (Resnick, 2002, p. 36). Enriched activities outside the classroom such as these have been associated with higher scientific reasoning ability for students (Gerber, Cavallo, & Marek, 2001). Studies identify pre- and post-visit preparation, teacher professional development, and integration with classroom learning as factors that reinforce the learning that takes place in these different settings (Anderson, Lucas, Ginns, & Dierking, 2000). Nevertheless, "further study of young people's informal learning with technology and its relationship to their formal training is both a research need and a gap" (Fitzgerald, 2005, p. 4).

Such studies, along with the work cited in this chapter, can help achieve more seamless student learning, creating "classrooms without walls" that break down distinctions now separating the formal and informal realms. In addition, they support the development of a science of learning that brings together "understandings of both informal and formal learning environments, drawing on the best features of all known learning environments to build the schools of the future" (Sawyer, 2006, p. 568). Research on technology-based informal learning certainly will not provide all the answers. However, it can suggest fruitful directions through an emphasis on the learner focus, role of motivation and context, customized just-in-time learning, social interaction, and home- and community-based activities (Sawyer, 2006). In so doing, emphasis on learners and learning can help guide the transformation of our schools in ways that make them most effective for preparing workers and citizens needed for our nation to be competitive in the 21st century.

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