Journal of Computer Assisted Learning (2003) **19**, 308-319

A study of user experiences mediated by nomadic web content in a museum

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Abstract How should nomadic web content be designed to improve and transform user experiences in a hands-on museum? In this study, 15 users were studied while using an electronic guidebook designed to augment user experiences via wireless technologies at the Exploratorium, an interactive science museum. Several recurring themes emerged from the analysis, such as users' sense of isolation and users' attempts to make a seamless transition between real-place and virtual contexts. This paper shares a preliminary framework for organising user interactions with handheld devices, user experiences based on interviews and insights regarding the role of nomadic web content.

Keywords: Experiential; Handheld; Informal; Interview; Museum; Navigation; Science; Teachers; Wireless; World-wide Web

Introduction

The Electronic Guidebook Research Project began in 1998 at the Exploratorium, in partnership with Hewlett-Packard Laboratories and The Concord Consortium, (http://www.exploratorium.edu/guidebook) to develop a nomadic resource to enhance a visitor's experience at the museum. The Exploratorium is an interactive, hands-on science museum housed in San Francisco's Palace of Fine Arts, a cavernous, semicircular open space occupying over 110,000 square feet, with 50-foot ceilings. Several hundred exhibits about science, art and perception are on display at one time, out of more than 650 designed on-site. The exhibits are frequently relocated within the Museum as part of a continual prototyping process. In the spirit of the Exploratorium's vision of informal science learning, the exhibits are designed to promote playful exploration and discovery of scientific phenomena. Some exhibits involve observation or one-handed manipulation to move a disc, knob or lever, while others involve two-handed manipulation or whole body interaction. Many of the exhibits are noisy and involve sand, water, electricity, magnetism, heat and soap.

This paper focuses on a descriptive study conducted in the context of the Electronic Guidebook Project in which nomadic web content was created to explore and better understand user experiences with wireless handheld devices while at the museum. The notions of *nomadic web content* and *nomadic inquiry* were adapted from the field of nomadic computing.

The principal idea is that a computer-based information appliance can be carried

Accepted 14 May 2003

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anywhere by a user to access information; in this context, the accessed information would prompt the user to experiment further in the real setting rather than providing an escape from that setting (through, for example, playing a game — head down, completely engaged in the virtual world). A travel guide providing directions, historical context, information, and background stories served as a metaphor for the Guidebook. The Guidebook could also be used to plan a visit and take notes, and could be personalised with sketches, ticket stubs, postcards or other visit memorabilia. With an electronic guidebook, visitors might:

- access additional information about exhibits;
- extend their interaction with exhibits by using the networked handheld devices to engage in measurement, data collection and other experimentation to understand better the phenomena demonstrated by the exhibits;
- explain phenomena to others and mediate conversations using the Guidebook as a support tool; and
- capture their museum experience through online records for later reflection or future visits.

There are many reasons for studying the use of wireless handheld devices in an interactive science museum. Because museum visitors spend about 30 seconds at an exhibit (Cone & Kendall, 1978; Beer, 1987), a key notion was to identify ways to support sustained engagement and inquiry by creating a 'seamless visit' to the Exploratorium. With such a visit, users could explore an idea before coming to the museum, experience phenomena and/or test out ideas at the museum, and continue a personal investigation after leaving the museum. It was necessary to avoid thinking of the handheld as simply a miniaturisation of workstation desktop applications; instead, it was necessary to design technologies that could fundamentally change a visitor's interactions in a productive way for learning, collaborating and teaching in informal settings. While the museum has many elements that make using a handheld device difficult (e.g., sand, water, hard floors, etc.), the Exploratorium also has limited exhibit labelling and visitors often complain about having trouble understanding the key idea and scientific principles behind exhibits, finding their way around the museum and getting the most out of a visit. Moreover, because exhibit locations often change on the floor, handheld devices and location-aware technologies could help the visitor locate exhibits and provide suggestions to follow conceptual pathways through the museum. It was therefore hypothesised that a handheld computer could promote longer engagement with each exhibit, motivate deeper engagement through elaborated explanations, provide historical information and suggestions of interactions to try; and help visitors make real-world connections to the science phenomena featured in an exhibit. The setting posed a challenging but potentially rich context for studying ways in which museum visitors might use this technology and ways in which nomadic content, activities and experiences could enhance visitor experience.

To realise this vision, a test-bed and wireless infrastructure was created at the Exploratorium to conduct research on:

- IT infrastructure (networked components delivering the information);
- human computer interaction issues around form factors, content design and handheld uses; and
- the potential impact of wireless infrastructure and nomadic web resources on teaching and learning science.

The wireless infrastructure and nomadic web content designed to support the research is described, followed by a preliminary framework for organising user interactions and findings into user experiences with the electronic guidebook.

Wireless infrastructure and research test bed

Early phases of the project tested different sizes and weights of handheld devices and deployed a wireless network using a variety of handheld computers and radio-frequency identification (RFID) tags to link visitors with exhibit-related content delivered by a web-based server (Semper & Wanner, 1999; Spasojevic *et al*., 2001). A touchscreen tablet computer (Hitachi ePlate), a clamshell pocket computer with keyboard (HP Jornada 690/720) and a pocket computer with on-screen keyboard (HP Jornada 548) were tested and compared. Given the light weight of the clamshell compared to the tablet, a workable screen area to design content (16.7 cm, 640 × 240 pixels), a keyboard that allowed users to contribute notes or opinions and a longer battery life than the pocket computer, the HP Jornada 690/720 was selected as having the best form factor and screen size to develop nomadic web content.

To make the handheld context-aware, a point-of-information station, or 'pi-station', was designed to hold a HP Cooltown infrared beacon, which sends the URL via a script to a handheld that is near an exhibit (Fleck *et al*., 2002). The web page corresponding to this URL is then automatically delivered to the handheld device's browser from the content server via the museum's wireless network, and displayed on the handheld device's screen. The development and testing of the pi-station demon-strated the feasibility of delivering text, images, and digital audio and video over a wireless infrastructure to a handheld. It also allowed users to construct a record of their visit by bookmarking exhibit content, taking digital pictures from cameras near the exhibit, and accessing this information later on a personal 'MyExploratorium' web page in the museum or after their visit (see Fig. 1).

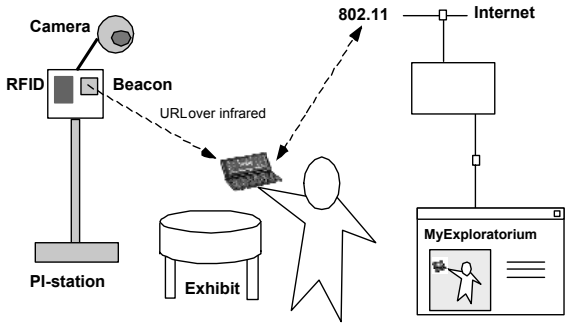

Fig. 1. Wireless set-up at the Exploratorium

Framework for organising user interactions

With a wireless infrastructure in place and proof-of-concept studies completed, in-depth studies of user experiences were made as a precursor to formal learning studies.

The concept of wireless web access is not new. Wireless handheld devices have been explored as nomadic information guides in situations as diverse as science centres, convention centres, transit stations, sports arenas, community centres, public parks, libraries, and museums (Grant, 1993; Abowd *et al*., 1997; Rieger & Gay, 1997; Inkpen, 1999; Cheverst *et al*. 2000; Jones *et al*. 2000; Kirk, 2001; Mandryk *et al*., 2001). Several innovative technology research projects have

demonstrated the feasibility of portable computers for nomadic inquiry learning and education in informal settings. Handheld computers have been used to augment classroom learning and project-based science activities in outdoor settings (Olsson, 1997; Tinker & Krajcik, 2001). Using probeware (portable computer and sensors), learners can carry out personal investigations, collect real-time data from the environment (e.g., streams or local ponds), and interpret the graphical results while still in the field (Bannasch & Tinker, 2002).

The approach to developing nomadic inquiry opportunities for the current research was driven by theoretical interests in understanding how users negotiate and bridge virtual and physical contexts and how ubiquitous technologies can dynamically support learners in *nomadic inquiry*.

Inquiry is an approach to science teaching and learning that facilitates learners' active participation in the process of exploration, observation, critique and investigation (Krajcik *et al.*, 1999). Learners sort out information, conduct investigations to satisfy their own questions and revise explanations as they gain new knowledge. Nomadic inquiry presents many opportunities to select 'driving questions' and to answer them using resources drawn from different contexts, because the participant is able to move among a variety of physical contexts such as classrooms, offices, museums, outdoors, automobiles or homes. The support of nomadic inquiry poses several interesting challenges in designing user experiences that allow smooth transitions between these physical contexts as well as between virtual (handheld) contexts and physical (exhibit) contexts. The handheld presents a window into a virtual context that contains its own set of representations, identities, and pathways into other virtual interactions and web resources. This research explored ways in which users are able to support and engage in nomadic inquiry, attend to competing physical and virtual resources, and reconcile these multiple contexts into a 'seamless visit' to the Exploratorium.

There was specific interest in understanding how different users responded to nomadic web content in an environment like the Exploratorium before engaging in further study of before-museum and after-museum contexts. It was hypothesised that such a resource could benefit not only visitors but also other audiences in their roles as teachers, museum staff, and explainers[*]. Moreover, while a future goal is to study 'learning conversations' among groups of users (Pea, 1993), it was first necessary to clarify phenomena of interest and identify which interactions were valuable to explore further — and thus to focus on the individual as a unit of analysis.

The first step was to identify and categorise typical user interactions in museum settings into a working framework, drawing upon earlier studies and concurrent research with the electronic guidebook (Table 1) (Spasojevic & Kindberg, 2001; Fleck *et al*., 2002). This framework helped to distinguish the types and ranges of possible interactions. Recognising that a nomadic device could be designed to support many different kinds of functions and interactions, and that to study all interactions simultaneously would not be a fruitful approach, there was an initial focus upon the design of the nomadic web content for exploring, requesting information, explaining, and recommending.

[*] Explainers are Exploratorium student volunteers and staff aged 15–20, who serve as the primary point of contact with the public. Explainers answer questions about the exhibits, perform demonstrations and help maintain exhibits.

Nomadic web content resources

A collection of handheld resources were developed by the Exploratorium staff for the HP Jornada 690/720 model. The exhibits (Spinning Blackboard, String Squirter, Echo Tube, Humming Plates, and Aeolean Landscape) ranged from being contemplative, involving simple observation and reflection (e.g. Aeolean Landscape) to highly interactive, playful, and hands-on (e.g. Humming Plates). These exhibits were selected in part because a rich set of supplemental materials was available to serve as a foundation for handheld multimedia resources.

Table 1. Framework for analysing user interactions

Interaction type	Examples
1. Exploring	Hands-free: the device is tracking in background
2. Requesting information	Looking up exhibit background information Searching in a digital library
3. Requesting Expert Advice/Recommending	Seeking expert-generated advice Cognitive guidance via hint or prompt Posing a question for immediate answer Suggesting ways to play with exhibit
4. Documenting/Remembering	Taking field notes Taking a picture/videos Recording a noise/voice Bookmarking
5. Playing a Game	Standalone game Participatory game with multiple players
6. Collecting/Measuring/Monitoring	Collecting real-time data Graphing data Polling
7. Creating/Building	Model Making (Manipulating models and data) Making representations Creating a publication Creating a postcard or presentation Creating an online exhibit Creating lesson plan
8. Communicating	Instant text messaging Posting to a bulletin board Screen sharing Paging Talking, phoning, walkie-talkie
9. Assessing	Test one's own understanding: Self-assessment Finding out what others know: Peer assessment Learner assessment by teacher
10. Reflecting	Reflect in a journal; Respond to written prompts

With limited screen real size, resources were designed to enable navigation by tapping on screen pictures and short text blocks using a stylus (see Fig. 2 in which a user taps on images and text to see more information about the Humming Plates exhibit). Applying the design principles provided by Woodruff and colleagues proved useful for shaping the content design for the electronic guidebook (Woodruff *et al*., 2001.)

Fig. 2. Sample screen of nomadic web content.

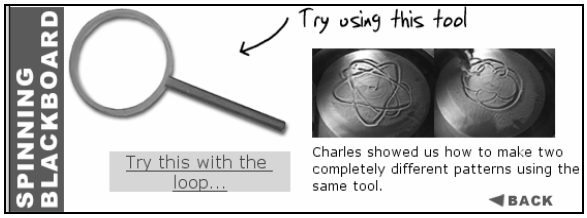

Fig. 3. Nomadic web content suggesting ways to play with the Spinning Blackboard exhibit.

For example, an image with a short text description was sufficient as a tap target for leading users to consistently find content they expected to see.

The nomadic web content created in the project contained different types of information that could be mapped onto the framework with background information such as:

- the history and evolution of the exhibit;
- 'Try This' activities (see Fig. 3); user-contributed responses (for example, users can input their observations and theories, and read ideas input by others);
- digital videos of ways to interact with the exhibit;
- text and audio explanations along with digital video links to other related exhibits on the floor and links to real-world phenomena.

In addition, the users could bookmark pages on the handheld device for future reference.

Methods

Three categories of users were selected to participate in the study: Explainers (high school and early college students volunteers), science teachers and museum member visitors. Fifteen participants are reported in this study: five visitors, four teachers and six explainers. (Two pilot subjects used to refine the interview protocol are not included and three participants were dropped from the main study because of poor audio recordings.) After giving the participant five minutes of training on the handheld, researchers shadowed individual users for about 45 minutes while the user visited the exhibits. A participant could navigate the handheld to find particular online resources for any of the five exhibits, or see a page automatically appear as they approached an exhibit. Users did not view exhibits in any particular order.

While visiting the exhibits, user utterances were captured using a wireless microphone and recorded onto audiotape. Researchers made observations and noted when the attention of the users was focused on the virtual space (the handheld) and when it was focused on the exhibit. Also, when users moved between exhibits, the time spent at each exhibit, as well as other signifiers marking the beginning and end of episodes were recorded. After visiting the exhibits, participants were then interviewed individually for about 45 minutes using a semi-structured approach. Users were asked about their background, opinions about the nomadic Web content, explanations of their actions, functionalities they liked/disliked, and speculations about potential uses for this technology in their particular role as a teacher, visitor or explainer.

The interviews were transcribed, then reviewed by two researchers who marked user comments that were significant to the framework (Fig. 2) as well as other comments that stood out on their own. From this review, several emergent themes were identified. The interview data was analysed a second time for the presence or absence of particular themes for each category of user, to determine the final 'identified themes' (Table 2).

Themes and findings

Although three sources of data were collected (field observations, interviews and log files), only the interview data from teachers, explainers and visitors are reported in this paper (see Table 2 for an overview of the interview results).

Table 2. Percentage of users who articulated identified themes

Identified theme	Teachers (%)	Visitors (%)	Explainers (%)
Anthropomorphic	0	25	33
Customisable	40	50	50
Directive	20	25	0
Discovery	0	25	50
Explanations	40	0	83
Exhibit history	0	25	50
FAQs	20	25	33
User input	20	0	50
Exhibit linking	20	0	50
Record experience – photo, bookmark	20	25	50
Extend experience – pre-museum, post museum	80	50	33
Isolation – less hands-on with exhibit	100	50	50
Isolation – less social	40	25	33
Motivates doing	80	75	67
Motivates thinking	60	25	67
Novelty	40	0	33
Social identity	40	0	50
Virtual/Real – probe/instrument	0	0	50
Virtual/Real – seamless representation	1	75	50

A sense of isolation (Isolation theme)

While on the exhibit floor, users were observed to move smoothly between looking at handheld resources and playing with exhibits. Typically, a user would hold the handheld in one hand to watch a video, listen to an audio track or read text, then manipulate the exhibit with the other hand (for example, turning a knob, drawing a sand pattern or resining a bow). On occasion, a user would interact with another person to show the handheld resource to someone else on the exhibit floor. When the exhibit required two hands to operate, the user would either put the handheld down on a table or put it into a pouch held by a shoulder strap. Users, especially younger users, appeared to switch their attention back and forth easily between the handheld and the exhibit.

Nonetheless, users reported that the handheld contributed to a sense of isolation, both from less social interaction with others in the museum and from interference with exhibit play. The following samples of users responses are representative of the comments drawn from interviews:

> It was more like you were interacting more with the handheld than the exhibit. That (the handheld) becomes almost the primary exhibit.
>
> I didn't really notice other people; I wasn't paying attention to anybody except for reading the screen.
>
> I found it distracting from the hands because the reason to come to a hands-on museum is to interact with exhibits.
>
> I was actually surprised by how much I didn't realise I was in a museum, because I suddenly became so focused on the screen, which sort of takes away from the experience because part of what I like about being here is that it's such an open place. It's a nice place to walk around and just watch other people playing with things.

Given the high level of ambient noise at the Exploratorium, users had to wear an

earphone to hear the audio from digital videos, which might also have contributed to a sense of isolation. Two users used these analogies to describe their experience with the handheld:

> It's like a car window that separates you from reality.
>
> It's kind of like going to a party and reading a book.

When users were not given a particular problem to solve or group task to accomplish, they, especially teachers, felt the handheld limited exhibit play. Teachers, however, were encouraged by the idea of using a handheld for instructional activities before and after a museum visit, and by using the handheld for students in a structured activity while at the museum (i.e. Extending Experience theme, Table 2).

Integrating real-place and virtual contexts (Virtual/real theme)

There were two related themes in the area of bridging virtual (handheld) and real (exhibit) contexts. Some explainers wanted to bridge real and virtual by engaging the handheld as an integral part of an exhibit, such as using the handheld as an audio recorder, data collection, or probing device.

> It would be really cool if it had a microphone hooked-up to it (handheld) and I said something in and it went right into the computer and showed me what it looked like. That would be cool.

Other users made attempts to create a shared attention space to integrate virtual and real world contexts, especially with the more contemplative exhibits that required only one hand to operate. For example, users could watch a video and compare the video to the real exhibit on the floor; users could also listen to audio while playing with an exhibit without having to switch their focus. However, reconciling the virtual context and the physical context was difficult when anchors such as physical artefacts or pictorial representations were missing. For example, the online pages for the Echo Tube exhibit suggest using echo return time to measure the length of the Echo Tube with a stopwatch. And, in the online pages for the Spinning Blackboard exhibit, the digital videos show special tools for creating patterns in the sand (Fig. 3). Users actively shifted attention between the exhibit and the handheld looking for these tools to try out suggested activities ('Try This' content) but were often disappointed when there was not a seamless mapping between the handheld, the content represented in the handheld, and the real exhibit:

> (Interviewer: Was there something in this experience that was enjoyable/lacking?)
>
> There's no stop watch there so you can actually do it there.
>
> All the tools. One thing about having this video, you have to make sure that all the tools [artefacts] are out there.
>
> Spinning Blackboard [exhibit], I could see how it would work if [we had] the proper tools at the exhibit, which we didn't.

Some users also expected the same text from the exhibit graphics to exist in the handheld to see if there was a coherent mapping between the exhibit and the content in the device, while others did not want to see any duplication with information found in the exhibit and the handheld resource. This suggests a need to orchestrate activity between the handheld and the exhibit more efficiently, align museum floor artefacts and virtual information, and identify 'content bridges' such as the suggestive 'Try This' videos and audio that might help build a seamless experience.

Nomadic web content (Explanations, exhibit history and social identity theme)
Users were asked which kind of nomadic content resource they enjoyed the most. Some users, especially explainers, reported they were drawn to explanations, videos, and histories of the exhibit along with other explanations provided by museum staff. Many Explainers, who are often new museum volunteers, found the Electronic Guidebook especially useful in providing insider tips and tricks for exhibits, as well as for providing information they might have missed in their training and orientation meetings. Because users recognised particular people in the video clips (i.e. social identity), they also chose to spend more time looking at those resources:

> The videos I found fun because I knew the people in the videos, not because I was interested in what they were doing.
>
> Being able to see Paul [Exploratorium senior teacher]. It's fun, his stuff is always good, it's way beyond.
>
> It was fun to see all the people I knew, seeing them explaining things.

Some visitors and explainers also mentioned that they liked the videos that were anthropomorphic:

> I like the video clips, not just the kind of showing or demonstrations, but just the actual person talking in detail about something. I think it's a nice, personable touch, ironically delivered on a completely impersonal device, but it adds a nice human touch and warms up the experience . . . I liked the human piece of it. Being told vs. figuring it out on your own (Directive vs. discovery theme).

Users had different preferences for how they used and wanted to use a handheld device in their Exploratorium experience. Some users felt the handheld should be used only after playing first, while others felt it was necessary because you might 'do it wrong.' Both kinds of users were observed displaying this pattern of behaviour.

> You always want to know why [the exhibit] works, why it does what it does. When you figure that out, then you understand it more, THEN, you can finally start to sink your hands in it and play with it.
>
> You have this handheld that is trying to tell you information, which is great to know the information, but I would rather play with the exhibit and later, when I came again or in the future, I would want to know further explanations.
>
> It would take away from my experience if I was told other secret things about how to figure it out or how to play with it.

Enjoyable experience using nomadic web content (Motivates doing and motivates thinking theme)
A majority of users reported (and demonstrated by observation) that the handheld resources motivated them to try new ways to interact with the exhibit as well as prompted them to think about many ideas inspired by the nomadic web content.

Discussion & conclusions

Trends in information technology development are enabling users of mobile devices to connect to the World-wide Web via wireless connectivity anytime and anywhere. From an instructional standpoint, this capability of universal access extends the walls of a classroom, home or office to allow ubiquitous information access, peer-to-peer communication and real-time knowledge networking. Museums, like other learning places, are turning to mobile devices and wireless technologies as a way to enhance visitor experiences, extend exhibit graphics, offer alternative explanations and representations of phenomena, and provide historical information of primary

artefacts. However, the risk of using this technology to provide more information in a setting that is hands-on, mediated by conversations with others, and cognitively challenging (e.g. noisy, unstructured, and with multiple ongoing events) is that interactive learning opportunities offered by a physical space are turned into a 'heads-down' one-way transmission of information via a tiny display. Even if online activities are provided to prompt learners to input theories, opinions, or notes into the device to support more learner–constructed interactions, visitors are engaged in heads-down activity rather than heads-up interactions with primary phenomena, live events, or other people in the museum.

These findings present conflicting accounts: the handheld devices motivated users to try new activities and interact with exhibits in new ways, yet users also found the experience to be socially and physically isolating. When the nomadic web content was not well-coupled with the exhibits and objects on the museum floor, the user experience was less appealing. These observations have several implications for the design of nomadic inquiry environments. The content, interaction and activities to support nomadic inquiry using an electronic guidebook require careful instructional design to take advantage of learners' mobility, the surrounding setting and the participants in that setting. Ideally, the interactions will include a broader range than those implemented in the current electronic guidebook, but resemble more closely the preliminary framework shown in Table 1.

Nomadic inquiry takes place when the learner is moving between spaces and information contexts, in the absence of the cultural norms of schooling, teacher, and a structured curriculum. Inquiry as an approach to learning science requires careful orchestration of instructional, informational, social and cognitive support to encourage learners to formulate their own questions, plan and conduct an investigation, select appropriate tools and techniques to gather data, and draw upon resources to generate explanations and synthesise findings (NSES, 1995). For example, a handheld device that can prompt a learner to collect the temperature of a heated exhibit on its own will not teach children scientific inquiry. However, inquiry learning takes place when a learner chooses where to take a measurement, reflects upon the meaning of the temperature data collected, makes inferences or interpretations about data to plan the next measurement, and entertains plausible explanations. It remains a challenge to provide guidance to the informal learner, whether that guidance is computer-assisted support or enacted directly by a teacher. Nonetheless, it is the choice of the learner whether or not to take advantage of learning opportunities even if provided with suggestions.

Outside the social boundaries of schools, learners have to be 'lifelong learners' and be highly self-motivated because of the many free choices available with no traditional learner accountability (e.g. grades and other performance measures). As a learning tool, it is doubtful whether a wireless handheld could serve as a standalone learning tool — but when coupled with a wide choice of activities, access to the World-wide Web, other personally-relevant participants in the learning environment, and powerful desktop applications to support richer representations, such a device has the capability to support a personalised, informal learning experience.

In summary, just as when designing robust curricula, careful thought is needed to understand how to design nomadic web content to support nomadic inquiry: How does one provide enough guidance, explanations, prompting, and assessment, yet retain flexibility for choosing personally-relevant problems especially in a museum

setting? Mobility opens many possibilities to interact and capture experience in the real world, but it must be accompanied with self-motivation, guidance (online or in person) and instructional support.

Future work

The Electronic Guidebook project continues to advance and refine a wireless test-bed and infrastructure for research on nomadic inquiry and nomadic web content to support user experiences at the Exploratorium. Further data collection and analysis to include pairs and family groups will help inform the design of nomadic web content to support a 'seamless visit' and refine the informational framework, as well as ways to help understand how the design of nomadic web content can mediate conversations and interactions in informal settings, rather than reinforce social isolation. A particular focus of future work will be on using the handheld as a performance support tool for 'explainers-in-training' whose responsibility is to answer questions and scaffold inquiry in visitors, teachers and other explainers. In addition, future research will explore ways to free the visitor from the need to hold a device while at the museum, but still enable the capture of museum experiences for later reflection and interaction on the World-wide Web. These studies will include front-end evaluations to better understand how learners and instructors might prepare prior to a museum visit and will the test assumptions about the kinds of inquiry activities that learners pursue that are inspired, structured or motivated by captured museum experiences after a museum visit.

Acknowledgements

This research was a collaborative effort with members from The Exploratorium, HP Laboratories, and The Concord Consortium. The author gratefully acknowledges the following people: Katherina Audley, Stephen Bannasch, Doug Conaway, Margaret Fleck, Marcos Frid, Tim Kindberg, Hugh McDonald, Franci McFarland, Eamonn, O'Brian-Strain, Rakhi Rajani, Natalie Rusk, Robert Semper, Mirjana Spasojevic, and Robert Tinker. The author also acknowledges Liza Gross and Hugh McDonald for editorial assistance, and Robert Tinker from the Concord Consortium for his insights on prior work that led up to this research.

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