Suggested Guidelines for Designing Interactive Exhibits

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Well-designed interactive exhibits can be highly effective; but, they may fail dismally if they are poorly designed. This article offers a review of the literature from the perspective of what has been learned from interactive devices. Many of the suggestions apply to all exhibits, but several are especially important when the exhibit involves interactive components.

Visitor input is of critical importance to the development of interactive exhibits. Visitor evaluation helps to answer a number of questions. For example, during the planning stage, evaluation can provide information about the knowledge, misconceptions, attitudes, and interests of the potential audience. During the preparation stage, evaluation can provide information about what does and doesn't work. After installation, evaluation can be used as a basis for making final adjustments to improve the effectiveness of the exhibits. The reader is strongly encouraged to consult publications such as *Curator*, *ILVS Review*, and past issues of *Visitor Behavior* for more in-depth considerations. In addition, an article by C. G. Screven (1990) and a book by R. Loomis (1987) provide excellent overviews of visitor evaluation.

Developers of interactive exhibits should also be familiar with several publications that discuss design issues in greater detail than is possible in this article. Kennedy's (1990) *User Friendly: Hands-on Exhibits That Work* and Levy's (1989) *Cogs, Cranks, and Crates: Guidelines for Hands-On Traveling Exhibitions* are both published by the Association for Science-Technology Centers (ASTC); they provide information, checklists, and suggestions that should be valuable to an exhibit development team. Norman's (1988) *The Psychology of Everyday Things* is a wealth of easy-to-read information on human factors– information that can be easily applied to exhibit design. Miles, Alt, Gosling, Lewis, and Tout's (1982) book, *The Design of Educational Exhibits*, has an excellent chapter on exhibit media, part of which discusses interactive exhibit devices. In addition, there are several articles that attempt to provide overviews and/or suggestions with respect to interactives (e.g., Flagg, 1991b; Screven, 1991; Wagner, 1991). For considerations in designing labels for instruction and interpretation, see Bitgood (1991a) and Serrell (1983).

I define an "interactive exhibit" as a device in which the visitor's response to the exhibit produces a change in the exhibit. This definition is restricted to *physical interaction* with a device; it does not include "mental interaction." Interactives might include something as simple as pressing a button which illuminates a light or something as complex as a sophisticated interactive computer system. The important point is that there is a visitor-controlled change in the exhibit. Another way to say this is that "the message to be delivered is, to one degree or another, under the physical control of the visitor" (Shettel, 1991). This definition distinguishes among other types of active response exhibits – "simple hands-on" and "participatory." "Simple hands-on" involves responses such as touching or climbing. Touching animal fur or climbing on a gorilla sculpture are examples. "Participatory" involves making comparisons between the visitor's response and some standard. Assembling a turtle skeleton or comparing your jumping distance with that of a cougar are examples of "participatory." (The standard for the turtle skeleton is every piece in its correct place). Examples of "interactive" exhibits might include lifting a flip panel to reveal text, pressing a button to change scenes from summer to winter, or holding a magnifying glass over an object to reveal something previously unseen. There is a cause-effect relationship between the visitor response and a change in the exhibit. Table 1 summarizes these differences.

The distinctions among these three types of exhibits are not generally made in the literature. In fact, the terms "hands-on," "participatory," and "interactive" are often used interchangeably. When distinctions have been made, they have not been consistent with the current perspective. However, I believe the distinctions made here are important for two reasons. First, the design guidelines are more complex for interactive exhibits since visitor-exhibit interface (principles of human factors) must be considered. Control devices and response feedback mechanisms play a critical role in interactive exhibits, but not for simple hands-on and participatory exhibits. A second reason why the distinction is important is that the intended and actual impact of these exhibit types may be different. To minimize confusion, it is helpful to distinguish types of response engagement from the actual or potential outcome on visitors. The right-hand column of Table 1 ("Possible and/or Intended Impact") outlines the impact that these exhibits might have on visitors. As can be seen, these outcomes can be quite different. Simple hands-on and participatory activities may help to focus the learner's attention on the objects, may facilitate affective learning, and may communicate sensory-perceptual knowledge; but, these forms of direct response exhibits are probably not as capable of creating cause-effect reasoning such as: "I remove the air from the tube and objects still fall due to gravity instead of

Table 1

TYPE OF RESPONSE ENGAGEMENT	EXAMPLES OF EXHIBIT TYPE	POSSIBLE AND/OR INTENDED IMPACT
SIMPLE HANDS-ON (Exhibit prompts the visitor to touch, climb, etc.)	1. Touching animal fur. 2. Climbing on a statue of an animal. 3. Dressing up in firemen's clothing.	1. Produce sensory and/or perceptual learning. 2. Focus visitor's attention on object. 3. Create an increase in interest, a change in attitudes, etc.(affective learning).
PARTICIPATORY (Exhibit prompts a response and the outcome is used to teach a point by comparing it with some other response or standard; goes beyond simple hands-on)	1. Comparing jumping distance (or some other visitor response) with other animals. 2. Feeling several objects and comparing them on characteristics such as coolness, roughness, etc. 3. Assembling a turtle skeleton and comparing with a correct assemply.	1. Teach similarities and differences between objects or events. 2. Focus visitor's attention on object. 3. Produce an increase in interest, a change in attitudes, etc.(affective learning).
INTERACTIVE (Exhibit prompts a response which changes the state of the exhibit; the change is under the control of the visitor.) LEVEL 1: Simple engagement (e.g., press a button, light turns on) LEVEL 2: Prolonged engagement (e.g., interactive computer game)	1. A label with a flip panel. 2. Devices with controls (buttons, levers, cranks, etc.) in which a response on the control makes a change in the exhibit (lighting, sound, object's position, etc.). 3. Interactive computer tutorials, self-testing devices, games, etc. 4. Magnifiers (magnifying glass, microscope) that when used correctly reveal what was previously unseen.	1. Teaching of cause-effect relationships (using either discovery learning or guided learning.) 2. Teach similarities and differences between objects, events. 3. Focus visitor attention on object or event. 4. Affective learning (increase in interest, attitude change, etc.). 5. Self-testing of visitors. 6. Conceptual orientation of visitors.

float like I thought they would."

This article attempts to provide guidelines that include two aspects of interactive exhibits: stages of evaluation; and design of the exhibit in terms of the physical device, labels for instruction and explanation, and the visitor-exhibit interface.

Stages of Visitor Evaluation

The Planning Stage

1. Prepare clear and explicit goals and objectives. What do you want to communicate? How will you know if you are successful. That is, what will the visitor be able to say, feel, or do if it works? Is an interactive device the best way to communicate your message? Too often interactive devices are chosen because they are considered in vogue rather than because they are the most effective medium for communicating the message.

Below is a partial list of possible goals one might have for interactive devices:

- Magnifying an image. The goal might be for the visitor to use a microscope or magnifying glass in order see something that is usually unseen.
- Discovering a physical phenomenon. An example is seeing metal filings form a pattern at the poles of a magnet when the visitor places a magnet over a glass-covered tray of metal filings.
- Comparing objects. For example, the visitor might press a button that alters the scene from one visual image to another in order to compare some property of objects (e.g., Mt. Saint Helen before and after the volcano exploded).
- Demonstrating a physical action. Pressing a button might activate a vortex of vapor that mimics the air currents of a tornado (Oppenheimer, 1986).
- Demonstrating a concept. Borun (1990) used an interactive device to correct one of the common misconceptions about gravity – that a ball would float if it were in a vacuum. Another example is from Driscoll (1990) who evaluated an interactive computer tutorial that demonstrated phenomena of color and light.
- Focusing visitor attention. An interactive device such as a computer could be used to focus visitor attention on exhibit objects. Worts (1991a; 1991b) described interactive computers that instructed visitors to examine paintings more closely and offered possible interpretations of the meaning of the artworks.
- Visitor self-testing. Interactive computers are also used to allow visitors to self-test their knowledge (e.g., Screven, 1991).
- Describing how things function. For example, a visitor might operate controls that demonstrate how a motor works.
- Orientation to an exhibit area or to the museum. A menu-driven computer that explains exhibit themes serves this function (Morrissey, 1991). More ambitious is the computer system at the Franklin Institute of Science that can prepare individualized tours for visitors (Mintz, in press).

2. Define your audience. Is the exhibit going to be designed for children from ages 6 to 10 years? For all ages? Pinpointing the intended audience will make design and evaluation of the exhibit easier as well as increase its success.

Kennedy (1990) and Oppenheimer (1986) suggested that exhibits be designed for a diverse audience in terms of age, physical size, learning style, level of knowledge, etc. This includes people with physical impairments. Unfortunately, this advice is not always followed. For example, a recently opened exhibit in a major science museum allows the visitor to reach into a plexiglass enclosure to arrange blocks in a pattern similar to a task on popular intelligence tests. However, only small children can reach into the rear of this plexiglass enclosure because a larger person's forearms do not fit. Since this exhibit is appropriate for all ages, it should allow physically larger visitors to use the device.

3. Conduct a front-end evaluation study to determine the audience's pre-knowledge, interests, attitudes, and misconceptions. For example, Minda Borun (1990; 1991) found that visitors shared several misconceptions about gravity. Once identified, the museum was able (for most visitors) to correct these misconceptions with specially designed interactive devices. See Screven (1990) and Shettel (1989) for a more detailed discussion of front-end evaluation.

4. Consider how the interactive device will relate to other exhibits in the area. One must be very careful in designing exhibit spaces. As Melton (1935) concluded, every exhibit element competes with every other element for the visitors' attention. It is important that an interactive device receive its share of attention without dominating the exhibit area to the point that other exhibit displays are ignored. Ambient noise, crowding, and other disruptive stimuli should have minimal negative impact on the visitor's attention to exhibits.

It is comforting to know that computers, if properly used, can effectively direct attention to objects on display rather than compete with those objects (e.g., Worts, 1991a; 1991b). At the Art Gallery of Ontario interactive computers are used to focus visitors attention on artworks in the *Group of Seven* gallery. Worts evaluation data convincingly demonstrated the effectiveness of this, as well as other, interactive devices.

5. Consider multiple stations. Devices such as interactive computers are popular, but accessibility to the device may be a problem under crowded conditions. When space and funds are available, it is wise to provide several interactive stations in order to allow for greater access (e.g., Kennedy, 1990).

The Preparation Stage

1. As it is being prepared, trial test the device with a sample of visitors. Changes can be made to improve its ability to teach; or, if the device doesn't communicate after several modifications, then a new exhibit concept may be designed. Trial testing is perhaps the most important guideline for interactive devices since it is difficult to anticipate how visitors will use a device unless you test it. Testing of this type is generally called "formative evaluation." McNamara (1990) reported that the majority of exhibits developed at the Virginia Science Museum are initially effective for 10 percent or less of respondents. This percentage dramatically rises with trial testing and revision. For a more detailed discussion of formative evaluation see Screven (1990).

As part of formative evaluation, one must ensure that the device will attract and hold visitor attention. If visitors do not approach, stop, read, and interact, the exhibit is not likely to deliver its message. Wagner (1991) suggested using eye-catching display titles and color to pull visitors to the exhibit if attraction is likely to be a problem. Time at the exhibit is also dependent on several factors including the nature of the interactive controls, distracting sights and sounds, the time it takes for the device to reveal the outcome of a visitor response, etc.

The Post-Installation Stage

After the final device has been installed, there is still work to be done. It is important to determine how the interactive device functions in relation to other exhibits in the area and to "fine tune" the device. Evaluation during this stage is necessary because it is difficult to predict the exhibit's effectiveness even if front-end and formative evaluations have been successfully used (Screven, 1990).

1. Even after installation, small, inexpensive changes may often be made to increase the exhibit's effectiveness. Post-installation changes should be conducted in a systematic manner using visitor feedback. "Remedial evaluation" is the term used to describe this type of evaluation (Screven, 1990). Trial testing and revision, similar to formative evaluation during the preparation stage, can make the difference between a resounding success and a dissappointing failure. For example, a change in the control device (e.g., from a computer keyboard to a joystick) might improve effective usage of an interactive computer exhibit. While this type of adjustment is ideally implemented during the preparation stage, some problems may not be obvious until after the exhibit is installed.

2. It is important to conduct follow-up checks to determine if the device continues to operate properly. Maintenance over time can be and usually is a problem. At some point, a judgment must be made as to the useful life of an exhibit. Unfortunately, at this time, there is no acceptable rate of "down time" for interactive devices. In fact, to my knowledge, the Saint Louis Science Center is the only institution monitoring "down time" on their interactive devices (Bonner, 1991). This information is extremely important if we are to assess the cost-effectiveness of interactive devices. Eventually some standard of acceptable "down time" may be developed.

3. In addition to measuring time that a device is "out-of-order," computer driven devices can be used to record data on the frequency of use, time of use, accuracy of answering questions, whether or not the visitor completed the sequence of operations programmed on the interactive device, and other such information. Armed with this information, more intelligent decisions can be made for redesigning hardware and software, and for future budget projections.

Exhibit Design Considerations

The Interactive Device

1. Provide implicit cues for responding. Norman (1988) described this as the principle of "visibility." Devices can often be designed so that their visual appearance makes correct usage obvious.

I recently worked with a science museum which had an exhibit called *The Human Battery*. It was not immediately clear to visitors where they should place their hands even though there was a diagram showing the correct positioning of hands. Only about 30% of visitors placed their hands on the correct plates. The addition of a simple hand outline on the plates where the hands should be placed dramatically increased the percentage of visitors who were able to use the device correctly.

It is always best for the desired visitor response to be obvious independent of verbal clues, rather than dependent on instructions or illustrations (Kennedy, 1990 , Miles et al., 1982; Norman, 1988). For example, Miles et al. (1982) point out that large colorful press-buttons and levers generally provide obvious cues to their function.

2. Effective mapping of controls also helps to make the appropriate response obvious and it helps to minimize incorrect responses. Mapping refers to the relation between the movement and placement of controls and the effect that the response has on the device. For example, to control several lights one might arrange the controls in the same spatial pattern as the lights. Thus, the light on the right of the apparatus is controlled by the right-hand switch, the light on the left of the apparatus is controlled by the left-hand switch, and so on. The reader is encouraged to read Norman (1988) for positive and negative examples of mapping in common everyday devices.

3. Design for durability and ease of maintenance. Interactive

devices almost always require more resources than non-interactives. This makes adequate budgeting essential. One of the most frequent mistakes is to fail to budget for trial testing during the preparation stage (see "Preparation Stage"). In addition, failure to budget for "fine tuning" (see Post-Installation Stage) can also result in the failure of an exhibit.

Interactive devices that are "out-of-order" deliver the wrong message to the public. It is inevitable that interactive devices will be pounded on, hit, kicked, and abused in every other possible way. Thus, the materials used should be as durable as possible. In addition, since maintenance can be time consuming and frequent, the devices should be designed so that they can be easily repaired. For example, access panels can be conveniently placed to allow for maintenance (e.g., Wagner, 1991).

Low tech devices in some cases are preferred to high tech ones. For example, there is a low-tech self-quiz on gorillas at the San Francisco Zoo that allows visitors to slide a plastic marker to answer True or False for each question on the self quiz. Visitors can then check on the accuracy of their answers by looking on the rear of the display. The device appears to be highly effective. A high-tech version of a gorilla self-quiz was observed in another zoo; visitors pressed one electronic button for "True" and another for "False." The device then gave feedback whether or not the response was correct. Unfortunately, the device needed considerable maintenance and visitor efforts were frustrated when it was inoperative.

4. Plan for safety and comfort. Any device must be safe for visitors of all ages. Loose objects should not become flying missiles. Objects should not break into dangerous pieces. Avoid devices that have sharp edges and hinges that pinch fingers. Don't make the device tempting to climb and thus risk a fall.

You can plan for the comfort of users by providing seating where visitors are likely to spend more than a minute or two, by designing physical equipment so that it is comfortable to use (doesn't require bending, stretching, etc.), and by ensuring that bright lights are not shining in the visitors' eyes.

Instructions and Interpretive Messages

1. Chunking of text. If information is provided in small chunks rather than all at once, it is easier to attract visitor attention and it is easier for visitors to process the information. Bitgood, et al. (1986) found a substantial increase in label reading when a 150-word label was divided into three labels of 50 words each.

Screven (1986) recommends using interactive devices to "layer" information by dividing it into small chunks and making only a small portion available at one time. One low-tech approach is to use flip panels. Major information is presented on the outside of the panel and lifting the panel reveals secondary information. The high-tech approach, on the other hand, might use computer-layered copy in which the visitor can call up a variety of information on the computer screen. Computer layering allows the visitor to access a greater amount of information as well as providing the opportunity for branching menus. Using a computer only as an encyclopedia, however, should be avoided. One of the great advantages of computers is its tremendous capability of motivating the learner through user-machine interaction.

2. Keep instructional and explanatory labels and diagrams to a minimum. One strategy is to empirically determine the minimum required instructions. Diamond (1991) tested prototypes without labels and added only those instructions necessary to produce the correct response. Remember that the visitor must process a considerable amount of information as he/she approaches the device. If there is too much information to process, the visitor is likely to overlook some of the information resulting in failure to follow the instructions or understand the message. However, while instructions should be kept at a minimum, it is important to remember that if an unfamiliar interactive device is being used, the visitor should be told what the machine does (Miles, et al., 1982).

3. Instructions should be easily available when needed, not buried in text or presented only at the beginning of the sequence. In addition, it is important that instructions are not obscured by the visitor when operating the device (Miles, et al., 1982). Keeping the mental load of the visitor to a minimum is important.

4. Place the instructions where they will be read. Instructions should be placed where they will be noticed and proximal to the controls that must be operated. If they are placed too far away from the controls referred to in the instructions, they may be ignored or it will be difficult for the visitor to conceptually connect the instructions with the controls.

5. Make the instructions easy to understand. Use simple terms and make sure that they are understandable to your audience. This means trial testing the instructions. Instructions should also be presented in the order that they are to be carried out.

6. Minimize the number of instructions (parsimony of instruction). Bitgood (1991b) found that less than one-half of the visitors followed the eight steps necessary to observe the demonstration of gravity in the *Falling Feather* exhibit. If there are too many instructions, visitors may become confused, may give up before all steps have been completed, or are more likely to perform the steps incorrectly. Minimizing the number of instructions does not mean that several simple steps should be presented as a single, more complex instruction.

7. Provide instructions for sensory impaired users. Captioned instructions for the hearing impaired and an audio track for the sight impaired are extremely desirable and may also help those with poor reading skills (Kennedy, 1990).

Driscoll (1990), when evaluating an interactive computer exhibit at the New York Hall of Science, found that an optional audio narration, in addition to the written text on the monitor screen, was widely used. The redundancy aided poor readers and gave an alternative to those who preferred the hearing mode.

Visitor-Exhibit Interface

1. Anticipate how visitors might make errors and try to minimize these errors with physical or psychological constraints (Norman, 1988). For example, on a computer keyboard it is easy to press an adjacent incorrect key (e.g., "one" instead of "two"). The fact that these two keys are next to one another increases the chance one of these numbers will be pushed incorrectly in place of the other. If "one" turns the system on and "two" turns it off, an error can be very costly to the user. By using "one" and "zero" instead of "one" and "two," the possibility of pushing the wrong key is minimized, since the "one" and "zero" keys are far away from one another on the standard keyboard. Another way to reduce user errors is to make controls for different functions look different (Kennedy, 1990). For example, a green pushbutton may be used for starting a device and a red pushbutton for stopping (However, note the possible problem with color blindness).

2. Controls must provide feedback to user. The user should be told if his/her response is registering in the device by some visual or auditory change such as a change in the computer screen, feedback text on the screen, or a sound. Interactive devices work even better if redundant feedback is given to users (e.g., Diamond, 1991). Judy Diamond (1991) found that in the exhibit, *Radioactive Rock*, visitors needed redundancy in order to see the effect of radiation. Redundancy included hearing clicks, seeing a red light, and reading a dial to indicate the strength of radiation.

3. Timing of events. How long does it take for the device to be activated once a response is made? Text and graphics should appear as quickly as possible. It is also desirable for visitors to be able to control the speed at which the display responds.

4. Sensitivity of controls. How sensitive are the controls? Are they oversensitive? Menninger (1991) reported that a common complaint in an evaluation of an interactive videodisc at the Getty Museum was an oversensitive touch screen.

5. Selection of controls. Controls may be either mechanical (e.g., wheels, handles, levers, cranks) or electrical (e.g., pushbuttons, trackballs, joysticks). The user's energy is directly transmitted to the exhibit when mechanical controls are used, while electrical controls let the device do the work.

Touch screens are easy to master and overcome many of the problems associated with keyboards. Other devices have also proved useful. For example, Driscoll (1990) reported that a trackball device used as a computer control was easy for visitors to master. In addition, when several functions are involved in a task, controls for each function should look different (Kennedy, 1990).

6. Placement of controls. Kennedy (1990) argues that controls should be placed within 10 inches of the front of an exhibit. Trial testing should ensure proper placement.

7. Computer software navigation. It should be easy to navigate through the exhibit program. Ideally, the program should be at the beginning when the visitor approaches. Alternatively, it should be obvious how to get to the beginning. Several evaluation studies reported a problem when the device is not reset before a new visitor attempts to use it (e.g., Menninger, 1991; Flagg, 1991a; Mintz, 1990). Flagg (1991b) asserts:

> "The most successful interfaces between users and electronic exhibits make it immediately obvious how to navigate through the program. Interfaces that rely on introductory screens may not be as effective, because visitors typically begin a program where someone else left off." (p. 10).

8. Perceptual and physical limitations of users. Designers must be aware of the perceptual and physical limitations of the human body (Miles, et al, 1982). Controls and instructions should not be placed too high or too low since it requires extra work and may interfere with the visitor's performance. See Kennedy (1990) for more detailed anthropometric guidelines relevant to designing interactive exhibits so that they accommodate a wide range of physical sizes of users.

9. Plan for multi-person use. Visitors often use interactive devices as a group. For example, Driscoll (1990) found that visitors tended to share the *Color & Light* exhibit computer as a group even though it was originally designed for one user at a time. If possible, exhibits should be designed to accommodate this inherent sociability factor. Duensing (1987) reports: "We have noticed at the Exploratorium that not only is it fun for people to do things together at an exhibit, it is also fun to watch others" (p. 141). Providing more than one seat at a station and enough space for others to observe the user should help accommodate group usage of the interactive.

10. Design for the physically disabled. Moveable seats are desirable so that wheelchair bound visitors can use the exhibit unobstructed. Kennedy (1990) suggests specific dimensions for designing the exhibit table/counter for wheelchair access.

11. Required time of use. It is sometimes difficult to keep visitors at one exhibit for a prolonged period of time. Other exhibits may draw visitors away after a minute or two. On the other hand, a successful device might have the opposite effect, i.e., resulting in one visitor dominating time on the exhibit. In this case, limiting time on the device may be

necessary. For example, the Denver Museum of Natural History has a driving test device in which visitors use a coded plastic card. The device is therefore able to restrict visitors to a single use of the device, enabling others to have their turn.

12. Select meaningful response requirements. Interactive devices can be effective in guiding meaningful outcomes, such as understanding a natural phenomenon or a concept. However, interactives are too often used in a meaningless way. For example, Borun (1977) found that "...pushbuttons are frequently only start buttons and don't allow real interaction with the display. They do not help visitors to perceive significant cause and effect relationships... We conclude from the above that pushbuttons seem to hinder rather than help the communication of scientific facts and principles (p. 67)."

13. The use of controls should be clear. A button is obviously for pushing, a round handle for turning, levers are for pulling, etc. (Kennedy, 1990). If necessary control labels should tell what to do (e.g., "press," "push," "pull"). If there is more than one control, is their sequence obvious? (Wagner, 1991).

Final Thoughts

The suggested guidelines in this article are no substitute for creative thinking. Designing an effective interactive device requires a combination of: well-conceived objectives, creative thinking, knowledge of the principles of visitor-exhibit interaction (human factors), competent engineering, visitor evaluation, and common sense. Any one of these elements is useless without the others. Keep in mind that communicating the message is the most important outcome of effective design. The most creative and clever device will not overcome the lack of appropriate learning objectives. Interactive devices must be used intelligently if they are to have their maximum effect in museums, zoos, aquariums, and other exhibition settings.

There is still much that we need to know about designing effective exhibits whether they be of the interactive, participatory, simple hands-on, or hands-off type. We believe that the gap between what we need to know and what we currently know can be closed more quickly if visitor researchers, educators, and exhibit designers work together.

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Note

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Where to get more information about interactive exhibits

ILVS Review: A Journal of Visitor Behavior.

This journal contains many articles relevant to interactive exhibits and is published by:

ILVS Publications
611 N. Broadway, Suite 600
Milwaukee, WI 53202
(414) 223-4266

Association of Science-Technolgoy Centers

ASTC publishes a number of monographs dealing with interactive exhibits. For a complete list of ASTC publications write:

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