Cyberlaboratory: Using Human Observation and Cyber Technologies for Research on Free-Choice Learning[1]

Shawn Rowe[1], Susan O'Brien[1], Mark Farley[1], Jenny East[1],
Laura Good[2], Kathryn Stofer[3]

[1]Oregon Sea Grant, Oregon State University, Corvallis, Oregon, United States
[2]Center for Ocean Solutions, Stanford University, Stanford, California, United States
[3]Department of Agricultural Education and Communication, University of Florida, Gainesville, Florida, United States

Corresponding author: shawn.rowe@oregonstate.edu

Abstract

A fully-automated, video-based data collection system has been installed in a public museum/aquarium for research on life-long free-choice learning in everyday contexts. The system links video observation tools, interactive computer-based kiosks, and face detection software with a research control and content management system that allows for data collection and potentially customization of visitor experiences. This paper provides a brief overview of the system as well as some of the initial research projects being carried out by study staff. Researchers are studying family interaction with and learning from physical interactives, digital display platforms, live animal interactions, and staff facilitation. Initial findings from the early phases of this four-year, nationally funded project are presented including data on understanding of complex scientific visualizations projected on digital spheres as well as findings from video observation of volunteer docent practice. Three current research projects involving the use of multi-touch tables, interactive wave tanks and live animal touching experiences are also described.

Introduction: A laboratory for studying learning

[1] This work is the English language manuscript version of Rowe, S., O'Brien, S., Farley, M., East, J., Good, L., & Stofer, K., (2016). Ciberlaboratório: usando observação humana e cibertecnologias para a pesquisa sobre aprendizagem por livre escolha**.** **(**Cyberlaboratory: Using Human Observation and Cyber Technologies for Research on Free-Choice Learning.) In L. Mssarani, R. Neves, & L. Amorim (Eds). *Divulgação científica e museus de ciência: O olhar do visitante - Memórias do evento.* (pp. 23-36). Rio de Janerio: Red de Popularización de la Ciencia y la Tecnología en América Latina y el Caribe – RedPOP & Museu da Vida / Casa de Oswaldo Cruz / Fiocruz. *Available online at http://bit.ly/2bP28IF*

Oregon Sea Grant's Free-Choice Learning (FCL) Laboratory is situated at Hatfield Marine Science Center (HMSC), an Oregon State University marine science research facility on the west coast of the United States housing a Visitor Center (VC) that functions both as a public science museum/aquarium and as a laboratory for studying self-paced, leisure-time lifelong learning. Our research focuses on learning activities that take place outside of classrooms, are self-motivated, and are guided by the needs and interests of learners. Our FCL lab studies how people learn through these activities, both as individuals and as groups. Findings can inform better educational and research practices in informal science education venues as well as the practice of public science communication broadly.

The HMSC campus houses university, state and federal agency researchers, educators, and outreach specialists. The VC serves a public audience of approximately 150,000 people a year as a donation-only, interactive, science center and aquarium, highlighting the research of scientists on site through a combination of computer-based, physical interactive, and live animal exhibits. Since 2004, a research initiative involving informal science education (ISE) has worked to develop a culture of evaluation and research surrounding informal, free-choice science learning in the VC.

In recent years, the US National Science Foundation has funded the installation of a research infrastructure within the VC, using emergent technologies to study behavior, capture responses and adapt content to visitor needs. The "*Cyberlaboratory*" (NSF-ESI 1114741) was established to exploit emerging technologies in a museum setting and across related learning contexts.

The need for new tools for studying learning in everyday settings is evident both in the ISE literature and in practice. Hein (1998) argues for the museum as a forum for eliciting and building on visitors' prior knowledge and experiences in everyday ways to build science knowledge and literacy. This constructivist perspective is widespread in the ISE field (Rowe, 1998) and within the published research literature (Phipps, 2008). It is taken as a given within the ISE field that such customization also requires tapping into visitors' interests in ways that honor their choice and control in learning activity. More recently, the ISE field has recognized the need to create continuity across the myriad places and times learners' engage in science learning (NRC, 2009), and cyberlearning ("learning that is mediated by networked computing and communications technologies" (NSF, 2008, p. 10)) has been advanced as one of the best ways to create that continuity. Yet, very few interactive exhibits at museums incorporate tools that allow for visitor input about the experience or methods of customizing their experience, much less help form connections among museum-based, environmental-based, and school, home or afterschool based experiences.

In practice at museums, parks, and afterschool venues, a variety of technologies (including augmented reality, handheld computers, and human recognition systems) have caught the attention of exhibit and program developers interested in supporting the kind of free-choice learning that Hein and other researchers in the field envision. ISE professionals are looking to find ways to utilize these new technologies to engage learners and visitors, to improve free-choice learning experiences and to conduct research and evaluation without violating what makes these experiences unique.

Cyber Tools for Data Collection

The Cyberlab's current research tools and technology platforms are comprised of three separate but interrelated systems: a video-based observation system, an observational control system, and a database. Fully automated, video and audio-based observation systems are the core tools to record visitor interactions in varied levels of researcher-controlled detail. These observation systems can work independently or in conjunction with the control systems (described below), which can be configured to trigger exhibit content changes based on output results from the observation systems.

Facial detection and recognition engines built into new exhibits utilize cameras to detect faces, and further, map a visitor's face and store the pattern in a database. Once the unique data-print pattern for a particular face has been stored, the system recognizes the same person at other exhibits. Face recognition makes it possible to create a unique user ID number and associated database for every visitor. An Observation Control System allows researchers and evaluators to alter response parameters of adaptive exhibit content. Customizable conditional filters applied to visitor data can trigger content change in an exhibit or handheld application based on a given researcher's line of inquiry. A database contains two primary areas: 1) information about the museum itself entered by researchers and 2) information about visitors collected by the automated system. A simple floor map divides the VC into regions associated with particular exhibit elements or experiences. Each region is pre-loaded with attributes describing the physical properties, learning affordances, and ideas that are associated with that place in the museum. Thus, for instance, a database region that corresponds to an aquarium tank contains information about the fact that the area includes live animals, signage, water, and if appropriate artifacts or biofacts as well as basic information about the type of content of the signage (e.g., biology, nutrition, geology, etc). Similarly, a database region that corresponds to a digital interactive contains information about the fact that the area includes a computer, a digital interface, information about the content of the exhibit, whether there is associated signage, etc. Additional software built in to digital interactives tracks keystrokes, hand gestures, and basic use information about the software which is then also entered into the database.

Because the face recognition system makes it possible to assign a unique, anonymous user ID to all visitors, that ID is then associated with data about all user movements, user selections from various interactive opportunities, user manipulation of digital exhibits, audio comments made to learning partners, relationship links with other users, and time spent at each exhibit. The longer the user spends at the facility, the more data is compiled on choices, learning styles and understanding. Moreover, specially designed adaptive exhibits can be configured to respond to user data, and alter content to suit individual user needs and learning preferences and experiences based on real-time analysis of exhibit use during the visit.

Current Research Areas

The Cyberlab project team has undertaken a variety of research efforts over the last four years exploring the range of traditional museum-based, free-choice, ISE experiences: Physical interactives, digital interactives, live animal interactions, and staff interactions.

Physical Interactives

There is a large body of research on interactive science exhibits as rich places for learning (e.g. Allen, 2004; Gutwill and Allen, 2010). Much of this work (e.g., Dierking, 1987; Bitgood, 1993; Borun, et al., 1996) has explored the link between family behaviors and exhibits. However, theories directing both the design and evaluation of interactive exhibits have traditionally drawn from cognitive and developmental psychology, which focuses on individuals rather than small groups of learners. Learning in the museum context may be better viewed as a social endeavor requiring alternative methodologies for data collection and analysis that take seriously the group as the unit of analysis (Dierking, 2002; Rowe and Bachman-Kise, 2012).

Our wave lab exhibit serves as a platform facilitating research on learning as groups interact among themselves and with exhibit components using physical interactives. The wave lab exhibit utilizes three interactive flume tanks filled with water allowing visitors to explore concepts relevant to coastal issues, from the physics of waves (especially tsunami waves), and beach erosion, to wave energy production. A substantial effort was put into the prototyping phase as we designed and implemented exhibit components and interfaces where visitors could be both hands-on and minds-on as they interact with the exhibit and researchers could easily manipulate the user interfaces, materials, and tasks presented to visitors. The prototyping phase focused on exhibit design, construction, and implementation and on effective methods of researching learning in such exhibits. Our current research with the wave lab platform focuses on tinkering and play as entryways to engineering concepts in a museum setting using video and audio of family interactions in iterative build and test activities. Cyberlab cameras allow us to view simultaneously multiple angles of view on families. This is important as the tanks are large, and the tasks have multiple components from building lego structures to controlling the size, type, and number of waves from a touch-screen kiosk.

Initial analysis involves quantitative exploration of gross-scale data about movement in and around the exhibit, numbers of participants, and time spent at each exhibit component. More detailed analysis of targeted interactions is completed by having a researcher periodically flag video that meets criteria for family group size, time spent, and activity density. This data is downloaded to a separate computer for video-analysis of interaction focusing on patterns of use, collaboration, and discourse patterns in speech.

Digital Interactives

We also carry out research with two different digital platforms of interest to museums and other science learning venues, digital spheres and multi-touch tables. Digital spheres such as the Science on a Sphere display system have allowed us to carry out research on how data visualizations designed for academic scientists might be made more meaningful to museum visitors through appropriate scaffolding. Introduced by Wood, Bruner, and Ross (1976), scaffolding is a term used to describe a process whereby an expert or an interactive itself provides appropriate supports for a novice as they negotiate a new task that is too difficult for them to complete on their own. In our own work, we have identified a number of ways of scaffolding false-color satellite data visualizations of ocean features such as wave height, chlorophyll concentrations, and sea surface temperature that scaffold novices in ocean sciences as they make meaning of those images (Phipps and Rowe, 2010).

In our current work using the Cyberlab, we have used interviews and eye-tracking to investigate academic scientific experts and novices as they attempt to make meaning from global visualizations of ocean data on spheres and flat surfaces (Stofer, 2013).

Laboratory interviews revealed that non-science undergraduates struggled with decoding almost every part of unscaffolded visualizations, while experts had difficulty only in understanding the time of year and season represented. Novices did not always use supporting elements such as the title of the image (e.g., Sea Surface Temperature) and color key (e.g., the graphic image presented near the visualization indicating what the colors represented, temperature or wave height, for instance), could not understand jargon in unscaffolded titles, conflated the meaning of the rainbow color scale used across multiple topics, and could not always orient themselves geographically to the visualizations centered on the ocean. However, their understanding improved on scaffolded visualizations. Interviews with our public audience revealed further struggles with meaning-making; scores were lower than either laboratory participant group (Stofer, 2013).

With the installation of a multi-touch interactive tabletop, we are interested in investigating the social interactions and collaborations occurring around this form of technology. We are exploring how visitors engage with the content and each other as well as how conversations, gesture and technological novelty mediate learning and interaction among family groups. Visitor interviews, observations, and analysis of video of interactions is providing evidence of a variety of collaboration strategies employed by children and adults as they work together to make sense both of the technology and the content of the exhibit (the electromagnetic spectrum).

Video recordings of the adult and child interactions at the multi-touch table have been analyzed using a rubric to quantify levels of engagement on three different dimensions ranging from very low, to low, moderate, high, to very high. The three dimensions included responsive engagement between adult and child, learning strategies and opportunities, and directive engagement by the adult.

Analyses show that the table elicits moderate directed collaboration among, mostly dyads of adults and children, represented by moderate ratings for both responsive engagement and learning strategies and opportunities dimensions. For responsive engagement, this indicated that the adults or children spent approximately an equal amount of time focused on the exhibit or turning away and looking around. It also means that in a majority of instances the adults and children appear to be listening to each other by acknowledging comments or questions the other learners make. A “moderate” rating for learning strategies and opportunities indicates that in a few instances, adults and children reference the content of the exhibit, there may be one or two questions about exhibit content, and one or two references about prior knowledge or events outside of the immediate exhibit experience. For the directive engagement dimension, a majority of the groups demonstrated low levels, or less explicit instruction by the adult as to how to use the exhibit or perform tasks, but analysis also showed that in some groups, children over ten take the lead in directing adults on how to use the exhibit. This research may give insight to how the public uses this form of technology in a public science center while providing evidence of learning via social participation.

Live Animal Interactions

Many studies such as Falk et al. (2007) and Fraser & Sickler (2009) have demonstrated increasing efforts to justify the overall value of visitor experiences within zoos and aquariums in the U.S. There is limited research on the impact of live animal encounters and touch tank experiences in museums, but the few studies there are point out that such exhibits can be rich settings for learning science (Ash, 2003; Ash et al. 2008). Regardless, live animal encounters and animal touch experiences are commonly featured in many informal science education venues. The effort, time and money required for establishing and maintaining touch tanks and live animal exhibits within museum education programs is apparently motivated by the general belief that touching and interacting with live animals facilitate affective reactions of care, therefore helping create conservation awareness (Rowe and Kisiel, 2012).

HMSC features a large touch-tank containing marine invertebrates of the northeastern Pacific Ocean. Using the HMSC touch tanks as a focal point for data collection is allowing us to explore more deeply the impact of live animal interactions on visitors' conservation attitudes and/or behavior, a topic which has been investigated in many studies with inputs for research in education, psychology, sociology, cultural studies and tourism (e.g. Ballantyne et al., 2007; Falk et al., 2007; Hughes, 2011; Kisiel et al., 2012; Rowe and Kisiel, 2012), most pointing to positive correlations, at least to some degree. Nevertheless, it can be difficult to document the outcomes and impacts of FCL experiences with live animals. Quantitative results can be misleading, so much of the research in the area relies on qualitative data. Our current project allows us to combine both large-scale quantitative data on use of and interactions at touch tanks with deep qualitative analysis of videoed interactions as well as comparison between family experiences at the museum touch tanks, focusing specifically on the manipulation of choice and control by learners (O'Brien, et al., 2014).

Staff interactions

Finally, our automated data collection system is being used in conjunction with cameras placed on visitors to explore the practices of volunteer docents and facilitators in the museum context (Good, 2013). In this respect, we are looking at the ways in which combinations of video data can illuminate complex visitor-staff interactions, useful for unpacking interpretive practice. Museum settings, including aquariums, zoos and science centers, rely heavily on their volunteer docent populations to interact with and communicate science and conservation concepts to the visiting public. Docents often make up a substantial portion of a museum's educational staff as a whole. As such, the interactions docents have with museum visitors are important to meeting the educational expectations of museums, while improving public science literacy as a whole,. However, research to date is rather limited around topics concerning docent practice, docents' reflection on that practice and sources of docent learning. Thus, we have little understanding of the interpretive practice docents actually undertake when they are interacting with visitors, why they choose to enact particular strategies, and how they came to learn those practices, especially in consideration of regular staff training routines a museum may employ.

For this study, visitors were asked to wear small digital video cameras that attached over their ears throughout their visit. The researcher then isolated video from those cameras shared with docents who reflected with the researcher on the video interactions and their own practice. Thematic analysis using constant comparative methods demonstrated four claims about docent practice: 1) docents view teaching in the museum as opportunities to spark interest with new experiences; 2) docents utilize a shared repertoire of practice and information in their community developed from understanding visitor patterns of interest; 3) docents believe that being a docent means balancing potentially conflicting roles; and 4) docents use interpretation as a pedagogy to engage visitors with science and create personally meaningful experiences. Analysis of significant interactions between docents and visitors shows that such practices are mediated through a variety of discursive and physical tools and implemented by docents as a means of engaging visitors with science and conservation.

Implications and Conclusions

The projects briefly reported here build on the last nine years of work by the FCL Lab at HMSC. Traditionally, our studies of free-choice learning in ISE settings, like those in museums around the world, have employed video, observational, survey and interview tools that are time and effort intensive for data collectors and for participants. Through the use of less-obtrusive, built in observation systems keyed to information collected from digital interactives, handheld devices, and wearable video, we can significantly decrease the amount of person time devoted to data collection allowing for more sustained focus on analysis. At the same time, from a participant perspective, data collection is more seamlessly woven into the leisure and learning experience at the museum and may even be able to help customize that experience.

It is also worth mentioning here that from the beginning of this project, we have been engaged in a variety of conversations with visitors, other researchers, and administrators about the ethics components of this and similar projects. We have worked very closely with the Oregon State University Institutional Review Board and Human Studies Board to ensure that participants are informed about data collection, knowledgeable about their participation and comfortable with our work. Visitors are aware that we are collecting data remotely as data from floor interviews shows, and they have very few issues or questions about it. To date, we have had no complaints from visitors to the museum about the project or their involvement, and we have no evidence that visitation to the museum or to specific exhibit areas is suffering. Most importantly, we have no evidence that the visitor experience is being affected negatively in any way. In fact, we have evidence of just the opposite. Visitors report enjoying knowing what we are doing and being a part of it. This has made us eager to pursue a second line of research where visitors become true co-researchers working alongside us to describe and understand their learning (O'Brien, 2015).

References

Allen, S. (2004). Designs for learning: Studying science museum exhibits that do more than entertain. *Science Education*, *88,* S17-S33.

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching*, *40*(2), 138-162.

Ash, D., Crain, R., Brandt, C., Loomis, M., Wheaton, M., & Bennett, C. (2008). Talk, tools, and tensions: Observing biological talk over time. *International Journal of Science Education*, *29*(12), 1581-1602.

Borun, M., Chambers, M., and Cleghorn, A. (1996). Families are learning in science museums. *Curator, 39*(2), 123-138.

Ballantyne, R., J. Packer, K. Hughes, and L.D. Dierking (2007). Conservation learning in wildlife tourism settings: Lessons from research in zoos and aquariums. *Environmental Education Research 13*(3), 367–83.

Dierking, L. (2002). The role of context in children's learning from objects and experiences. In S. Paris (Ed.), *Perspectives on object-centered learning in museums.* (pp. 3-18). Mahwah: Lawrence Erlbaum Associates.

Good, L. (2013). *Unpacking docent practice in free choice science learning settings: a qualitative study documenting the what and whys of docent interpretive practice.* Unpublished Doctoral Dissertation, Oregon State University, Coravllis, OR. Available at http://hdl.handle.net/1957/38635

Falk, J.H., Reinhard, E.M., Vernon, C.L., Bronnenkant, K., Heimlich, J.E., & Deans, N.L. (2007). *Why zoos and aquariums matter: Assessing the impact of a visit to a zoo or aquarium*. Silver Springs, MD: Association of Zoos and Aquariums.

Fraser, J. & Sickler, J. (2009). *Why aquariums & zoos matter handbook*. Silver Spring, Maryland: Association of Zoos & Aquariums

Gutwill, J. P. and Allen, S. (2010). Facilitating family group inquiry at science museum exhibits. *Science Education*, 94(4), 710–742.

Hein, G. (1998). *Learning in the Museum.* London: Routledge.
Hughes, K. (2011). Designing Post-Visit Action Resources for Families Visiting Wildlife Tourism Sites. *Visitor Studies*, 14:1, 66-83.
Kisiel, J., Rowe, S., Vartabedian, M. & Kopczak, C. (2012). Evidence for Family Engagement in Scientific Reasoning at Interactive Animal Exhibits. *Science Education*, 20 (0), 1–24.
National Research Council, (2009). *Learning Science in Informal Environments: People, Places and Pursuits.* Committee on Learning Science in Informal Environments. Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington DC: National Academies Press
NSF Task Force on Cyberlearning (2008). *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge: A 21st Century Agenda for the National Science Foundation.* Washington DC: National Science Foundation.
O'Brien, S. (2015). Learning research in public, within the public eye, and with public participation. Accessed at http://blogs.oregonstate.edu/freechoicelab/2015/03/20/learning-research-in-public-within-the-public-eye-and-with-public-participation/
O'Brien, S., Rowe, S., Dierking, L, & Farley, M. (2014). Family Engagement in Live Animal Touch-Tanks and Natural Tidepools: Links to Learning and Conservation Dialogue. Proceedings of the 13th annual PCST meeting, Salvador, Brazil.
Phipps, M. (2008). An iterative investigation into the implementation of handheld computers as learning tools in a science museum. Unpublished Doctoral Dissertation, Oregon State University, Coravllis, OR. Available at http://ir.library.oregonstate.edu/xmlui/handle/1957/8988
Phipps, M., and Rowe, S. (2010). Seeing satellite data. *Public Understanding of Science (19)*3: 311-321
Rowe, S. (1998). *Learning talk: Understanding how people talk and think about learning in the St. Louis Science Center*. St. Louis, MO: St. Louis Science Center.
Rowe, S., and Bachman-Kise, J., (2012). Mediated action as a framework for exploring learning in informal settings. In D. Ash, J. Rahm, and L. Melber (Eds.), *Putting theory into practice* (pp. 143-163). Rotterdam: Sense.
Rowe, S., & Kisiel, J. (2012). Family engagement at aquarium touch tanks—Exploring interactions and the potential for learning. In E. Davidsson and A. Jakobson, (Eds.), *Understanding interactions at science centers and museums – Approaching sociocultural perspectives* (pp. 63-77). Rotterdam: Sense.
Stofer, K. (2013). *Visualizers, Visualizations, and Visualizees: Differences in Meaning-Making by Scientific Experts and Novices from Global Visualizations of Ocean Data.* Unpublished Doctoral Dissertation, Oregon State University, Coravllis, OR. Available at http://hdl.handle.net/1957/38635
Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, *17*(2), 89 – 100