



Museum Visitor Studies, Evaluation & Audience Research

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**Annotated Bibliography:
Best Practices for Science on a Sphere[®]
and Using Inquiry**

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INTRODUCTION

Randi Korn & Associates, Inc. (RK&A) was contracted by the Science Museum of Virginia (SMV) to compile research to inform the development and subsequent evaluation of its Science on a Sphere[®]-based *Sphere Corps* program.

Two guiding questions focused the research:

- ◆ What can we learn from the implementation and evaluation of other NOAA-funded Science on a Sphere[®] programs to inform the development of SMV's *Sphere Corps*?
- ◆ What are best practices in the use of inquiry for short-format programming in informal learning environments? How can they inform the development of SMV's *Sphere Corps*?

In the first section of this literature review, we offer a set of questions that staff can use to guide reflection about the annotations that follow. The twelve annotations are organized under two headings—"Section 2: Science on a Sphere[®] Best Practices," and "Section 3: Best Practices for Using Inquiry."

SECTION I: REFLECTION QUESTIONS

During the Clarifying Intended Visitor Impact workshop on March 17th, one goal will be to reflect on the meaning and implications of the annotations in this literature review for developing *Sphere Corps*. To this end, we offer this set of questions for staff to reflect on while reading the literature review:

- ◆ What are common elements of successful Sphere experiences? Are these applicable to *Sphere Corps* as you envision it? Why or why not?
- ◆ What challenges have other Sphere programs and exhibits faced? How might *Sphere Corps* overcome those challenges?
- ◆ What are elements or strategies of an effective inquiry approach?
 - ❖ Consider elements of Science on a Sphere[®] that might work well for an inquiry-based approach. Why might these elements work well?
 - ❖ What elements of Science on a Sphere[®] might present challenges for facilitating inquiry?
- ◆ What are common outcomes achieved through inquiry?
 - ❖ Given the *Sphere Corps* impact framework, what impacts and indicators seem possible to achieve through inquiry? Why?

SECTION 2: SCIENCE ON A SPHERE® BEST PRACTICES

Goldman, K. H. et al. 2010. *Science on a Sphere®: Cross-Site Summative Evaluation*. Unpublished manuscript. Edgewater, M.D.: Institute for Learning Innovation.

TYPE OF RESOURCE Unpublished manuscript

METHODOLOGY Literature review, review of Science on a Sphere (SOS)® evaluation reports, and semi-structured interviews

CENTRAL IDEA A cross-site summative evaluation explored which outcomes are most likely to occur when visitors engage with SOS® to determine which outcomes warrant further research.

SUMMARY

- ◆ The Institute for Learning Innovation (ILI) reviewed literature and evaluation reports to determine: the broader learning potential of visualization experiences like the Sphere and the specific learning potential of the Sphere experience itself. Further, ILI trained staff at sites with SOS® to conduct visitor interviews to assess learning and factors that influence learning.
- ◆ A review of the literature on the learning potential of science visualizations revealed that “visualizations can reduce the amount of effort required to solve problems; may support scaffolding and the construction of mental models; allow learners to understand complex science topics more completely; and can enhance understanding of specific dynamic concepts when animated or simulated.”
- ◆ A review of SOS® evaluation reports revealed several distinct findings; these include, but are not limited to: visitors are interested in seeing local information, visitors’ dwell time is limited without facilitation and seating, visitors find it difficult to see images at the top of the Sphere suggesting that use of the axis-tilt feature is wise, and visitors appreciated having supportive information like labels and arrows to interpret data sets.
- ◆ ILI presents four key findings from the summative evaluation: (1) Most visitors who experienced SOS® reported learning new information; (2) visitors’ perceptions of their Sphere experience were best represented by statements that reflected the authenticity of the Sphere, including its ability to represent the complexity and change in Earth (or other planetary) systems; (3) visitors felt that seeing information projected on the Sphere is more realistic and provides more perspective; and (4) facilitation of the Sphere correlates strongly with visitors’ perception of learning.
- ◆ Findings also suggest that content influenced visitors’ perceptions of learning; visitors who saw atmospheric data sets were more likely to perceive new learning than those who did not. Possible explanations include that visitors may know less about atmospheric content and thus perceive greater gains in this area; and interaction effects (such as the relationship between facilitation and content) may be responsible but were not studied.
- ◆ ILI also made recommendations for four areas of further research: the impact of Sphere facilitation, two-dimensional versus three-dimensional presentation systems, controlled studies on content, and perceived versus actual learning.

People, Places, and Design Research. 2009. *Summative Evaluation: Water: H2O = Life*.
Unpublished manuscript. St. Paul, M.N.: Science Museum of Minnesota.

TYPE OF RESOURCE Unpublished manuscript

METHODOLOGY Interviews

CENTRAL IDEA A summative evaluation of an exhibition that included Science on a Sphere[®] explored visitors' perceptions of exhibit highlights, learning of key messages about water, and recognition of scientific data.

SUMMARY

- ◆ People, Places and Design Research interviewed 399 visitors as they exited the *Water: H2O = Life* exhibition to explore their experiences, perceptions, and learning. Additionally, they intercepted 50 visitors and asked them their opinions of Science on a Sphere[®].
- ◆ The most frequently mentioned exhibition highlight was Science on a Sphere[®] (33 percent).
- ◆ Science on a Sphere[®] was mentioned as the second most stopped at exhibit, with 77 percent of visitors indicating they “stopped long enough to find out what it is about.”
- ◆ Science on a Sphere[®] was the most memorable visual to visitors as representative of their exhibition experience, with 34 percent indicating it as “a visual image [they] would remember the exhibition by.”
- ◆ A smaller portion of visitors perceived Science on a Sphere[®] as an experience that “changed how [they] think about water” (28 percent) or “helped [them] visualize or understand something about environmental issues related to water” (22 percent) compared to other exhibits.
- ◆ 40 percent of visitors selected Science on a Sphere[®] as an exhibit that “present[ed] data gathered by scientists.”
- ◆ Findings suggest that *Blue Planet* (an audio program projected on the Sphere) was effective at conveying information and presenting memorable visible images, but less effective in changing how people think about water.
- ◆ Many visitors who were invited to view *Blue Planet* remembered and were struck by a blue line that demonstrated the small percentage of Earth’s water that is fresh.
- ◆ Some visitors indicated that viewing *Blue Planet* changed how they think about water, but the change was mostly associated with seeing a global perspective projected on the Sphere.

Randi Korn & Associates, Inc. 2009. *Remedial Evaluation of Oceans Revealed: Powers of the Planet*. Unpublished manuscript. Manteo, N.C.: North Carolina Aquarium on Roanoke Island.

TYPE OF RESOURCE Unpublished manuscript

METHODOLOGY Naturalistic observations and interviews

CENTRAL IDEA A remedial evaluation of an exhibition and programming designed around Science on a Sphere[®] explored visitors' overall experience, behaviors, and learning.

SUMMARY

- ◆ RK&A observed three programs designed around Science on a Sphere[®], two unscripted and one scripted, entitled *Oceans 101*. 20 to 30 visitors attended each program. Eight visitors were interviewed post-program.
- ◆ RK&A also observed 41 walk-in visitor groups comprised of 144 visitors and 22 walk-in visitors were interviewed as they exited the exhibit.
- ◆ Program observations showed that most programs were delivered in lecture format and involved few questions posed to visitors. Very few visitors posed their own questions to presenters. Visitors were quiet and most stayed for the duration of the program.
- ◆ Without facilitation, observations demonstrated that the majority of visitors stayed three to four minutes; watched between one to two data sets; and did not look at text or introductory panels.
- ◆ Observations also demonstrated that visitors' engagement with the Sphere without facilitation varied considerably; some were fully engaged while others left quickly. Many exhibited interest in data sets that represented human activity or familiar natural phenomena.
- ◆ Interviews showed that the majority of walk-in visitors articulated basic to little understanding of Sphere data sets; program participants articulated greater understanding, although this sample was small.
- ◆ Most program and walk-in visitors said they would be unlikely to change their behavior based on their program or exhibit experience.
- ◆ Recommendations included: adding seating to the exhibit to increase dwell time and comfort; and, as part of each program, consider including one concrete change that visitors can make in their everyday lives to address environmental concerns, as this was a goal of the exhibit.

Pacific Resources for Education and Learning. 2007. *Evaluation of the Bishop Museum's Science on a Sphere*[®]. Unpublished manuscript. Honolulu, H.I.: Bishop Museum.

TYPE OF RESOURCE Unpublished manuscript

METHODOLOGY Program observations, post-program survey, on-site interviews, and follow-up e-mail survey

CENTRAL IDEA An evaluation of two educational programs designed to accompany Science on a Sphere[®] demonstrated gains in visitor learning and recommended changes in program design to improve effectiveness.

SUMMARY

- ◆ Pacific Resources for Education and Learning (PREL) evaluated two programs developed by the Museum: a public program on global warming and science education programs designed for schools. Findings from the public programs are presented here.
- ◆ The 20-minute public program on global warming aimed to: increase understanding of global warming and Hawaii's connection to it and empower visitors to make decisions that would reduce their impact on global warming.
- ◆ PREL observed six randomly selected public programs conducted by a range of staff, administered a post-program survey to 29 participants from those programs, interviewed 13 participants on-site following programs, and received responses from six participants via the follow-up e-mail survey.
- ◆ PREL found that the greatest impact of the program was on participants' knowledge of the causes of global warming (as opposed to beliefs, as most respondents entered with positive views of science and a belief in global warming).
- ◆ Findings from interviews suggest that presenting information on the Sphere made it more realistic and authentic than a flat-screen presentation; further, findings revealed that Sphere data sets that "used the technology fully" (i.e., time-lapsing, data mapping), such as worldwide sea level rising, were most memorable to participants.
- ◆ Based on observation and interview findings, PREL gave specific recommendations for improving the program's impact. They recommended decreasing audience distractions by: decreasing traffic flow through the presentation area, providing sufficient seating before the presentation begins, accommodating multiple viewing angles, and increasing audience participation through activities and questioning.
- ◆ Another recommendation based on findings was to ensure consistency among presenters; observations demonstrated that presenters emphasized different things during presentations and PREL recommended a peer review process that would improve and ensure consistent presentation style.
- ◆ Observations suggested that not all science content is ideally presented on the Sphere; PREL suggested that only content that lends itself to spherical display should be shown.

Grack Nelson, A. 2006. *Science on a Sphere®: Formative Evaluation Report*. Unpublished manuscript. St. Paul, M.N.: Science Museum of Minnesota.

TYPE OF RESOURCE Unpublished manuscript

METHODOLOGY Observations and interviews

CENTRAL IDEA A formative evaluation of Science on a Sphere® at the Science Museum of Minnesota explored visitors' behaviors and experiences in the exhibition.

SUMMARY

- ◆ Staff at the Science Museum of Minnesota observed and interviewed 50 visitors (8 years and older) as they exited the exhibition. Observations explored specific behaviors, including dwell time, and interviews helped explain behaviors and visitors' meaning-making.
- ◆ The playlist was 55 minutes in length. Visitors stayed for a median time of 3 minutes, 29 seconds compared to the front-end study which found a median dwell time of 3 minutes. The front-end study included a much shorter playlist, about 7 minutes in length.
- ◆ Findings showed that visitors who sat down during the experience stayed significantly longer than those who did not (8 minutes versus 3 minutes).
- ◆ Observations showed that more than one-half of visitors circled less than half the Sphere. Most of these visitors (81 percent) realized they could circle the Sphere but chose not to, and only 14 percent thought it was *not* necessary to move to see the entire visualization.
- ◆ In a front-end evaluation, 40 percent of visitors were interested in the Sphere's technology; this evaluation asked visitors to elaborate. Two-thirds of visitors were interested in how images are projected and aspects of Sphere display (e.g., how it moves).
- ◆ 82 percent of visitors were observed looking at labels associated with data sets; some labels included questions but little information is available about the effectiveness of questions as only one-quarter ($n = 10$) noticed the questions.
- ◆ Visitors suggested changes to help them better understand the Sphere visualizations; these included improving audio, providing labels for visualizations, allowing visitors to see the top of the Sphere, and slowing down the image rotation.
- ◆ When asked to articulate the main message of the Sphere visualizations, few visitors articulated a message related to basic global cause-effect processes (the intended message). Staff hypothesized that this was because the playlist did not contain a cohesive storyline.

RMC Research Corporation. 2004. *Science on a Sphere® Front-end Evaluation*. Unpublished manuscript. Baltimore, M.D.: Maryland Science Center.

TYPE OF RESOURCE Unpublished manuscript

METHODOLOGY Observations, interviews, and written surveys

CENTRAL IDEA A front-end evaluation of Science on a Sphere (SOS)[®] explored visitors' responses to the Sphere visualizations, including engagement and meaning-making.

SUMMARY

- ◆ RMC Research Corporation intended to explore the learning potential of the Sphere via three aspects: visualization of data on the Sphere, interpretive program scripts, and Sphere placement in the Museum; however, due to contextual constraints, the ultimate focus of the evaluation was on visitors' responses to Sphere visualizations.
- ◆ RMC observed, interviewed, and administered surveys to visitors participating in Sphere programming. Programs varied between 20 to 40 minutes and were based on NOAA scripts or presenter knowledge and choice.
- ◆ Findings suggest that seating and limiting other audio distractions (such as museum announcements) may enhance Sphere presentations.
- ◆ Although the evaluation did not specifically explore presentation content or style, unsolicited comments from visitors suggested that facilitation of the Sphere helped visitors understand and focus on content.
- ◆ While unclear how prevalent the trend, some visitors appreciated presentations in which the presenter was extremely knowledgeable about content, used humor, and paid attention to children in the group.
- ◆ Observations showed that when large numbers of children were present, the presenters kept them engaged by asking many questions. Findings suggest that young children (6 years and younger) were the most difficult to engage with the Sphere.
- ◆ Findings also suggest that there was little interaction between visitors during presentations except when shown a visualization of Earth's topography. RMC hypothesizes that slowly rotating the Sphere and engaging visitors in discussion of a familiar topic led to this increased engagement between visitors.
- ◆ Findings suggest that personally relevant content is of interest to visitors; for example, data sets that show familiar places and/or locally relevant content.
- ◆ Findings suggest that visitors primarily learned big ideas such as "The Earth is always changing," mechanical explanations such as how the continents formed, and what visualizations of global phenomena, significant events, and time and scale look like.
- ◆ Visitor-suggested modifications to Sphere presentations included: repetition of images, tilting the Sphere, and zooming in.
- ◆ Findings suggest visitors did not express great curiosity about how data was collected but instead took its existence for granted.

SECTION 3: BEST PRACTICES FOR USING INQUIRY

Gutwill, J. P., and Allen, S. 2010. *Group Inquiry at Science Museum Exhibits: Getting Visitors to Ask Juicy Questions*. Walnut Creek: Left Coast Press, Inc.

TYPE OF RESOURCE Book

METHODOLOGY Randomized controlled experiment using video-recorded observations and telephone interviews

CENTRAL IDEA A research study of the Exploratorium’s Juicy Question activity suggests key elements for encouraging group inquiry at science museum exhibits.

SUMMARY

- ◆ The authors note that there is no universal definition for inquiry, but that it often includes scientific processes such as observing, questioning, experimenting, and explaining.
- ◆ The purpose of Juicy Question is to teach two important inquiry skills—proposing questions (asking juicy questions or suggesting something to try) and interpreting results (voicing discoveries), as well as to encourage collaboration among group members at exhibits.
- ◆ The two primary audiences for Juicy Question are families with children ages 8 years and older and field trip students in grades 4 to 7.
- ◆ Juicy Question is based in the research on learning; specifically, it: fosters a cycle of learning, builds on learners’ prior knowledge, explicitly identifies skills, supports meta-cognition and collaboration, uses cognitive scaffolding, builds on intrinsic motivations, and supports visitors’ learning agendas.
- ◆ Juicy Question has four steps: play with the exhibit, brainstorm and select a Juicy Question (a question to which no one knows the answer *and* which can be answered with the exhibit), use the exhibit to investigate the question more deeply, and reflect on discoveries.
- ◆ Findings from the research study suggest that Juicy Question significantly enhanced the amount and quality of the two inquiry behaviors taught, improved inquiry skills not taught (i.e., coherent investigations—multiple experiments in pursuit of a single question; and collaborative interpretation—interpretations that built on one another), and seemed to support conceptual understandings of science.
- ◆ The authors suggest the following key aspects of Juicy Question that contribute to its success as a group inquiry activity: everyone is asked to participate, group members negotiate to choose a question to investigate, participants are required to verbalize their discoveries, and facilitators are given an important role.
- ◆ Because this study occurred in a lab-like environment, the authors provide suggestions for adapting the activity for the chaos of the museum floor, such as: educators can pose an initial question to get visitors started and offer question “starters” (i.e., questions with stems like “What would happen if ...?”).

Allen, S., and Gutwill, J. P. 2009. Creating a Program to Deepen Family Inquiry at Interactive Science Exhibits. *Curator: The Museum Journal*, 52(3): 289-306.

TYPE OF RESOURCE Journal article

METHODOLOGY Randomized controlled experiment using video-recorded observations and telephone interviews

CENTRAL IDEA An article published one year prior to the Exploratorium's book detailed in the annotation above offers additional insight into key elements of and ways to adapt their group inquiry activity, Juicy Question.

SUMMARY

- ◆ The authors note that most definitions of inquiry focus on scientific process and skills rather than scientific content.
- ◆ Based on formative evaluation findings, the Exploratorium narrowed their original list of inquiry skills from six to two because the burden on the visitor was too great.
- ◆ An important step in the Exploratorium's program development process included defining characteristics of a feasible program. Given their context, these included being: appropriate for a broad range of ages, interests, and backgrounds; accessible to those *without* strong science backgrounds; intrinsically enjoyable; quickly learnable and easily remembered; and applicable across a broad range of exhibit types and topics.
- ◆ Another important step in the Exploratorium's planning process was choosing a pedagogical structure; the approach of "cognitive scaffolding" was chosen because the goal was for visitors to eventually apply the inquiry skills on their own at other exhibits.
- ◆ The authors note an important insight from their research study: the decision has to be made whether to *teach* the processes of inquiry or *provide* an isolated inquiry experience.
- ◆ A juicy question is one to which *nobody* knows the answer *and* can be answered *using the exhibit*. This definition is intentional; visitors are more engaged if they do not already know the answer and feel more successful if able to answer the question using the exhibit rather than having to rely on previous knowledge they may or may not possess.
- ◆ "Why" questions are not "juicy" because they often require previous knowledge or explaining the invisible. Better question stems for *experimentation* are "what happens if?"
- ◆ The authors also note challenges of adapting the activity to other contexts: the activity is best for small groups of 3 to 5 and exhibits with a high degree of physical manipulation; the skill of the educator also determines level of enjoyment.
- ◆ The authors suggest adapting the activity for larger groups who are participating in an experience with little opportunity for physical manipulation: adjust the specific inquiry skills targeted to emphasize *observation* rather than experimentation.
- ◆ Visual Thinking Strategies (VTS) developed by Abigail Housen is suggested as an alternative framework for environments where *observation* is being emphasized, since it offers visitors opportunities to share interpretations of what they observe and identify evidence for such interpretations.

Housen, A., and Yenawine, P. 2001. *Visual Thinking Strategies: Understanding the Basics*. New York: Visual Understanding in Education.

TYPE OF RESOURCE Publication

CENTRAL IDEA A guide to implementing Visual Thinking Strategies (VTS) discusses key aspects of facilitating this method for looking at works of art.

SUMMARY

- ◆ Visual Thinking Strategies uses art to teach thinking, communication skills, and visual literacy to beginning viewers.
- ◆ VTS encourages skills associated with aesthetic thinking (and examining other visual phenomena), including observing, speculating, and reasoning on the basis of evidence.
- ◆ The works of art are chosen to allow viewers to draw upon, apply and reflect on what they already know.
- ◆ VTS includes three key questions:
 - ❖ *What's going on in this picture?* This question suggests that there is something about the image that can be figured out. This wording is carefully chosen to encourage meaning-making as opposed to generating a visual list.
 - ❖ *What do you see that makes you say that?* This question encourages closer looking and grounds interpretations in visual data. The wording of this question keeps discussion focused on the image being discussed.
 - ❖ *What more can we find?* This question encourages more and deeper looking and suggests to viewers that there is more to find in the image.
- ◆ Other key aspects of VTS include:
 - ❖ Acknowledging every response in a neutral way, pointing to relevant details, and paraphrasing to indicate understanding and ensure group understanding.
 - ❖ Acknowledging each response as having equal value; group discussion of a topic usually leads to greater accuracy, and most interpretations align with the artist's intent if grounded in visual evidence.
 - ❖ Linking thoughts by acknowledging agreements/disagreements, connecting thoughts that build on each other, and pointing out shifts in thought. By doing this, viewers become aware of how thinking unfolds and that one observation leads to another.
 - ❖ When answering questions, the first response should be "Can we answer that by looking?" If not, ask "Does anyone know the answer to that?" or "Where could we look to find that out?" The intent is to encourage thinking about how to acquire information.
 - ❖ VTS discussions typically last 15-20 minutes and include groups of no more than 25 people (ideal size is 15).
 - ❖ Summarizing or reaching consensus is unwise because it takes the power away from the viewer and accurately remembering everything said is difficult.

National Research Council. 2000. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*, S. Olson and S. Loucks-Horsley, eds. Washington, D.C.: National Academy Press.

TYPE OF RESOURCE Book

CENTRAL IDEA A practical guide for teachers, professional developers, administrators, and others who wish to effectively emphasize scientific inquiry. The book includes a background discussion of inquiry, a literature review arguing for the value of inquiry, and actions that interested parties can take to promote inquiry.

SUMMARY

- ◆ This book is framed around chapters that define inquiry, provide examples of inquiry-based teaching, offer assessment tools, support the value of inquiry with research, and list resources that support inquiry. Formal education is the primary context.
- ◆ The authors note: “learning environments that concentrate on conveying to [learners] what scientists already know do not promote inquiry; rather, an emphasis on inquiry asks that we think about what we know, why we know, and how we have come to know.”
- ◆ Inquiry-based teaching and learning is distinguished from general inquiry and inquiry practiced by scientists. Inquiry-based teaching and learning ensures learners are:
 - ❖ engaged by scientifically oriented questions (“how” not “why” questions) that learners are motivated to answer and are answerable through observation and knowledge acquired from reliable sources;
 - ❖ prioritizing evidence, allowing them to develop and evaluate explanations that address scientifically oriented questions;
 - ❖ formulating explanations from evidence to address scientifically oriented questions by relating what is observed to what is already known;
 - ❖ evaluating explanations against alternative explanations; elimination or revision of explanations distinguishes scientific from other forms of inquiry; and
 - ❖ communicating and justifying their proposed explanations to others.
- ◆ Inquiry varies in degrees of openness and totality; the more learner -directed an inquiry, the more “open” the inquiry. Likewise, if all inquiry steps are included, the inquiry is considered “full” (versus “partial”).
- ◆ Intended learning outcomes are key to determining the degree of inquiry (e.g., is the goal to learn a particular science concept and/or acquire certain inquiry abilities?). Guided inquiry is best for teaching particular science concepts; “open” inquiry is best for cognitive development and scientific reasoning.
- ◆ Inquiry takes time and often requires a series of experiences as opposed to a singular experience.
- ◆ Not all science subject matter can be effectively taught through inquiry.
- ◆ For learners to develop the ability to ask questions, they must “practice” asking questions; it is a myth that true inquiry *only* occurs when learners generate and pursue their own questions, although this is desirable. If the outcome is learning science content, the question’s source is less important than the nature of the question itself.

- ◆ A skilled facilitator remains the key to effective inquiry; it is a myth that inquiry teaching occurs easily through the use of hands-on or kit-based instructional materials.
- ◆ It is a myth that inquiry can be taught without attention to subject matter; learners start from what they know and inquire into things they do not know.
- ◆ Teachers and/or facilitators need to “do” inquiry to learn its meaning, value, and how to use it to help others learn.
- ◆ Strategies in which facilitators study their own or others’ practice are especially powerful in building their knowledge of how people learn most effectively (e.g., studying videos of teaching).
- ◆ Knowledge is built from what one already knows and believes. Many learners’ preconceptions are inconsistent with accepted science knowledge, and their ideas about natural phenomena are unlikely to change simply by being told. Inquiry must start with these preconceptions.
- ◆ When people think of science as a set of facts, they are less likely to seek evidence for different explanations, think about why one set of evidence is stronger than another, and make good decisions about which explanation has the most support.
- ◆ Effective learning environments include four elements: learners, knowledge, assessment, and community. These environments:
 - ❖ elicit learners’ knowledge and build on it as a starting point for the experience.
 - ❖ encourage connections between ideas and help people think about the “big idea” underlying a subject; they learn where it applies and how.
 - ❖ help people learn to monitor and regulate their own learning by questioning why they believe something and whether there is sufficient evidence for it.
 - ❖ require articulation of ideas, challenging those of others, and negotiating deeper meaning along with others. Mistakes are necessary if learning is to occur.
- ◆ Answering questions during inquiry-based teaching is allowed; responding to questions should support deeper understanding and transfer of knowledge. There are many ways to respond to a question—set up a simple investigation, have someone look it up, or answer it if there is a higher priority based on the goals of the activity.
- ◆ While learners are more motivated to answer questions they pose themselves, the teacher must consider what is feasible to answer in any given context. Not all questions posed are worth investigating given the goals of a particular learning context.

Ansbacher, T. 1999. Experience, Inquiry, and Making Meaning. *Exhibitionist*, 18(2): 22-26.

TYPE OF RESOURCE Journal article

CENTRAL IDEA An article discusses the merits of designing for experience-based learning in museums, a model that is collectively known as the inquiry cycle.

SUMMARY

- ◆ The author argues for a museum model that promotes experience-based learning. This model includes three primary elements: direct experience, process, and understanding.
- ◆ One's own experience is touted as the key element in learning. What we experience with our senses, interplay between the physical world and the mind, is called *direct experience*.
- ◆ *Understanding* refers to using our mind to find regularities and relationships among different experiences, a synthesizing of experiences into one larger theme or idea.
- ◆ The *process* the mind uses to create understanding is to compare real-world experiences to what the mind already knows and vice versa.
- ◆ The *inquiry cycle* is going between understanding and direct experience through the above process, creating more and deeper understandings of the world.
- ◆ Two implications of this model for museum design are noted: (1) knowledge and understanding cannot be delivered whole into people's minds; a visitor must engage in his/her own inquiry cycle; and (2) each individual's inquiry cycle is unique, as it depends on one's experiences and capacity to process experiences.
- ◆ The outcomes of experience-based learning are also known as "making meaning," "learning," and "doing science."
- ◆ Two misunderstandings with regard to "making meaning" are noted: (1) the model does not imply that all meanings are equally good or correct; it says that the meaning an individual makes is valid for that individual, and those with larger bases of experience and better process skills will pursue inquiry at higher levels; (2) individuals do not have to make meaning all on their own; facilitation of the experience is key, but caution should be taken not to impose pre-determined outcomes.
- ◆ This model shifts the focus from cognitive to experience outcomes (i.e., engaging in the process of learning); the goal of exhibition development is to determine what you would like visitors to be able to see and do and how those experiences can be connected to form inquiry cycles, and the goal of exhibition design is to create an environment that facilitates these experiences.
- ◆ The author encourages an "inside out" approach where the museum starts with the specific experiences that will be most engaging, meaningful, and memorable for visitors and builds out to integrate these experiences into an overall theme.
- ◆ The author notes that following this model means that a museum experience needs outcome *and* experience goals, and a connection must be shown between the two.
- ◆ Experience-based learning is not limited to experiences with physical manipulation; observation, looking at labels, and talking with others are also examples.

Edelson, D.C., D.N. Gordin, and R.D. Pea. 1999. Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences*, 8(3): 391-450.

TYPE OF RESOURCE Journal article

METHODOLOGY Observations, interviews, and document review

CENTRAL IDEA An article draws on six years of evaluation about the effectiveness of scientific visualizations to offer insight into the opportunities for and challenges of designing inquiry-based experiences using technology.

SUMMARY

- ◆ The authors created four computer-based programs that are designed to promote scientific inquiry by having students explore climate and climate change.
- ◆ The authors note three learning opportunities offered by inquiry: (1) developing general inquiry abilities (e.g., developing and refining researchable questions); (2) acquiring specific investigation skills (e.g., exploring quantitative data); and (3) developing an improved understanding of science concepts.
- ◆ The authors note the learning value of scientific visualizations as three-fold: rendering complex data for visualization to facilitate discovery; providing opportunities to participate in the practice of science; and facilitating mastery of an investigative skill that has become increasingly important to scientific practice.
- ◆ The authors note five challenges to inquiry-based learning in this context: (1) learner motivation, i.e., an interest in the investigation, its results and implications; (2) learner capacity to apply investigative techniques like analysis and interpretation; (3) background knowledge necessary for inquiry activities, e.g., generating questions; (4) ability to organize and manage complex activities; and (5) practical constraints (e.g., scheduling).
- ◆ The authors then propose strategies they created to address these challenges:
 - ❖ *Present a meaningful problem that establishes a motivating context for inquiry.* Focus on a meaningful, controversial, and open scientific topic that: is familiar; has implications for participants; addresses important social and policy issues that draw on people's sense of fairness and entitlement; and remains an issue of legitimate uncertainty and controversy in the scientific community.
 - ❖ *Provide "staging activities," structured investigations that introduce learners to relevant investigation techniques and provide background knowledge.* Exposed students to the potential impacts of global warming through discussions, readings, and videos.
 - ❖ *Offer "bridging activities," activities that employ practices familiar to learners to introduce the unfamiliar practices of scientists.* Students drew best guesses of average world temperatures on a blank map of the world using crayons to assess prior knowledge and create awareness of knowledge gaps that elicit curiosity in further exploration. The activity also introduces the idea of color as value.
 - ❖ *Embed information sources that support investigative processes and provide background knowledge as needed.* Beginners are given contextual scaffolds (latitude and longitude markings, keys for numerical values of color on a map, etc.).

- ❖ *Provide record-keeping tools that learners can use to document and manage their process.* Students maintained an electronic journal that helped them keep track of their questions, analysis, results, etc.
- ◆ The authors note a main lesson learned is that technology-based inquiry learning requires an integrated process of both technology and activity design.