Chapter 20

NAIVE NOTIONS AND THE DESIGN OF SCIENCE MUSEUM EXHIBITS

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"Without air pressure things would not fall."
"It is summer when the earth is closer to the sun."
"The rotation of the earth creates gravity."

These incorrect statements are widely-held naive notions. Research on "naive notions", also known as "alternative schemas," "misconceptions," or "preconceptions," is changing our understanding of the process of science education and has important implications for informal settings.

Studies of science students from elementary and middle school (Nussbaum,1979) through high school and college (Clement, 1982; McClosky, 1982) indicate that students enter the classroom with preconceived notions about the way things work. What we assume to be science learning tends to be merely memorization of a string of words. Even students who give correct answers to test questions often do not apply these ideas to experiences outside the classroom.

Research on naive conceptions demands a revolution in our approach to science teaching in the classroom and in the science museum. Educators must uncover pre-existing misconceptions in order to get students to change their minds. The implications for the design of science museum exhibits are clear. Visitors are likely to interpret exhibits through a filter of pre-existing naive notions and leave the museum with their misconceptions intact or even reinforced.

A common misconception about misconceptions is that they are held by children and replaced through formal instruction. Most of the research on naive theories is based on studies of children in classrooms. However, there are indications that naive notions are widespread among adults. Unless they have experiences which cause them to become aware of the flaws or limitations in their early explanations, people hold on to them. The science museum, which attracts visitors of all ages, provides an excellent laboratory for studying naive notions.

The Franklin Institute is engaged in an 18-month study to discover visitors' naive notions about gravity and air pressure and to develop exhibits which help people restructure these concepts. The project is intended to establish a new model for the design of effective science museum exhibits.

The first phase of study involves video-taping interviews with museum visitors to identify widespread naive conceptions. Phase two involves the development of prototype exhibits which deal with key misconceptions to encourage visitors to confront the limitations of their explanations and to come to understand the way scientists explain the phenomena.

This research project explores misconceptions about basic aspects of science treated by exhibits in the Franklin Institute Science Museum and tests the ability of hands-on exhibits to address and correct such misconceptions.

Thus far, the study has addressed the following questions:

- What are the most common misconceptions about the concept of gravity?
- How widespread are these misconceptions in the population of museum visitors?
- Are misconceptions about gravity related to age or gender?
- Can a misconception be corrected if visitors are presented with simple devices and explanations which confront the particular problem?

The concept of gravity has been chosen because of what seemed, in pilot interviews, to be a recurrent and fairly widespread set of misconceptions about its nature, cause and effect. Many visitors believe, for example, that gravity could not operate in the absence of air.

A set of pilot interviews, focused on the subject of gravity, has been conducted at the *Gravity Cone* in the astronomy exhibit. (The *Gravity Cone* models the gravitational field of a large body. A relatively small ball is put in orbit, describes an elliptical path and eventually falls out of the opening at the bottom of the inverted cone.) Analysis of these interviews has allowed us to refine and standardize the set of questions (protocol) to be used in later interviews.

The pilot study has also yielded information about the age groups of visitors who would be able to participate effectively in the study. We have discovered, for example, that visitors less than nine years of age had difficulty with the interviews because the concepts were highly abstract. Interviews have been recorded on videotape in order to have a permanent record for reviewing and evaluating the study.

Preliminary results indicate that very few of the 100 visitors interviewed at the *Gravity Cone* exhibit are able to explain what the exhibit is about. Further, a substantial number of our subjects, regardless of age, believe that gravity is related to air pressure. When asked whether a ball would fall in a vacuum, over one-third of the visitors interviewed predicted that the ball would float.

The responses below are typical of the ones given in response to the question, *"If I removed all the air from a tube and dropped a ball in, what would you expect to happen?"*:

> "The ball would not fall. If there isn't any air there isn't any gravity, I think."
>
> "The ball would not fall. My teacher said if you pumped all the air out of this room you'd get zero gravity."

Responding to the question *"What is gravity?"* one adult visitor said:

> "Gravity is the layer of air mass... Gravity is air, 14.3 lb. of air per square inch. That's the air density... Some people think it is an attraction between two objects, but in my opinion it isn't."

To test the idea that this naive conception could be corrected by means of a hands-on device, we have built a device which allows visitors to see a ball fall in the air and in a vacuum. The label explains that gravity has to do with the attraction of masses and that air is not necessary. Both the device and explanatory label have gone through a process of testing and modification (formative evaluation).

While the sample has not yet been completed, preliminary analysis of responses of visitors who used the prototype indicate that the vast majority are able to state that gravity is not caused by air pressure and that gravity is not dependent on the presence of air for its effect.

Interviews with visitors who used the device indicate that a very high proportion of people who read the label and operate the device understand what it was supposed to show. Eighty percent are able to correctly explain that it is designed to show that gravity does not need air to operate. Moreover, many people clearly state that this is not what they expected and that they now have a new understanding of gravity!

In the original sample, only 54.6% of the people interviewed said that they would expect an object to fall in a vacuum. After using the prototype correctly, 96.2% of those interviewed said that an object would fall in a vacuum.

The responses below are typical of the comments made by visitors after using the device:

> "I would expect that it wouldn't fall at all; it would just float there. It didn't; it fell anyway.... If you watched when they went on the moon, they were floating in space. It surprised me because I think of something without air as floating, I just do!"
>
> "The ball does the same thing (with or without air), goes right to the bottom."

"If you look at that device, gravity doesn't need air."

This is a very important finding for science museums. It tells us that carefully constructed and evaluated devices can really teach. Formative evaluation incorporates a dialogue with the visitor into exhibit design; elements of a teacher-student discussion are embodied in the materials and explanatory labels of the final exhibition.

The second misconception which will be addressed is the notion that gravity is caused by the rotation of the earth. Approximately 10% of both the baseline and post-prototype samples expressed this view in the interviews. And by way of explanation:

> "The moon's gravity is less because its rotation is slower than the earth's."

As science museum professionals, we believe in learning by doing, so to understand naive notions and how they interfere with science learning you need to go out on the floor of your museum, station yourself at a device that is supposed to illustrate a basic science concept such as gravity, magnetic polarity, air pressure, electrical conductivity or anything else which deals with basic principles rather than specific facts. Ask ten to twenty visitors of varying age to tell you in their own words what they think the exhibit is all about. When words for basic concepts come up, ask people to explain what the words mean. It's a sobering experience! But, it will also show you how quickly you can uncover important shared misconceptions and how you might go about approaching exhibit design empowered by this new information.

Conclusion

The science museum has great potential for correcting visitors' misconceptions. The powerful combination of hands-on devices and explanatory text can produce the "aha" or breakthrough perception which opens people to new understandings. Yet, current museum practice does not often realize this potential.

The dramatic impact of the first prototype exhibit device on visitors' understanding of gravity is encouraging for museum educators. It demonstrates the possibility of bringing about conceptual change with a well-researched, well-designed and well-labelled device. Further, it emphasizes the importance of front-end analysis of visitors' naive theories and formative evaluation to insure that the exhibit is understood.

References

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Footnote

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