The Electronic Guidebook: Using Portable Devices and a Wireless Web-based Network to Extend the Museum Experience

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handheld computers, wireless networks, electronic guides, mobile computing devices

Recent advances in wireless network technologies create the potential to significantly enhance the experience of a visit to a museum. On the exhibit floor, visitors carrying wirelessly connected portable devices can be given opportunities for exploration, sharing, explanations, context, background, analytical tools, and suggestions for related experiences. When these devices are part of a Web-based network, they can help extend the museum visit: in advance, through activities that orient visitors, and afterward, through opportunities to reflect and explore related ideas.

The Electronic Guidebook project is a study of visitors equipped with such technologies, conducted by the Exploratorium in partnership with researchers at Hewlett-Packard Labs and the Concord Consortium. The project is investigating how a Web-based computing infrastructure can provide museum visitors with an augmented museum experience, so that they can better plan their visit, get the most out of it while they are in the museum, and be able to refer back to their visit once they have returned to their home or classroom. The goal is to understand what technological infrastructure supports this extended museum experience, and to obtain preliminary data on how different aspects of the technologies, and the content delivered through them, affects engagement with the exhibits and pre- or post-visit learning activities.

The project created a test-bed and tested a network using a variety of handheld computers and radio-frequency identification tags to link visitors with exhibit-related content delivered by a Web-based server. Visitors in the study were able to access Web-based content, including text, images, video, and audio, during a visit. In addition, they were able to construct a record of their visit by book-marking exhibit content, creating images, notations, and other artifacts and to access it on a personal Web page in the museum or following their visit.

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Keywords: handheld computers, wireless networks, electronic guides, mobile computing devices

1 Introduction

The exhibit environment in museums excels in providing the public with direct experiences with phenomena, ideas, and objects. But while the exhibits provide compelling opportunities to stimulate inquiry and exploration, they are not, by themselves, completely successful in supporting conceptual learning, inquiry-skill building, analytic experiences, or follow-up activities at home or school. An ideal learning experience with exhibits would include ways of capturing the visiting experience for later reflection, being able to access additional material that provides a context for the exhibit, and extending the interaction with the exhibit beyond simple manipulation. If museums are to fulfill their potential role as multi-dimensional educational institutions, they need additional mediation techniques that support these needs. And these techniques need to augment the simple exhibit experience without destroying the informal ambiance that is the hallmark of museums. In effect what is needed are tools that can provide the kind of contextual support with exhibits that is offered by the familiar travel guides but defined in a new interactive way.

Fig. 1. Visitors using the Electronic Guidebook in the Exploratorium

Guides are an important part of our travel experience. We use them in advance to plan our trips. They provide us with an historical context for the country or city we are going to see. We take them along to provide quick access to essential information like addresses and transit information. We use them as in-depth guides to tours of historical landmarks. They help us translate words and exchange currency during our visit. We personalize them with notes, hotel brochures and postcards from the places we have stayed. We refer to them after the trip to remind us of our visit, and they form the basis of talking about our trip with our friends. The best guidebooks become dog-eared by use by the end of a trip and become keepsake reference points for whenever we "revisit" the journey. In short they serve as an ongoing tool for enhancing our direct visit experience with a place and culture.

Emerging computer and network technologies have the potential to significantly enhance the experience of a visit to a museum, giving visitors the opportunity to transcend the traditional limits of time and physical space as they engage in a museum's offerings. Electronic guides, enhanced via interactive technology, can not only serve as reference information, but also provide expert guidance, dynamic advice, recommendations for further inquiry, and other learner supports no paper-based travel guide can provide. On the exhibit floor, additional information, guidance, or feedback at the right time can turn a simple interaction with an exhibit into a meaningful learning experience. Inexpensive, portable devices, can give visitors opportunities for exploration, sharing, explanations, context, background, analytical tools, and suggestions for related experiences (Figure 1).

The visit can be extended through sustaining learning opportunities, in advance through activities that orient visitors, and afterward through opportunities to continue reflection and explore related ideas. By adding personalized technology to the museum experience in these ways, we can greatly enhance the visit's educational value (Figure 2).

2 Research Project

The Electronic Guidebook project [5] is a National Science Foundation funded activity designed as a proof of concept research study to explore the potential of portable computing devices and a wireless Web-based network. Headquartered at the Exploratorium [6], the project is a partnership of the Exploratorium, Concord Consortium, an educational research and development organization and HP Labs, the research and development laboratory of Hewlett-Packard Company. The Exploratorium worked with the Concord Consortium to identify the technical issues and potential uses of handheld devices in the museum setting, and the museum formed a partnership with HP Labs to develop and test a Web-based, wireless network deployable in the Exploratorium' physical space. The aim of the project is to investigate how a mobile computing infrastructure can enable museum visitors to create their own "guide" to the Exploratorium, using a personalized, interactive system to better plan their visit, get the most out of it while they are in the museum, and be able to refer back to their visit once they have returned to their home or classroom.

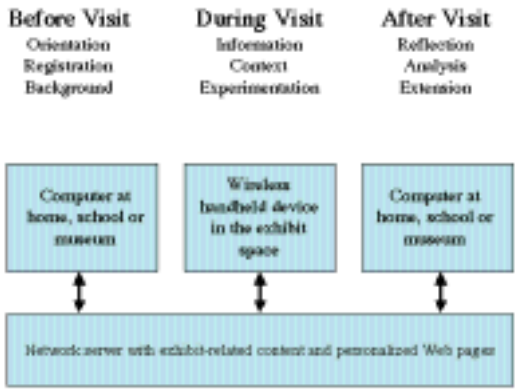

Fig. 2. The Museum Experience Extended through a Wireless Web-based World

The Electronic Guidebook project focused on three simultaneous strands of investigation: 1) information technology infrastructure (networked components delivering the information); 2) human computer interface issues (form factors, interfaces, and usability issues for various audiences); and 3) content development (design, formatting, and topical content of deliverable information). The project was designed as a proof of concept study to explore potential avenues for future research and development. It was not envisioned to support the implementation of a fully functional system but rather to point the way for future developments. A key idea was to create the test-bed within the existing museum context and use off the shelf technology to the extent possible so as to be able to explore this technology in a realistic setting. Often technology projects are tested in idealized conditions without the distractions and the messiness that occurs in the real world. Our goal was to study the interaction of all of the elements, technology, functionality and content within an authentic situation.

The project worked with an existing set of exhibits in the museum that are part of the “Matter World” exhibit area. These exhibits that addressed topics in sound, mechanics and heat are highly interactive, distributed in space and individual in design. Because these exhibits have been in the museum for many years there exists a rich set of supplemental materials (text, images, teaching activities, exhibit developer interviews, etc.) already developed. While this material could provide a rich context for the visitor it is usually not readily accessible because it is scattered in files, offices and the brains of staff members.

3 The Test-bed

Initial developmental studies which tested different devices, networks and servers were pursued in 2000 by Concord Consortium and the Exploratorium. For the test-bed we augmented the museum environment with technologies developed by the Cooltown research program at HP Labs [8][9]. In the Cooltown scenario, all physical entities (people, places and things) have a ‘web presence’ [3]. Nomadic users navigate from the physical to the virtual world by picking up links to web resources using a variety of sensing technologies such as infrared receivers and barcode readers [7]. Those readers are integrated with their handheld device, which is wirelessly networked. Users access electronic services by using handheld devices to pick up URLs from barcodes or infrared ‘beacons’ attached on or near the objects of interest. Those services are provided using wireless web technology: web browsers on the handheld device and web servers in the environment. The services can be adapted for users based on their context, e.g. their identity, location, device capabilities, personal interests and preferences.

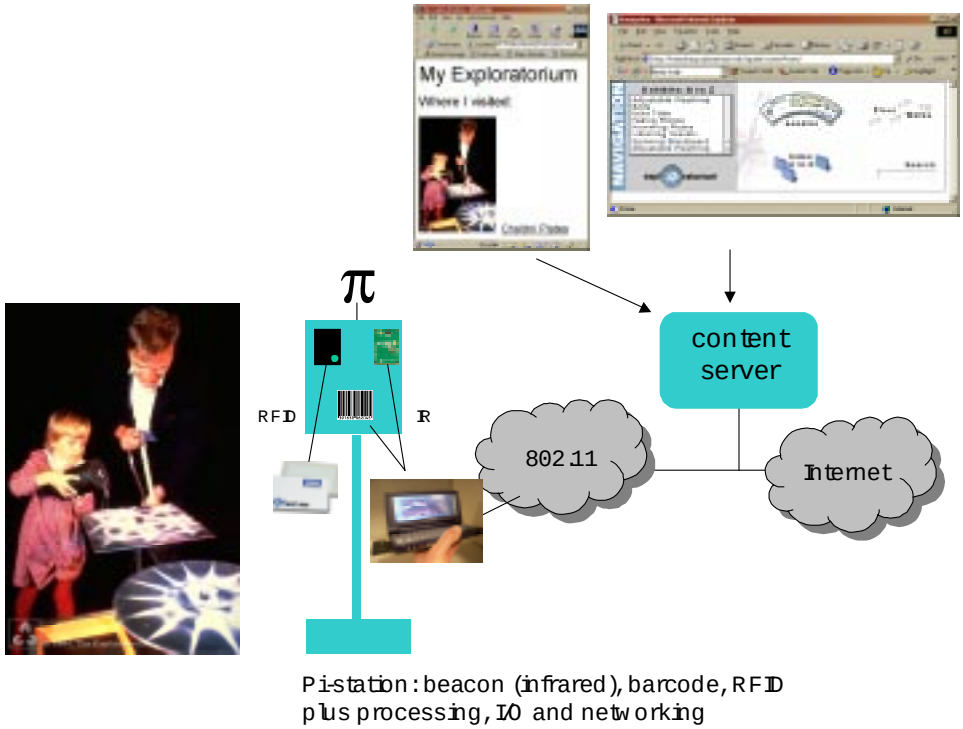

Fig. 3. The Augmented Interactive Museum.

Fig. 4. Handheld Devices. Left to Right: HP Jornada 548; HP Jornada 690; Hitachi ePlate.

The Electronic Guidebook project test-bed (Figure 3) consists of a wireless handheld carried by the visitor, a "pi-station" (point-of-information station) at each exhibit, and a content server connected to the World Wide Web on the Internet and accessible both inside the museum and also from home or school. The visitor located in the museum space was identified using the handheld with either a short range IR transmission, RFID sensor [10] or a barcode swipe. Data transmission to the handheld was provided using a radio LAN system in the exhibit space that provided connectivity to a Web server which is connected to the public Internet.

Each pi-station is a tall stand, with a base that can contain a laptop and a panel at eye level that can contain an IR beacon [2], RFID reader, barcode, and/or camera. At each pi-station, the visitor can "sense" the URL of the main page for the corresponding exhibit. The page is then retrieved from the web server and displayed with a browser on the handheld. The pi-station was designed to help test different interaction modalities and to facilitate working with different exhibits for different tests. In the future system design, some of this functionality might be built into the exhibit itself.

Three types of handhelds (Figure 4) have been used for the studies: HP Jornada 690's and 720's (a Handheld PC with a physical keyboard), HP Jornada 540's (a Pocket PC with on-screen keyboard), and Hitachi ePlates (touch-screen tablets). The handhelds are connected to the network using 802.11b cards

Fig. 5. Echo Tube Pages

which provides wireless connectivity at 11 mbps. A single 802.11b base station is connected to the Exploratorium's network near the exhibits.

The Jornadas have IR communication ports and Esquirt software that allows them to collect URLs from Cooltown IR beacons. When the visitor points the Jornada at an IR beacon, the beacon transmits to the Jornada the URL of the on-line content associated with that beacon. A barcode reader is attached to the Hitachi ePlate. The raw ID provided by the barcode is mapped to a URL, which is then treated like the URLs provided by beacons.

Information and contextual material for each exhibit is displayed on the handhelds using a modified web browser. When the visitor picks up a beacon or barcode for an exhibit, the main page for that exhibit is automatically displayed. The browser's user interface has been simplified so that the only browser buttons are: forward, back, home, and a bookmark, which we added to allow visitors to record visited pages in their personal scrapbook.

Using the System

Visitors carry the electronic guidebooks with them as they walk through the museum floor. As a visitor walks up to a particular exhibit, the guidebook provides interaction, information, and ideas about the

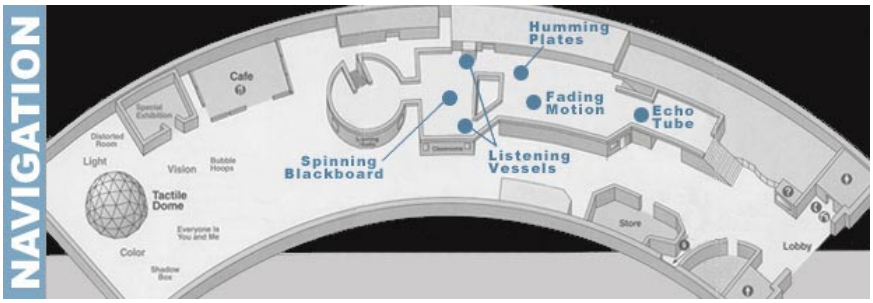

Fig. 6. Electronic Guidebook Home Page.

exhibit. When approaching the Exploratorium's Echo Tube exhibit, for example, visitors see a small Web page on their handheld guidebook, suggesting ways of interacting with the tube, such as clapping and counting to measure the speed of sound. The guidebook also provides visitors with intriguing questions to consider (such as, "What does a dog bark in the tube sound like?") and a way for them to enter their own questions and observations (which other visitors can then access). In addition, visitors can learn more about the science of echoes (with deeper explanations than available on the exhibit label), real-world connections (for example, recommended locations in the San Francisco area for hearing echoes), and the history and evolution of the exhibit itself (including stories from the exhibit developers). The system allows visitors to save items of interest to a personalized Web page that they can access after their visit at home or school.

All exhibits have a main page whose URL is stored in the pi-station, as well as 3-4 sub-pages (Figure 5). When the main page gets downloaded by the browser (after picking up a URL through a beacon or a barcode) the visitor can click on any part of the image to get to the ‘‘nuggets” page which provide links to several areas for further exploration of content related to the exhibits.

In addition to the individual exhibit pages, the visitor can access the Electronic Guidebook home page (Figure 6). The home page contains a list of exhibits and a map of exhibit locations. It also gives the visitor access to a personal scrapbook page on the server where they can record URLs of interesting material which can be reviewed later on the WWW from any browser.

4 Research Studies

The research team that is studying the use of the test-bed is made up of museum educators, scientists, educational technology researchers, learning researchers and human-computer interface researchers. The project started with a set of questions that the test-bed was designed to help answer.

Technology Development

- What is the feasibility and effectiveness of various wireless receiving and transmitting solutions for an exhibit space including distributed and/or centralized infrared and radio transceivers?
- What is the appropriate distributed computing power relationship between the handheld device, the exhibit computer, the transceiver system and the network servers?
- What is the optimal integration of the dynamic user database in the World Wide Web environment?
- What are the appropriate handheld device data sensors for the museum exhibits and the design issues surrounding the interface between these sensors and the exhibits themselves?

Interface Design

- What is a feasible system for providing handheld devices to the public? How can we distribute these devices equitably and to a diverse cross-section of our visitors? Will the devices be used by individuals or by multiple visitors in a group? How will security be handled? What are the logistics of carrying them on the exhibit floor?
- What are the issues surrounding the use of these physical devices during a visit to an exhibit environment? How can we integrate the devices into the complex social activity of a museum visit without fragmenting a group? How can they be comfortably handled during a prolonged visit?
- What is an appropriate software, hardware and exhibit graphics interface design for the experience at the exhibit, at home before or after a visit and in the Learning Studio as part of the museum visit? What are the important accessibility issues? For example, how many visitors have web access? For those who do not have web access at home, in what ways can we provide them with closure to their experience?
- What is the key hardware and software design issues (screen size, speed of use, amount of material) that form a threshold of feasibility for this idea? What are the specific design elements (text, graphics etc) which are important for the experience? What are the specific mediation components that this technology can support at exhibits (capturing information, providing context, creating representations, taking data)?

Educational Potential

- What is the effectiveness of the Electronic GuideBook system for capturing experience, providing context and extended interaction? How can we create resources that stimulate exploration and reflection rather than having the handheld just seem like an electronic textbook?
- What kinds of learning can we facilitate: Cognitive? Affective? Attitudinal? Skill-based? What are the key issues that might motivate the use of these devices? How can one create resources that stimulate exploration and reflection?
- What is the value of the different project components to the overall educational experience (i.e. pre visit, at the exhibit, in the museum's classroom spaces, in the home after the visit)?

The initial work has been focused on developing the test-bed and initiating the study with a series of initial research questions. These studies have focused on the following ideas:

- What are the basic affordances? For example, is the device easy to carry? Are screen graphics easy to interpret? Is the wireless connectivity reliable? Is the 1-2 meter range for reading a Cooltown beacon more convenient for users than the 1-10cm range for scanning a barcode?
- What is the visitor's attention to artifacts: how much attention does the user pay to each exhibit or piece of on-line content, and what is the quality of this attention? For example, did the user look at a particular page? If so, did they glance at it or read some text on it, for example? Was the user mostly paying attention to the exhibit, paying attention to the content on their handheld device, or fiddling with the device itself (e.g. trying to solve some problem with the interface)?
- What are the visitor's paths through physical and virtual space: what is the sequence of points in physical space (exhibits) and virtual space (web pages) through which the user passes as they visit the museum? Of particular interest are trajectories that correspond to high-level user events such as following a virtual link to get more information on a topic, deciding to walk over to another exhibit, shifting attention back and forth between the physical and virtual at a single exhibit.

The next set of studies (currently underway) are designed to help us better understand how different types of content (including different multimedia formats, types of suggested activities, and the ability for visitors to add their own observations and ideas) affect a user's experience at the Exploratorium and in what ways mobile electronic resources support or hinder a user's experience in the museum context.

Also planned are studies of the “out of museum” use of the network to explore its utility before and after a visit.

Overview of Studies

To date, we have carried out several rounds of informal visitor studies. The goal of these tests was to get a general sense of how visitors reacted to the system and to uncover major issues. The users for these initial tests were: 12 local school teachers (9 female, 3 male), 14 other adults (8 male, 6 female), and 8 young people, ages 10-17, (5 male, 2 female). The adults ranged in age from about 25 to about 50. All users were fluent speakers of English with no major physical disabilities.

The evaluation approached selected for the tests was participant observation with a project member shadowing a visitor or a small group of visitors. Visitors were directed up to the general area of the instrumented exhibits. They interacted with those exhibits and sometimes nearby non-instrumented exhibits. The project members observed the visitor's actions and reactions, and helped them out when they had major problems. Semi-structured interviews were held afterwards. The tests were done when the museum was open to other visitors.

For these initial tests, we used HP Jornada 690's, except for one subject who used an Hitachi ePlate. In depth content has been developed for six exhibits, including one pair of exhibits that are thematically related to one another. Most of the pages have heavily graphical content, with few mixed text/graphics content and parallel audio content. The content is formatted for the Handheld PC display size. A stand was placed next to each exhibit, with a barcode and IR beacon containing the appropriate URL for each exhibit's content. Content was designed primarily for an adult audience.

Lessons Learned

The overall reaction from the visitors was positive. They enjoyed reading the on-line content. Some adults felt that the content would not be interesting to children. However, children who used the system did actually spend a fair amount of time reading the online content while at the exhibit and trying out possibilities suggested by it. Visitors frequently commented that the handhelds were really fun, novel devices. On the one hand, this helped keep them interested. On the other hand, the “wow” factor of using the device distracted them from paying attention to both the exhibits and the on-line content.

Above all, visitors liked the idea of being able to bookmark information to look at later. Both teachers and children thought this feature would allow the children to play more during their museum visit, completing related homework assignments after the visit.

Aside from technical problems discussed below, the main negative comments were that using the handheld tended to distract people from playing with the exhibits. The issues here are both mechanical and cognitive. Holding the handheld prevents people from freely using their hands to manipulate the exhibits. Moreover, reading the content is itself distracting from interacting with the exhibit.

Using handhelds in a museum setting may also disrupt normal social interactions between members of social groups, because each visitor can get lost in the world of the device and pays less attention to the rest of his group. For example, we observed two boys moving around the museum floor together, talking about the exhibits and working things out together. Yet, when we gave them each a handheld, one spent more time reading the information on the device while the other was still interested in seeing as much as he could. On some occasions, when they needed two people to make an exhibit work, they had to spend time trying to find each other again. We believe that these issues can be overcome by designing a system to specifically support visitors conversation patterns, such as the system tested at an historic house [1][11] where the electronic guidebook became a third party in the visitor conversation.

Handheld design and features

Handhelds do not routinely come with straps. Carrying cases are only available for certain models. This represented a serious problem in the Exploratorium because visitors must have one or both hands free to operate the exhibits. When early trials made it apparent that a strap was necessary, we had to resort to tying a strap around the Jornada 690's hinge. However, even with a strap attached to it, a Hitachi ePlate was too heavy to use for a prolonged time during the visit.

Our original plan involved comparing audio renditions of content to parallel graphical versions, as in a recent handheld project at an historic house [1][11]. This study found that visitors preferred audio content to visual content, presumably because it left their eyes free to look at the exhibits. However, the Exploratorium is extremely noisy. When the Jornada is held in the hand, sound from its speakers is essentially inaudible. Some visitors were not even aware that any sound was playing. Headphones can be used, but the Jornada 690 happens to lack a headphone jack (a problem fixed in the Jornada 720). Therefore, the visitors had to be prompted, by on-screen graphics, to hold the handheld up to their ear.

Robustness issues are a concern for use in an interactive science museum. Robust devices are essential if on-line content is to be seamlessly integrated into everyday activities. The handhelds struck most visitors as too fragile to withstand being dropped or bumped. Many exhibits at the Exploratorium involve materials like sand and water, which handhelds were not designed to withstand.

The wireless network performance was adequate for downloading web pages and short audio files. However, network performance can be disrupted by obstacles such as elevator shafts. It is essential to test network performance in the place where it will be used and to check carefully for possible "holes" where performance is bad. Multiple wireless base-stations may be required in such a case.

Picking up Beacons and Barcodes

We found that visitors were able to sense beacons or barcodes with the handheld devices with little trouble. Other Cooltown demos have used a beep to indicate successful beacon or barcode pickup. Since this sound cannot be heard in the Exploratorium, visual feedback must be provided instead.

Likewise, we found that a brief hands-on introduction is required: sending visitors off with only verbal instruction isn't sufficient. However, all visitors became fluent with the devices quickly. The one person who used a barcode reader behaved similarly to those using beacons.

The visitors never accidentally picked up an IR beacon for a different exhibit. However, some visitors accidentally picked up an exhibit's beacon repeatedly, because they happened to hold the Jornada so that its IR port pointed at the beacon, while they were browsing the on-line content. We have since added features to the browser to minimize duplicate pickups by: ignoring them if they occur very soon after original pickup and by, querying the visitor about whether to redisplay the exhibit top-level page if the delay is longer.

Graphical User Interface

In these studies, we gave visitors only extremely brief instructions on how to use the browser interface. Visitors familiar with handhelds and browsers had no trouble using the interface. However, some visitors inexperienced with handhelds had significant problems successfully selecting objects on the touch screen, e.g. they dragged the stylus along the surface rather than tapping. The visitors also weren't familiar with standard browser buttons such as " back". However, these visitors did use the system successfully after brief hands-on instruction. For the last two trials, we added a practice exhibit to the check out process to alleviate this problem.

Content Design and Navigation

The visitors were navigating the content using a stylus and clicking on images or text hyperlinks presented on the web pages. When the top-level navigation page for an exhibit consisted of one large picture (e.g. Fig. 6), some visitors had trouble figuring out that they could click on part of it or which parts

of it were click-able. Some visitors expressed a desire to be able to see how much content there was for each exhibit and which parts of it they had/hadn't seen so far.

Many visitors to the Exploratorium seem to migrate from each exhibit to the next interesting-looking one. In such cases, the visitor only needs to be able to locate a pi-station once he/she has already approached the chosen exhibit. This is not difficult, so long as the pi-station has a reasonably distinctive appearance.

However, other visitors may wish to follow a tour or see a group of thematically related exhibits. Or the on-line content may suggest another exhibit closely related to the one they are at. It is unclear how to best direct visitors from one exhibit to another exhibit. Some of our test visitors had difficulty locating pi-stations on the same floor that were only a modest distance away, even marked by bright orange flags. The on-line map wasn't used much - probably because it was not prominent enough in the on-line interface or too difficult to relate to the 3D environment.

Future Research Plans

We plan to continue our research with the test-bed in the future with a specific aim of conducting studies with different audiences: general public, school field trips, Explainers (floor interpretive staff), teachers, members and staff. An important feature of our next study will be to examine the potential use of the system in before and after visit situations. Our aim is to continue to explore issues of using wireless networks and portable computers to expand and extend the museum visit experience.

5 Conclusion

An additional part of the Electronic Guidebook project is a conscious effort to stimulate discussions within the museum community and between museums and industry about the potential of using these systems in a museum setting. To initiate these discussions, the Exploratorium sponsored the first Electronic Guidebook Forum in the fall of 2001. This two-day forum brought together 39 researchers and developers from industry, academia, and the museum world for discussion of the latest findings on the application of handheld computers and wireless networks in museum exhibitions. The forum discussions centered on interrelated aspects of electronic guidebook projects in museums and on emerging questions from the field. The format included full group discussion of these topics, as well as discussion in small groups on lessons learned and recommended next steps. The goal of the forum was to identify key issues that will inform further work in the museum field on wireless handheld devices and stimulate research and implementation. An in-depth report on the forum is available [4].

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