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Doing something about the weather: Summative evaluation of Science Museum of Minnesota's *Atmospheric Explorations* computer interactives

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Abstract

The Science Museum of Minnesota's *Atmospheric Explorations* exhibit includes three interactive computer stations where visitors manipulate graphically displayed computer models of the Earth's climate systems. Using naturalistic methodology, a summative evaluation was conducted to assess visitor use and understandings of the three computer interactives. In using the simulations, most visitors engaged in a range of behaviors, defined in this study as: exploration, broadly-focused play, and goal-directed play. It was our impression that visitors manipulated variables and observed the results in such a way that they began to develop basic, but potentially very powerful ideas about the ways in which natural forces interact to make the winds, seasons, and clouds. Often these understandings seemed to be in the form of visceral models; for example, by playing at the *Winds* computer, visitors seemed to develop a gut-level feeling for the way that winds spiraled towards the center of an atmospheric low. Future iterations of *Atmospheric Explorations* can improve upon its current success by tapping the potential for teaching-learning interactions within visitor social groups, and by helping more visitors connect their computer experiences with their daily weather knowledge.

Introduction

The Science Museum of Minnesota is an educational and research institution devoted to the collection, study, and interpretation of objects of scientific significance. Over the past few years, a collaborative project between Augsburg College and the museum has developed a series of interactive computer models dealing with weather and climate systems. Funded by the National Science Foundation, *Atmospheric Explorations* allows visitors to manipulate variables impossible to manipulate in real life, and observe the results on a computer screen.

The goal of this evaluation study was to find out how visitors were using the components in *Atmospheric Explorations* and the messages they were taking away from their experience. This paper provides an overview of some of the important findings that emerged during the course of the summative evaluation. For a more detailed and thorough examination of the issues and data underlying these interpretations and conclusions, see the summative evaluation report (Gyllenhaal & Perry, 1998).

Background

Atmospheric Explorations is a thematic area of weather-related exhibits located in the Science Museum of Minnesota's *Experiment Gallery*. One of the many innovations in the *Experiment Gallery* is the Experiment Benches, which are partially fenced-off areas for open-ended, inquiry-based explorations of science topics like electricity, optics, and sound. These exhibits include appropriate equipment and support so that visitors can carry out any of a number of explorations and experiments on the topic. *Atmospheric Explorations* extends the Experiment Bench concept into the scientific realm of weather by giving visitors access to what has become a critical tool for both climatologists and weather forecasters: Computer models of climate systems.

The three computer interactives in *Atmospheric Explorations* run mathematical models of atmospheric phenomena. These models consist of complex equations describing the physical dynamics of wind generation, cloud growth, and seasonal changes in the heating of the Earth's surface. When visitors change some aspect of the model, their input has an almost 'physical' effect on the resulting wind patterns, cloud size, or temperature of the Earth. These models are not pre-determined animations -- they are mathematical predictions of what would happen in the real world, given the inputs that visitors have chosen.

The results of the models' calculations are displayed as moving graphic images, so that visitors can literally see the results of their experiments with the models. For instance, with the *Winds* computer, visitors give their input to the computer model by shifting high and low pressure systems around on a map of the United States, and then see the results of their manipulations as spiraling wind patterns marked by arrows, bubbles, and weather balloons moving with the winds. In *Seasons* visitors radically alter the Earth's seasons by changing its tilt and orbit around the Sun. In *Clouds* visitors alter humidity and temperature conditions on the ground and aloft, then watch the effects on the growth of clouds.

During the summer of 1997, *Atmospheric Explorations* was located in a partially enclosed section of the *Experiment Gallery*. The three computer interactives were on tables within the enclosed area. Visitors sat on stools in front of the computers and used trackballs and buttons to interact with the simulations. Each computer interactive had a hierarchy of screens, with four major levels:

- Introductory sequence -- This sequence introduced the concepts and gave brief directions on how to use the simulation.
- Core experience -- Each core experience had from two to four main screens where visitors manipulated variables and observed the effects.
- Help screens -- These screens answered questions that visitors might have about the content.
- Try This! screen -- The Try This! screen posed experimental challenges for the visitors.

Methods and Methodology

The summative evaluation of the *Atmospheric Explorations* was conducted using naturalistic inquiry methodology (Lincoln & Guba, 1985). Naturalistic methodology is based on building an intimacy with the respondents which allows them to talk frankly and openly about the subject matter, and to give a more honest rather than canned or cued response. Relying heavily on depth interviews with participants, this research results in rich and descriptive narrative data in participants' own words. The strength of this type of methodology is that it allows us to gain a deeper understanding of the participant's experience in their own terms.

Depth interviews and participant observations were open-ended and relied on an informal conversational interviewing style. Although we relied on pre-determined interview protocols to focus the interviews with each type of respondent, we did not ask any set group of questions. Instead our intent was to get the answers to the research questions by approaching the issues from as many different routes as necessary, listening carefully to the words the visitors used and the ways they described their understandings. The conversations often went in unanticipated directions and yielded information that we would otherwise have missed.

Data were collected over three three- to four-day intervals during the summers of 1996 and 1997, for a total of approximately 48 hours of data collection. Data were collected from a total of 115 groups of casual museum visitors (188 individuals) on weekdays and weekends, and during the day and evening hours. Similar data collection techniques were used for all three site visits, including face-to-face depth interviews (45 individuals in 27 groups), participant observations (26 individuals in 16 groups), and unobtrusive observations (162 individuals in 99 groups). Depth interviews always occurred in conjunction with unobtrusive observations.

Results

In conducting this study, many interesting themes emerged from the data. The following paragraphs describe these themes. When appropriate, we refer to quantities of visitors who held a particular viewpoint with the words *all*, *most*, *many*, *some*, *few*, and *none*. Because most of the sampling was purposive rather than random, these quantities should be interpreted only as descriptive of the population interviewed for the study, rather than as predictive to the larger population of all Science Museum of Minnesota visitors.

Overall, *Atmospheric Explorations* seemed to do an excellent job of using computer models to introduce museum visitors to weather phenomena in the context of Science Museum of Minnesota's open-ended, inquiry-based *Experiment Gallery*. Visitors responded favorably to the high quality graphics, the friendly user-interfaces, and the opportunity to manipulate variables and observe the results. Despite their relatively brief encounters with the computers, many visitors learned new ideas and developed a kind of "gut-level" feel for various aspects of the weather. Most visitors seemed to enjoy their playful encounters with the simulations, as they were caught up in the fantasy of controlling the powerful forces that make the weather. Following is a more detailed look at the results of this study. It is divided into two main sections:

- visitor interactions with the computers, and with each other
- visitor understandings of *Atmospheric Explorations*

Visitor Interactions

Time in exhibit. This summative evaluation did not include a tracking and timing study for the entire *Atmospheric Explorations* area. However, during unobtrusive observations, visitors were recorded spending anywhere from zero to more than 15 minutes engaged with a particular computer station. A timing study conducted on visitor engagement with just the *Seasons* computer indicated a range of 0 - 10 minutes, an average of 3.0 minutes, mode of 1.0 minutes, and a median time of 2.0 minutes (n = 74 visitor groups). These data are longer than is typical at stand-alone museum exhibits in general (Serrell & Raphling, 1992; Hirumi, Savenye & Brokenbrough, 1994), but are comparable with three other experiment benches at the Science Museum of Minnesota, where the average visit lengths were 2.8 to 4.2 minutes (Perry, 1994).

Use of options at the computers. Even when visitors stayed at an *Atmospheric Explorations* computer for more than 10 minutes, when they left the computer they were still only beginning to explore all the options provided by the computer simulations. Most visitors spent most of their time using the core parts of the simulation programs. They found the one, two, or three screens that it took to make things happen, and, in general, they spent most of their time using these screens.

We saw some visitors find and at least partially read the "Try This" screens. A few visitors actually tried one or more of the suggestions, but the "Try This" screens seemed to be having little impact on helping visitors to decide what to do next at the computer. We saw few visitors find and use the Help screens that explained the scientific concepts of the exhibit using diagrams and text.

Modes of engagement at the computers. Most visitors interacted with the *Atmospheric Explorations* computers in what can be described as a playful manner. We saw children, teenagers, and adults playing at the computer in the same sense that young children play in their environments. We recorded numerous indications that they were learning, in many ways and on many levels. While in the process of learning, they seemed to be enjoying intrinsically motivating experiences.

Most visitors who sat down at an *Atmospheric Explorations* computer went through at least two stages of use. First, they *explored* the program, trying to figure out what it was about and whether it was worth their time. Then, those visitors who decided to stay at the computer usually shifted into a stage of *broadly-focused play*. Only a few visitors seemed to be more serious in their intentions, eventually shifting into a *goal-directed play*. What follows is a more detailed description of these three modes of use.

- **Exploration**: Everyone started out in this mode. In this mode, visitors seemed to be investigating the interface devices and the program itself, rather than its content. They were trying to figure out what this particular computer was supposed to do. This sometimes seemed to be mindless behavior. However, a careful analysis of the data indicated that this stage often involved systematic exploration and intellectual engagement as visitors tried to make sense of the visitor interface, figure out what the subject matter was, and learn to navigate the structure of the program.

- **Broadly-Focused Play**: Once visitors figured out what the computer was for, many of them decided to see what they could do with it. These visitors were still exploring, in a sense, but they were now involved with the *content* of the computer program: they were playing with winds, changing the tilt of the Earth, or making clouds. Visitors began manipulating variables to see what would happen, generally starting in a trial-and-error mode. These trials could be either systematic or unsystematic, but they usually seemed to involve at least some level of intellectual engagement by the visitor. Visitor goals for this activity seemed very broad and diffuse. For example, on the *Winds* computer, visitors in this mode sometimes moved high and low pressure areas around the map to see the resulting changes in wind patterns.

- **Goal-Directed Play**: Some visitors said that they wanted to accomplish something more with the program: They wanted to grow the largest, or smallest, cloud; make a pinwheel of balloon traces into the center of a low pressure system; or bake St. Paul in the winter. A few visitors used the "Try This!" screen to set their goals. It appeared that some goal-directed visitors began to understand the relationships among variables, and consequently used the simulation to test their predictions. However, trial-and-error behavior was still common, especially when an initial prediction failed to achieve the desired results. Thus, even though visitors were now manipulating variables to reach a specific goal, many still were relatively unsystematic in their manipulations.

We also identified two other modes of visitor use of the *Atmospheric Explorations* computers: 1) we observed and talked with a few teachers, who explored the programs because they were thinking of ways that they could use them with their classes, and 2) there were a few visitors who used the computers to explore a personal interest in some depth. These respondents had either a fairly good background in weather or a pre-existing interest in computers and technology. Both modes were goal-directed, but neither seemed much like the playful behavior described in the first three categories.

<u>Science process skills.</u> A few years ago, the Chicago Academy of Sciences identified twelve "Skills for Thinking" (p.30, Perry & Edington, 1995). These skills include observing, comparing/contrasting, predicting, hypothesizing, manipulating variables, evaluating, and developing theories. In conducting this evaluation, we were interested in whether or not respondents engaged in these kinds of science process skills. We noted that most visitors who spent more than a minute or two at the computers seemed to engage in at least a few of these processes. For instance, at the *Seasons* computer, visitors were observed manipulating the Earth's tilt, making predictions about what would happen, letting their experiment play itself out, and then commenting on or attempting to explain their results.

<u>Social interactions.</u> Perry (1989) identified six characteristics of meaningful social interaction at a physical sciences exhibit: explaining/teaching behavior, developmentally appropriate interaction between an adult and a child or other group member, asking questions, directing a child's attention to important aspects of the exhibit, directing a child's behavior, and verbal exchanges.

During unobtrusive observations, most visitors engaging with the *Atmospheric Explorations* computers tended to operate individually, whether they were at the exhibit by themselves or part of a larger social group. It was not unusual to observe groups of two or more individuals seated together at the computer with one respondent using the interactive and the other(s) quietly observing. When visitors did interact with each other at the computer, some of them engaged in very sophisticated social interactions. For instance, we observed parents guiding their children and directing their attention and behavior; children showing parents what they had figured out about the exhibit; and groups of children working together to solve a problem they had defined themselves.

Visitor Understandings

Cognitive understandings. There were numerous indications that visitors to *Atmospheric Explorations* were thinking about some of the basic concepts that explain winds, clouds, and seasons. For example, these visitors said things like, "Winds go from high to low pressure," and "Clouds get bigger when there is high temperature and high humidity." Although these visitors did not appear to assemble complete new theories or radically alter their old theories, they seemed to be using some of the building blocks of a scientific understanding about weather to explain what they had seen and done at the computer.

Other visitors developed incomplete or incorrect understandings of weather-related phenomena. For example, some visitors indicated they thought that winds were strongest in the centers of the low pressure areas. Other visitors expected the lows to be areas of intense activity, drawing a relationship between low pressure areas and storms, like hurricanes and tornadoes.

A few visitors seemed to undergo rather major conceptual growth based on their experiences at the computers. They told us how their experiences in *Atmospheric Explorations* helped them achieve a new level of understanding about issues that they had puzzled over in the past.

Visceral understandings. Perhaps the most powerful learning that took place in *Atmospheric Explorations* left visitors with what might be called "visceral models" of the physical systems represented by the simulations. We've all heard scientists talk about the importance of these sorts of internalized models in their own thinking, and recent research indicates that this may be an important outcome of museum experiences (Spock & Perry, 1997). Many respondents seemed to have internalized aspects of the computer simulations as gut-level feelings for how winds, clouds, or seasons happen. Visitors usually had difficulty describing these internal models in words, since they seemed to be stored as images rather than as verbal concepts. One visitor who had taken geography in college told us how the *Clouds* computer helped him to truly visualize and get a gut feeling for clouds in a way that he had been unable to do when he took his college course.

Misconceptions. It is commonly agreed by museum professionals that visitors to museums arrive with their own preconceptions and ways of thinking about the phenomena they encounter. While museums have tried many ways to address -- in particular -- visitor misconceptions, they are not always successful.

Not surprisingly, there were some visitors to *Atmospheric Explorations* who walked away with their misconceptions about weather phenomena unchanged or inadvertently confirmed. This seemed to be a rather frequent occurrence at the *Seasons* computer, perhaps because so many visitors had developed misconceptions about this earlier in their lives. One of the primary misconceptions heard at *Seasons* was the idea that summer happens on the hemisphere of the Earth that is tilted towards the sun because that hemisphere is significantly closer to the sun.

Visitors who came to the *Seasons* computer with this misunderstanding sometimes used the program's animated graphics as evidence in favor of their version of the seasons. To make the effects of tilt and orbit more obvious to visitors, the Earth-Sun system in the *Seasons* interactive is not shown to scale. The Earth is grossly enlarged relative to the Sun, and there is a huge reduction in the relative size of the Earth's orbit. Visitors could point to the computer graphic in, for instance, northern hemisphere summer and show that Minnesota appeared to be significantly closer to the Sun than it was in the winter.

Personal connections. Although one might think that visitors' personal connections to the winds, clouds, and seasons would be obvious to them, many respondents in this study appeared to be thinking somewhat abstractly about the phenomena in the simulations, and did not seem to relate them to their daily lives.

This is a significant observation for three reasons. First, at many exhibits a feeling of personal connection is what gets people to stop and pay attention. A feeling of personal connection to the contents of the exhibit might attract a more diverse range of visitors to sit down at the computers. Secondly, much of the learning research supports the idea that when something is personally meaningful, it is easier to understand and remember (Anderson & Faust, 1973; Martin & Briggs, 1986). And thirdly, when connections are made to visitors' daily lives, it helps them continue to learn from their experiences even after they leave the exhibit.

Discussion

More and more research supports the notion that learning in museums needs to be thought of in a unique way. There is general agreement among the museum community that the goals of traditional educational settings are inappropriate for an informal educational environment such as a museum.

This discussion will relate some of ways in which we are trying to use published research to better understand various aspects of the learning that took place in *Atmospheric Explorations*. In the following sections we have synthesized three ways of knowing -- research, practice, and evaluation -- in ways that will help us better understand *Atmospheric Explorations* and set a course for the future development of similar interactives in museums.

Learning Through Play at the Computers

As detailed in the summative evaluation (Gyllenhaal & Perry, 1998), most visitors interacted with the *Atmospheric Explorations* computers in what can be described as a playful manner, and there were many indications that visitors were learning through play. Recent research has indicated that play is an important component of successful museum visits (Hilke, Perry, Middlebrooks & Hart, 1997; Perry, 1989). Play in these instances is defined broadly much in the same way that early childhood educators have come to understand the term.

It is important to differentiate this type of play from the play that one observes in an amusement park, or when children play a computer game. We might be tempted to call this "serious" play, but we saw many indications that it didn't feel particularly serious to the visitors who were sitting at the computer.

Recognizing visitors' behavior as play suggests a whole range of research that we can tap into on the creation of intrinsically motivated learning experiences (Lepper & Malone, 1987; Malone & Lepper, 1987; Perry, 1993; Rieber, 1996).

Learning Through Social Interactions

There is mounting evidence that much of what visitors learn in museums is learned through social interactions -- as much or more than from one-on-one interactions with the exhibits (Borun, 1996; Diamond, 1986; McManus, 1987; McManus, 1988; Perry, 1989). Research suggests that when visitors talk about what they are engaged in:

- their learning of verbal concepts is enhanced
- the content becomes more available to other group members
- there are increased opportunities for reflecting on and discussing the shared experiences after leaving the museum.

As described above, Perry has defined social interaction along six specific dimensions. For some families and other groups this sort of meaningful social interaction seemed to be very natural, and they were very good at it. For these groups, the open configuration of *Atmospheric Explorations* with plenty of places for visitors to sit together helped facilitate their interactions. The challenge will be to facilitate interactions within groups where the parent is less skilled as a teacher or more intimidated by computers or by the content of the exhibit. Research suggests that the design of the interpretation and labels can enhance appropriate teaching-learning behaviors for *all* types of groups (Perry, 1989). For example, it was found that when labels included simple initial questions that adults could ask their children, groups engaged in more meaningful social interactions.

Learning in an Open-ended Learning Environment.

We were interested in finding a larger context within which to examine *Atmospheric Explorations*. We turned to the educational technology literature and found a number of papers describing research on open-ended learning environments (OELEs) (Hannafin, Hall, Land, & Hill, 1994; Land & Hannafin, 1996; Land & Hannafin, 1997). Open-ended learning environments use technological tools -- including, but not limited to, computer models and simulations -- to support student-centered inquiry. Student-centered inquiry is in contrast to more structured and outcome driven learning environments. Learners typically use OELEs to construct or manipulate computer models of a concept, and they receive real-time, dynamic feedback about the effects of their actions. In theory, users' understandings evolve continuously and dynamically, as ideas are generated, tested, and revised (Land & Hannafin, 1997).

Although OELEs have been tested mainly in relation to the formal educational setting, they share a number of important similarities to the computer interactives in *Atmospheric Explorations*. Perhaps most important of all the ways *Atmospheric Explorations* and OELEs are similar is that they share a goal for the same kinds of inquiry-based outcomes among their users. Also, *Atmospheric Explorations* programs and many OELEs are built around computer/mathematical models of physical systems, and also include a user-friendly interface and variety of supporting materials. The most important differences are seen in the settings in which they are used and their intended audiences. For instance, OELEs tend to be used by students working individually and/or with peers in the same grade. *Atmospheric Explorations* is used by a museum audience with a broad range of ages, prior education, group compositions, and backgrounds.

The perspectives that we gained from the literature on OELEs have helped us better understand a number of aspects of *Atmospheric Explorations*. For instance, users of OELEs sometimes assimilated new data into existing theories and ignored inconsistent data (Land & Hannafin, 1997), in ways that paralleled the maintenance and justification of misconceptions at the *Seasons* computers. Also, naive users of OELEs tended to perceive and interpret information inaccurately and often failed to use system data to evaluate the limitations of their understanding (Land & Hannafin, 1997), just as some visitors to *Atmospheric Explorations* developed incomplete or incorrect understandings of weather-related phenomena.

Exhibit developers and evaluators would do well to closely follow -- and perhaps even contribute to -- the growing body of research on OELEs.

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