Technologies and Tools to Support Informal Science Learning

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Abstract: This paper explores the role of technologies in supporting informal science learning from seven perspectives. Together, the authors ask a common question: How can learning technologies—tools, spaces, and places—be designed to support learners within and across environments? Eight exemplars are offered to answer this question through an analysis of a specific instance of technology in a non-school environment. Collectively, the authors examine the role of tools that support: access to and distribution of information; scaffolds to help learners tackle complex tasks and deeper understandings; bridging learning across contexts; feedback and reflection; extension of learning experiences in a temporal way; aggregations of visible knowledge, social interaction, facilitation of social practices, personalized learning, and the breakdown of epistemic authority. The authors and two discussants reflect on the methodological innovation, technological advancement, and collaborations needed to move research in this area forward.

Introduction

This paper explores the role of technologies and tools in supporting informal science learning. Authors come from a variety of perspectives: university learning sciences programs, training programs for designers and museum professionals, informal learning institutions, and technology development. From eight different perspectives, the authors ask and answer a set of common question:

> How can learning technologies—tools, spaces, and places—be designed to support learners within and across environments? How do these studies of learning technologies provide insight into how to support learners, not only within settings but also across environments? How can these learning technologies support field-level collaboration across institutional lines of practitioner, researcher, and evaluator?

The authors answer these questions by presenting analyses of technology use, development, and research in non-school environments. In their analyses, the authors examine the role of tools that support various learning processes in informal spaces, including:

- access to, and distribution of, information
- scaffolds to help learners tackle complex tasks and deeper understandings
- bridging learning across contexts
- feedback and reflection
- extension of learning experiences in a temporal way
- aggregations of visible knowledge
- social interaction
- facilitation of social practices
- personalized learning
- the breakdown of epistemic authority

These exemplars of technologies are also designed specifically to reflect learning and teaching in informal spaces, reflecting visitors' expectations and mirroring norms of behaviors in informal environments.

Background

This session work is part of a National Science Foundation funded community-building project, *Building Capacity and Collaboration at the Intersection of the Learning Sciences and Informal Science Education* (Intersection). The Intersection project brings together international researchers to advance research and practice related learning outside of school. The goal of the Intersection project is to develop a community that will further the aims of both the informal science education and the learning sciences fields by building on key publications over the last decade, including *How People Learn* (NRC, 1999), *The Cambridge Handbook of the Learning Sciences* (Sawyer, 2006), the latest NRC consensus volumes *Learning Science in Informal Environments: People, Places, Pursuits* (NRC, 2009), and *Surrounded by Science* (NRC, 2010). These books summarize what we currently know about the processes, content, and contexts of human learning in science inside and outside of formal schooling.

The Intersection project's community building efforts include knowledge sharing and writing projects accomplished through online forums, a website for sharing ideas, and a face-to-face workshop held in August 2009. The intellectual work and conversations that happen through the workshop meeting and in the online spaces highlight synergies, challenges, and opportunities that arise when the informal science learning and learning sciences professionals work together. The Intersection project participants are conducting studies and writing papers that make progress in four key areas:

1. Understanding the concepts of learning and engagement
2. Equity, access, and methodology in informal learning
3. Informal learning pedagogy
4. Tools and technologies that support informal science learning

This interactive symposium is a collaborative effort between a subgroup of researchers and practitioners who are participating in the Intersection grant activities focused on the last key area, tools and technologies that support informal science learning

The authors in this symposium are members of the subgroup interested in applying learning sciences and informal science, technology, engineering, and mathematics (STEM) education methodologies and theories in order to study how to facilitate learning, most broadly considered, with technologies in out-of-school environments. In addition to participating in the workshop and online forums discussed above, the technologies subgroup has formed a special interest networking group and a wiki to begin to synthesize what is known about learning with technologies outside of school. This subgroup cuts across research groups, involves emerging and established leaders, and includes both informal learning institutions and universities. (Note: this work is occurring with additional colleagues.)

The authors have organized this paper to share the findings from their work with the broader learning sciences field. They offer eight diverse designs and studies of technology-supporting learning to better understand how pedagogy can be conceived in out-of-school environments. An author or small team of authors presents each of the eight perspectives below; the authors present findings from an empirical study or set of studies. Then, together, the authors engage the audience in conversations across the studies towards deeper conceptual understandings about the nature of learning with technology that occurs on school fieldtrips, in museums, in homes, in afterschool clubs, and similar places.

Symposium structure

The symposium session will start with a brief introduction by the chair, Heather Zimmerman. Next, the first authors of each of the eight posters (David Kanter, Kirsten Ellenbogen, Leilah Lyons, Steve Zuiker, Tom Satwicz, Heather Zimmerman, Matthew Brown, and Sandy Martell) will provide a two-minute fire-hose presentation of their topic. The bulk of the remaining time will be spent in small group conversation between the audience and presenters. The groups will come back for broader discussion, sparked by initial comments by the two discussants, Sherry Hsi from the Lawrence Hall of Science (an interactive science center in California) and Brian K. Smith from the Rhode Island School of Design. The discussants will make comments on posters in regard to connections to educational practice in informal institutions, learning theory, and the National Research Council new report, *Learning Science in Informal Environments: People, Places, and Pursuits* (Bell, Lewenstein, Shouse, & Feder, 2009). After the discussants' remarks, the time remaining will be spent on full group discussions. Final questions to seed this group, if questions do not arise naturally, include:

> What types of methodological innovation are needed to move our understanding of the learning here forward? What types of technological innovation and collaboration are needed to realize the potential these authors put forth*?*

Exemplars

Exemplar 1: Using the demand for data in a project-based science curriculum to bridge high school biology classrooms and an informal science center by David E. Kanter, Temple University

This analysis reflects on work conducted as part of a National Institutes of Health Science Education Partnership Award titled, "Supporting Student and Teacher Inquiry in Bioscience," a partnership between Northwestern University (Learning Sciences) and Chicago's Museum of Science and Industry (MSI). The work resulted in a project-based high school biology curriculum, "Disease Detectives," and related software, "Village Park Mystery," closely coupled to the museum's "Live from the Heart," a videoteleconference to a real-time coronary artery bypass graft procedure, experienced by the high school students in the informal museum setting. To address the mystery of what was wrong with the people in Village Park, the curriculum and software were designed to help students reason through real data including patient case files, medical images like angiograms, and a virtual cell laboratory, that they would ultimately "invent" Coronary Artery Disease (CAD), requiring and learning cell biology standards along the way. (The term "invent" is used as per Karplus to describe students' conceptual "invention," the middle of the original three-phase inquiry cycle.)

Students complete the project by devising a public health plan for Village Park, defended by data about the characteristics of individuals whose CAD (or lack thereof) would benefit from invasive procedures or non-invasive treatments. It is in completing this part of the project that high school students collect first-hand information from medical professionals about the relative merits of the invasive fix for CAD they are seeing via videoteleconference with other possible interventions for CAD, both invasive and non-invasive. In this way, by coupling the technology in the informal space to a project-based science curriculum for the formal classroom, the learning possible with the existing informal technology in extended insofar as the specialized data, only available in the informal setting, can learned as integral to students' ongoing investigation in the classroom, and as such might be expected to be learned more deeply. We present such changes in students' meaningful understanding of science concepts. On this basis, we emphasize the utility of altering the pedagogy that frames the use of even existing informal technologies to better support science learning.

Exemplar 2: Rain Table: Visualization technology using complex datasets that allows learners to control and follow water flow across the Earth's surface by Kirsten Ellenbogen and Molly Phipps, Science Museum of Minnesota

Water movement across the Earth's surface is among the most misunderstood concepts in earth science (e.g., Coyle, 2006). Concepts like "rivers always flow south" and "curving of water flow due to the Earth's spin" are common issues that emerge in everyday science experiences. One of the best ways to understand water flow is to watch the movement of water across the Earth's surface. However, this is not possible in most lab settings and physical models cannot capture the intricacies of unrestricted stream flow across large areas.

To overcome these obstacles, the Science Museum of Minnesota and the National Center for Earth-Surface Dynamics initiated a partnership with the Electronic Visualization Laboratory of the University of Illinois at Chicago to create a new visualization technology using complex datasets that allows learners to control and follow water flow across the Earth's surface. Using touch screen technology, Rain Table allows users to make rain with their fingertips, producing tens of thousands of raindrops that then flow down and across digital elevation models of real landscapes in ways highly analogous to actual landscape processes. (See an early prototype of Rain Table at http://www.youtube.com/watch?v=rc5I774Mnh4.)

Learning research on the Rain Table at the Science Museum of Minnesota has focused on public conceptions of the directional flow of water on the Earth's surface. Pre- and post-interviews with museum visitors were conducted using a large two-dimensional, non-interactive floor map of the world or Rain Table. Additionally, visitors were video recorded as they used Rain Table. Findings were analyzed with an eye toward understanding the directional flow in:

- Interactive and non-interactive contexts
- High and low elevation areas
- A de-contextualized situation
- A problem-based learning situation (e.g., avoiding run off from a factory when choosing a location for a house)

Findings were also considered in light of the museum visitor's age, the social grouping in which they explored the exhibit, and motivations for coming to the museum.

Exemplar 3: Mobile devices transforming the museum experience: Opportunistic user interfaces to exhibits by Leilah Lyons, University of Illinois at Chicago

The nature of learning in informal environments is individual, idiosyncratic, and opportunistic—suggesting technology employed in these settings should also take on these characteristics. For this reason, mobile devices have been a popular platform in museums (Tallon & Walker, 2008). In the tradition of audio guides, most implementations focus on delivering information to visitors, and many research projects have capitalized on devices' computational abilities to try to customize that delivery, inferring the desired content from the visitor's location (e.g., Abowd, et al., 1997), focus of attention (e.g., Bruns, Brombach, Zeidler, & Bimber, 2007), time spent in different areas (e.g., Benta, 2005), or user-provided preferences (e.g., Chou, Hsieh, Gandon, & Sadeh, 2005). The emphasis has been on individualizing output experiences, but mobile devices also permit the individualization of input experiences.

This analysis explores mobile devices as opportunistic user interfaces to exhibits, giving visitors opportunities to interact bidirectionally with an exhibit through their personal devices (Lyons, 2009). This approach is distinct from other innovative uses of mobiles in museums that view the museum as a whole as an interactive space, usually framed as a scavenger hunt (e.g, Yatani et al., 2004; Klopfer et al. 2005; Yiannoutsou et al., 2009). Rather, mobiles used as opportunistic user interfaces are intended to enhance visitor interactions with a single exhibit at a time. In this fashion, computer-based exhibits can be scaled up to support multiple simultaneous users, transforming the traditional single-user kiosk experience into a collaborative learning opportunity. The semi-private setup allows visitors to transition from peripheral to central roles in the shared experiences, and offers the promise of customized scaffolding to support user interactions with exhibits.

Exemplar 4: Cyber-stretching: The Taiga biome around kids' worlds by Steven J. Zuiker, Learning Sciences Lab, National Institute of Education, Singapore

Science education takes place in functional learning environments in and out of school settings (Scribner & Cole, 1973), and increasingly through designed spaces that cut across these settings. *Quest Atlantis* (QA) is a virtual space that leverages cyber-infrastructure and the technologies and methodologies of videogames to design for transformative play in these functional ways (Barab et al., 2009). Learners from a variety of countries, including Singapore, develop scientific knowledge through participation in QA activities and practices.

One popular unit engages learners as field investigators exploring water quality issues in the Taiga biome (Barab, Zuiker, et al., 2007). Highlighting the confluence of informal science education and learning sciences, these QA experiences are shaped by the diversity of cultural-historical backgrounds as much as the demands of QA's quests, missions, and units. Leveraging this diversity as a resource for learning is a central focus of the QA design. However, it remains unclear whether, and how, interactions provoke learners to think about themselves as systematic yet distinctive knowers and users of, and occasionally contributors to, science.

This analysis considers how the QA Taiga unit facilitates and, at times, frustrates social practices of meaning making in lived, albeit virtual, experiences. The analyses draws on case studies of Singaporean youth engaging QA in after-school programs and at home and contrasts them with other less informal school-based instances where teachers and students agreed that their classroom would function under a set of dramatic conventions that work to shift epistemic authority.

Exemplar 5: Understanding the pieces of knowledge in informal learning environments by Tom Satwicz, University of Washington

What role do informal learning environments play in life-long learning? Bruner (1996) speculated that many of life's experiences provide us with an intuitive understanding of more complex scientific theories. For instance, a young child playing with a seesaw develops an initial understanding of the rule of the lever, which may later be developed into a formal abstract algebraic form. Other work has argued that initial experiences result in small bits of functional knowledge that when overextended lead to misconceptions (Smith, diSessa, & Roschelle, 1993). Given the importance of prior knowledge in supporting new learning, informal learning environments offer important initial encounters with elements of more complex theories.

This analysis explores how artifacts, particularly new technologies, present in a variety of informal learning environments, provide representations of knowledge elements that may be later used in STEM learning. The analysis utilizes a framework that combines a knowledge in pieces perspective (diSessa, 1996) with Distributed Cognition (Hutchins, 1995) to analyze video recordings of young people playing commercially available video games. It is then argued that embedded into many games are elements of STEM knowledge that may be productively utilized in formal educational settings.

One case in particular explores a six year old boy's initial understanding of probability as evidenced by his talk-in-interaction while playing a mini-game on the popular website Webkinz. The analysis demonstrates that initial knowledge fragments are present in a combination of cognitive, social, and material resources that are coordinated in the service of solving a complex task.

Exemplar 6: Using digital photography on an Internet portal to extend and enrich outdoors learning experiences by Heather Toomey Zimmerman, Robert Jordan, Jennifer Weible, and Chris Gamrat, The Pennsylvania State University

This analysis reports on a research and design project that created an Internet-based photograph-sharing portal for a nature center and its visitors. The nature center has diverse programs, including an overnight school for fifth graders, outdoor trails for the general public, presentations for family audiences, and a visitors' center with exhibitions and live animals. The goal of the photograph-sharing website was to enrich existing programming in two ways. First, the portal allows visitors to extend and connect learning experiences across time and space (i.e., home, the center, and other Internet-enabled places). Second, photographic documentation of the center, with the ability to share and view others' photographs, allows visitors to focus observations of their community on ecology related phenomena and increase curiosity about ecological concepts.

Theoretically, the design work and resulting research build from a distributed intelligence and cognition frame (Pea, 1993; Hutchins, 1995), a "making thinking visible in a shared community" principle (Bell, 1997) from a knowledge integration perspective (Linn, 2006), and a model of family learning where parents and children work together to make sense of new content that they observe (Zimmerman, Reeve, & Bell, in press).

This project started with formative research on how Association of Science-Technology Centers' (ASTC) institutional members (i.e., science centers) use web 2.0 and related technologies with their members, especially families. This included a textual analysis with quantitative coding of 342 ASTC science center's websites. These findings on current educational practice with web 2.0 technologies, especially the role of photographs in science learning institutions, were used to design a new portal that encouraged visitors to share their experiences at the nature center from late winter to early spring as the center's grounds and trails changed with the seasons' change. The visitors could share their observations through photographs and writing a brief statement. The pilot study of the portal's use includes family and adult visitors groups that attended the nature center on weekend days. Methods include interviews, observations of groups using the portal, and analysis of visitor created digital artifacts. We report on the formative research, the design elements, and the pilot study of the portal being available to the membership of the nature center, both onsite and online.

Exemplar 7: Innovative Tools and Student Perceptions of Technology: Owl Tracking and GIS Mapping with Fifth and Sixth Graders by Sandra Toro Martell, University of Wisconsin-Milwaukee

Media representations and digital technologies can be used in conjunction with traditional hands-on approaches to promote engagement in authentic science activities in informal settings (Bell, Lewenstein, Shouse, & Feder, 2009). Previous studies have demonstrated that advanced technologies can help people "learn to see" in specific disciplines (Stevens & Hall, 1998), support visitor-to-visitor knowledge communication, and allow for new forms of knowledge communication among unacquainted visitors and beyond the actual museum visit (Stevens & Martell, 2003; Knipfer et. al, 2009).

This descriptive study builds upon these understandings by showing how urban fifth and sixth grade students' use of innovative technological tools informed their understanding of technology and their own learning across settings. Data from two sets of students over two years include student interviews, post-museum visit questionnaires, and videotaped observations of group activities around GIS Mapping in a school lab setting and use of owl tracking radar in a museum and outdoors.

This analysis sheds light on how these different resources can help children build understandings of scientific practices and discusses implications for both learning sciences researchers and informal science education practitioners in terms of the design and development of curricula that features both traditional and innovative technological tools.

Exemplar 8: Take a Stand: Creating an immersive social experience with people tracking, 3D game technology, and interactive storytelling by Matthew Brown and Ben Loh, Inquirium and Joyce Ma, Researcher/Evaluator.

This analysis presents the design and formative evaluation of Take A Stand, an interactive immersive exhibit installed at the Illinois Holocaust Museum and Education Center. The exhibit aims to teach young visitors the universal lessons related to the Holocaust (i.e., the power of one's actions, the challenges of standing up for others, and the importance of dealing with bullying) in the safety of an age-appropriate, simulated world. Using a computer vision-based people tracking system married with modern 3D video game technologies and a massive display, Take a Stand physically immerses visitors in a game-like narrative that places them in the role of bystanders in a socially fraught situation where they must decide whether and how they might want to act. Through their interactions, visitors experience personal agency and a sense that their actions can make a meaningful difference.

The formative evaluation considers two types of visitors: (a) 8-11 year old students who come as part of their school field trip (the target audience), and (b) casual museum visitors who visit apart from a larger organized group (the secondary audience). The study involves observation and informal interviews of approximately 120 visitors and their facilitators during the exhibit experience, which included an exhibit play as well as a docent-led introduction and debrief session.

The analysis discusses: (1) design goals and challenges, (2) technical implementation, (3) affective and cognitive goals, and (4) affordances of the technology for supporting new forms of informal experiences and learning. Implications are given based on this example on how to design simulated worlds to support informal science learning.

Symposium significance

The dual focus of this session, on the design of learning environments and the study learners engaged with technologies in out-of-school time, advances theoretical constructs and design principles of interest to learning scientists and informal science educators. This work adds empirical accounts to address outstanding questions in the recent NRC document (2009) about the nature of learning with media. Additionally, it adds needed out-of-school perspectives to learning sciences fields where the school-based accounts of learning with technologies often dominate the learning technologies discussions.

Discussants

Sherry Hsi from the Lawrence Hall of Science and Brian K. Smith from the Rhode Island School of Design will each present short remarks on the impact of this work on the learning sciences field and on educational practice in non-school environments.

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