COSMIC QUESTIONS

Summary Evaluation Report
September 2002—May 2003

Harvard-Smithsonian Center for Astrophysics
Cambridge, Massachusetts

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The whole thing makes me think. (MOS exit interview)

G13: We're made of the same thing as stars. I thought that was interesting because you never would think that. (MCFTA exit interview)

Will the universe collapse and there will be another big bang? Maybe it's a process that happens over and over again . . . I wonder if that's the heartbeat of God? (MOS phone interview)

Everybody who worked on this exhibit learned a lot. I wish it were a permanent part of this museum. (MOS staff)

INTRODUCTION

PROJECT HISTORY

In the spring of 2000, the Harvard-Smithsonian's Center for Astrophysics (CfA) contracted with the Program Evaluation and Research Group (PERG) at Lesley University to conduct a series of evaluations for the planning and execution of *Cosmic Questions* (*CQ*). The exhibition, which was originally entitled *Cosmic Horizons*, was funded by the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA).

The first phase of the evaluation, a front-end visitor study, assessing visitors' knowledge of and interest in space science and the cosmos, was conducted in May and June of 2000 at Boston's Museum of Science (MOS). The evaluation's second phase, a formative evaluation of the exhibition prototype, was completed in February of 2001 at the MOS. This summative report represents the third round of the evaluation process conducted by PERG, and is an evaluation of the current *Cosmic Questions* exhibition and related activities, based on data obtained by evaluators at two sites—Boston's Museum of Science and the Midland Center for the Arts (MCFTA) in Midland, Michigan. The summative evaluation was conducted from September of 2002 to May of 2003.

PROJECT DESCRIPTION

Cosmic Questions, a 5000-square-foot exhibition, was developed by Mary Dussault, Roy Gould, and other staff at the Center for Astrophysics, and designed by Jeff Kennedy Associates of Boston. CfA contracted with the Museum of Science to develop the

educational programs and materials. After being piloted in Boston, its first stop as a traveling exhibition was in Midland, Michigan. During the course of this evaluation, *Cosmic Questions* was installed at the Boston Museum of Science and the Midland Center for the Arts.

Cosmic Questions is an interactive exhibition, developed to promote reflection about and interest in "big questions" about the universe and humanity's place in the cosmos, along with providing the most up-to-date information about the universe. The exhibition is also designed to give visitors direct experiences in using the tools of space science and knowledge of how scientists investigate the universe. Through their experiences in the exhibit gallery and at the related activities of *CQ*—the play, the demonstration, and the planetarium show—visitors are encouraged to construct meaning and to find relevance in relation to their own world views and life experiences. A full description of each of the exhibition's components can be found in Appendix B.

PROJECT GOALS

Cosmic Questions was designed to encourage visitors' curiosity as well as to inform . Much of the exhibition was framed around three "big questions." The questions are:

- "What is the universe like?"
- "Was there a beginning to time?"
- "Where do we fit in?"

According to literature from the educator symposium, the goals of *Cosmic Questions* include enabling visitors to:

- Learn about key astronomical and scientific concepts including:
  - The composition of the universe and its vast scales of space and time
  - The physical and analytical tools of the astronomer: "learning from light"
  - The interplay of models, evidence and explanation in forming our understanding of the universe
- Increase their understanding of the nature of scientific inquiry by engaging in activities that explore "how we know" about the universe
- Encounter various human perspectives (historical, personal, cultural, artistic, etc.) on age-old cosmic questions
- Reflect upon their own ideas about the universe and the meaning and relevancy of the ongoing human search for answers to cosmic questions

RELATED ACTIVITIES

Cosmic Questions also included a number of activities that were designed to reinforce and expand the main ideas of the exhibition. In Boston, evaluators also collected data on these activities—a play, *Girl Meets Boy*; a planetarium show, *Journey to the Edge of Space and Time*; and a live demonstration, *The Real Time Machine*. In Midland, evaluators collected survey data from the planetarium show, which was held at Delta College Planetarium in nearby Bay City, Michigan. The demonstration took place on one day only, as part of a series of *Science Sunday* lectures related to *CQ*, and survey data was collected from participants. The play was not performed in Midland.

EVALUATION ACTIVITIES

PERG evaluators began the summative evaluation on *Cosmic Questions* in September 2002, when the full exhibition opened at the Museum of Science. Evaluation activities continued until May 2003. The summative plan consisted of multiple activities and was designed to address questions about the exhibition's impact on visitors in relation to the goals of the project. These project goals framed the development of protocols for visitors and staff. Data collection consisted of multiple activities, described below.

Note: All protocols used by the evaluators are included in the Appendices.

Our fieldwork consisted of the following activities:

CQ VISITORS

Table 1
Evaluation Activities: *CQ* Visitors

Activity	MOS	MCFTA
Exit interviews	100	39
Black Hole/Dark Matter exit interviews	30	N/A
Interactive observations	28	N/A
Black Hole/Dark Matter interactive observations	7	N/A
Short-term phone interviews	23	12
Long-term phone interviews	22	13
Planetarium surveys	80	115
Demonstration surveys	50	16
Play surveys	84	N/A

- **Exit interviews**
  PERG evaluators conducted a total of 100 overall exit interviews at the MOS, and 39 exit interviews at the MCFTA. At the MOS, these interviews involved a total of 159 individuals, while at the MCFTA, 78 people participated in the interviews. Visitors were selected at random, except that evaluators did not interview student members of school groups and sometimes bypassed parents with very young children. The evaluators interviewed visitors singly and in adult, child, or family groups at both museums.

  Note: A large majority of Midland visitors came to the MCFTA in family groups, but some of these visitors were interviewed individually by the evaluators.

- ***Black Hole* and *Dark Matter* exit interviews**
  The evaluators conducted 30 exit interviews with MOS visitors in the *Black Hole* and *Dark Matter* areas, located just outside the main exhibition hall. (This was done because so many visitors to the main gallery did not realize these rooms were part of the exhibition.) Evaluators selected visitors at random, but avoided students in school groups and adults with more than one young child.

- **Interactive observations**
  28 visitor groups were selected randomly by the evaluators, who accompanied these group members through the exhibition at the MOS. We asked visitors to "think out

loud," and share their observations and questions as they visited *CQ*. We also asked visitors to share their overall impressions and reactions to the exhibition.

- ***Black Hole* and *Dark Matter* interactive observations**
  A total of 7 visitor groups were observed in the *Black Hole* and *Dark Matter* areas at the MOS. These visitors were also asked to "think out loud" while they interacted with these components.

- **Follow-up phone interviews**
  Visitors to *CQ* were asked if they would agree to be interviewed either 3 to 7 days or 6 to 9 weeks after their visit to the exhibition. A total of 46 MOS visitors (23 after 3–7 days and 23 after 6–9 weeks) and 25 MCFTA visitors (12 after 3–7 days and 13 after 6–9 weeks) were interviewed by phone about their experiences at *CQ*.

- **Planetarium surveys**
  Visitor surveys were obtained from approximately 80 visitors who viewed *Journey to the Edge of Space and Time* at the MOS Hayden Planetarium, and 115 visitors who saw the presentation at the Delta College Planetarium in Michigan.

- **Demonstration surveys**
  Fifty surveys were obtained from visitors who attended *The Real Time Machine* demonstration at the MOS, and 16 visitors filled out surveys at the MCFTA about the demonstration.

  Note: The demonstration was presented on one date in early April at the MCFTA as a special *Science Sunday* lecture.

- **Play surveys**
  84 visitors filled out surveys that were distributed after performances of *Girl Meets Boy* at the MOS.

EDUCATORS

Table 2
Evaluation Activities: Educators

Activity	MOS	MCFTA
Teacher PD attendees (interviews)	4	N/A
Teachers who brought classes (surveys)	N/A	12

- **Teacher professional development interviews**
  The developers of *CQ*, Harvard-Smithsonian's Center for Astrophysics, sponsored a workshop for educators to build on the "big ideas" of the exhibition at the MOS in November 2002. About 6 weeks after the workshop, the evaluators interviewed 4 teachers who had attended.

- **Classroom teacher surveys**
  The MCFTA surveyed 12 teachers about the usefulness of the *CQ Teacher Guide* in preparation for their classes' visits to the exhibition. PERG staff reviewed these surveys. Most were from elementary teachers in the Midland area after their visits to *CQ*.

STAFF AND VOLUNTEERS

Table 3
Evaluation Activities: Staff and Volunteers

Activity	MOS	MCFTA
Administrator interviews	8	4
Interpreter/docent interviews	5	3
Demonstration staff interviews	4	N/A
Actor interviews	4	N/A

- **Administrative staff interviews**
  The evaluators interviewed key staff members at both institutions. A total of 8 administrators at the MOS were interviewed. PERG staff also interviewed 3 administrators at the MCFTA, and the director of the Delta College Planetarium during spring 2003.

- **Interpreter/docent interviews**
  PERG staff interviewed 5 volunteer interpreters at the MOS and 3 docents at the MCFTA during spring 2003.

- **Demonstration staff interviews**
  Four members of the MOS demonstration staff were interviewed by the evaluators during winter 2003.

- **Actor interviews**
  Four actors were interviewed by PERG staff during winter 2003.

Note: PERG evaluators did not conduct tracking studies for *Cosmic Questions*. The evaluators made an agreement with CfA staff for them to undertake visitor tracking studies for the exhibition.

VISITOR SAMPLE

At the MOS, the total number of participants for the exit interviews, interactive observations, and *Black Hole/Dark Matter* interviews was approximately 270; of these respondents, 159 visitors actively participated in the exit interviews (answered more than one question), 43 participated in the *Black Hole* and *Dark Matter* interviews, and 63 completed interactive observations at the MOS. Finally, an additional 46 MOS visitors completed follow-up phone interviews.

At the MCFTA, 78 visitors actively participated in the exit interviews (answered more than one question). Most of the Midland visitors were in family groups, and almost half of our sample consisted of children under 18. An additional 25 visitors completed follow-up phone interviews.

At both institutions, respondents were approximately equally divided between male and female.

The following table provides age-related data for MOS and Midland visitors:

Table 4
Visitor Sample
Exit Interviews, Interactive Observations,
Black Hole/Dark Matter

Age	MOS n=270	MCFTA n=82
<7	5	3
7–10	23	16
11–14	16	15
15–18	20	2
19–24	53	5
25–32	41	5
33–45	64	22
46–60	31	6
>60	17	8

A majority of our visitors at both museums were white. At the MOS, 170 respondents were white, 4 African American, 10 Asian and 7 Latino. (We did not collect ethnicity data for about 75 MOS visitors.) At the MCFTA, approximately 73 visitors were white, 1 was African American and 8 were Asian. The MOS had a significant number of international visitors—about 40, and there were more visitors from outside the local area—approximately 121, than local visitors—approximately 93.

Almost all of our Midland visitors were from Michigan, mostly from the Midland/Bay City/Saginaw area. Only 6 were from out of state; 5 of those respondents were from outside the United States.

REPORT

The findings contained in this report are organized into four sections. The first section concerns visitor interactions with the exhibition presented in the main gallery. The second section covers visitor responses to the related activities of the exhibition—the demonstration, play, and planetarium show. In the third section, the report deals with activities and personnel, including those based at the museums as well as local teachers, involved with the implementation and support of *CQ.* The fourth section details the benefits and challenges *CQ* offered each of its host institutions. Finally, the report concludes with a discussion of the findings.

Quotes throughout the report should be assumed to be from adults, unless otherwise identified, i.e. B13 for a thirteen-year-old boy and G8 for an eight-year-old girl.

FINDINGS PART ONE: VISITOR INTERACTIONS WITH *CQ* EXHIBITION CONTENT

> The whole exhibit is space and the universe and a journey of discovery. We know a lot and we don't know a lot. The exhibit gets that across.
>
> (MOS interactive observation)

> My life seems puny when I look at all these infinite creations in the cosmos, so I'm taking time out from what I think is so important in my life to look at the big picture. It actually gives me some peace to look at this.
>
> (MCFTA exit interview)

INTRODUCTION

Almost all of our respondents at both sites enjoyed their time in the *Cosmic Questions* exhibition. Approximately three-quarters of the visitors indicated that *CQ* had helped them to think about the "big questions" raised by the exhibition and over two-thirds said they had learned or experienced something new. Majorities also reported that the exhibition had prompted them to reflect on their personal relationship to the universe, and that they left the exhibition pondering a range of interesting questions. In follow-up phone calls, almost half of those interviewed from each museum indicated that their mental picture of the universe had changed as a result of their experience in the exhibition. (See Appendix A for charts detailing this and other frequency data.)

Visitors tended to use the exhibition in ways that were meaningful and interesting to them. They were drawn to those components that reflected their interests or their (often unspoken) questions. The exhibition seemed to have something for almost everyone in a wide age range—those who liked to read, those who were more interested in interactive activities, those interested in art, science professionals, novices, and the uninformed, etc. However, there were a minority of visitors who did not "engage" with *CQ*; most of those reported going through the exhibition quickly and superficially, whether due to a lack of interest, a lack of time, or their focus on young children.

A: LAYOUT AND VISITOR PATHWAYS

Visitors interacted with the *Cosmic Questions* exhibition in two distinct sites during the course of this evaluation; while the components were essentially the same, the physical layout of the exhibition varied between the two sites. (See Appendix C for a floor plan

diagram of CQ at the Museum of Science. A floor plan from MCFTA is unavailable. Appendix D shows an ideal floor plan for the exhibition.)

MOS

In Boston, the bulk of the exhibition was contained in one hall, with visitor traffic flowing around the *Cosmic Calendar*- and *Big Bang*-related components (on the outside wall) and *Cosmic Kitchen* (inside), situated in the center of the hall. Due to space limitations, the *Black Hole* and *Dark Energy*/*Dark Matter* areas were located just outside the main gallery, but without any connecting signage, so that many visitors were unaware that they were part of the same exhibition. A large number of museum visitors visited either *Dark Energy/Dark Matter or Black Hole* or the rest of the exhibition, but not both locations.

Most MOS visitors followed a basic pathway through *CQ*, picking and choosing among the components, moving in a counter-clockwise direction. However, several of our interactive observation visitors "broke off" from the pathway—they were drawn to the *Mechanical Map* and *A Ride Through Time,* and often continued through *CQ* in a clockwise direction. A few of these visitors noticed that something was missing in the presentations, and suspected that they were meant to approach some of the information in a different order.

> There was a lot of neat stuff there. I feel I didn't get to all of it. I don't think the exhibit flowed. It was sporadic. I felt I skipped things accidentally. I ended up wandering until I fell into the next neat thing. (MOS phone interview)

MCFTA

During the first several months of *Cosmic Question's* residence in Midland, about a third of *CQ* was displayed in the front of the gallery area. Due to space restrictions, the remainder of the exhibition was separated by two different exhibitions, one on each side of *CQ*. Although museum guards and volunteers were able to alert most visitors to the rest of the exhibition, the disconnection was disconcerting to some. (The exhibition was physically united after a few months.)

> I liked the exhibit, but some of it's here and there. If we didn't walk around the building we wouldn't have seen it. (MCFTA exit interview)

The *Cosmic Calendar*- and *Big Bang*-related components were located in a dimly-lit back room. Although a large number of visitors were encouraged to view the *Cosmic Kitchen* (and did, according to our interviews) which was also located in that room, very few respondents commented on the *Calendar*- and *Big Bang*-related components at the MCFTA.

Midland mounted a complementary exhibit of large-framed pictures from the Hubble telescope, which were displayed along the walls of one of the main exhibition areas, as well as in a small adjacent room. These were of great interest to visitors. In addition, a high-definition video screen, also integrated into the exhibition, showed several 12 to 20-minute presentations of Hubble images from deep space that MCFTA had obtained from NASA.

B: VISITOR REACTIONS

WHAT "STOOD OUT"

Visitors were asked to identify what "stood out" for them during their visits to *CQ*. Visitors at both museums mentioned a broad array of components, with different but overlapping favorites, including the *Cosmic Kitchen, Infrared* area, *Fly Through the Universe*, *Multiwave Viewer*/*Night Sky,* and the *Black Hole.* However, a broader range of components were mentioned in Boston. (Midland visitors often cited the additional Hubble pictures when asked what stood out.) Major differences in emphasis were the *Cosmic Calendar*, *Alien Life*, and *Big Bang* components, which were more popular in Boston, and the *Interviews With Astronomers*, *Information About the Telescopes,* and the *Rhythm of the Cosmos,* which were relatively more popular with Midland visitors.

The following table presents the most frequent visitor responses (in order of popularity) to the question, "What stood out?" (These responses were tabulated from exit interviews conducted at the entrance/exit to the exhibition, and do not take into account the separate *Black Hole* and *Dark Matter/Dark Energy* interviews conducted at MOS outside those components.)

Table 5
What Stood Out

MOS	MCFTA
Cosmic Calendar	*Cosmic Kitchen*
Cosmic Kitchen	*Black Hole*
Fly Through the Universe	*Infrared* component
Infrared component	*Fly Through the Universe* and interactives
Multiwave Viewer/*Night Sky*	Interviews with astronomers
Dark Matter	*Multiwave Viewer*/*Night Sky*
Black Hole	Chandra/other info about telescopes
Control a Telescope	*Rhythm of the Cosmos*
Alien Life room	Stars
Big Bang components & *A Ride Through Time*	*Control a Telescope*
Galaxy-related components	
Static ball	
Welcome Home	

On the Day of Viewing

Cosmic Kitchen and Cosmic Calendar

The *Cosmic Kitchen* was a great highlight for visitors of all ages at both museums.

> I liked the pie. You just need samples because I get hungry . . . I feel like it is very kid-oriented and the sound is nice. I liked the fact that there is a lot of virtual-like voice. There is no actual somebody talking, so you have a chance to imagine who is who, for example. (MOS exit interview)

> We are here with a five-year-old, so the kitchen is what we liked best. It identified with the young kids so they can understand the evolutionary aspect so that everything is tied together. Perfect for kindergarten, first-grade-type level. (MOS exit interview)

> B8: The apple pie, that was cool. (MCFTA exit interview)

> I liked the movie. The kids really liked it. We really liked it. (MCFTA exit interview)

The *Cosmic Calendar* stood out for visitors in Boston more than any other single component, but was rarely mentioned by MCFTA visitors.

> I liked the timeline that goes through the entire year, that really puts things into perspective, especially for people who can't conceive of billions of years. (MOS exit interview)

> I like this part [*Cosmic Calendar*]. It's very concise. It helps you have perspective on when certain things took place by putting it into one year. (MOS interactive observation)

> I liked the calendar . . . To see the correlation of time vs. calendar of year and how much could happen in one year. (MCFTA exit interview)

"Hands-on" Components

Visitors at both museums especially liked the "hands-on" components such as *Fly Through the Universe*, the *Black Hole*, the infrared area, and the *Multiwave Viewer*/*Night Sky*.

> Oh, and the other thing I really enjoyed was being able to take off from Earth and be able to travel a couple million miles out. That blended technology with hands-on stuff that isn't' too complicated with technology that isn't overwhelming. It was great information. (MOS exit interview)

> I was impressed with the wavelength explorer, where you can pick waves of light. I have been working with a project similar to that and this one might give me ideas of how to present some information. (MOS exit interview)

> I liked the section about the different lights, seeing the things in different ways. (MCFTA exit interview)

> I liked . . . on a fun level, the infrared camera and what I could reveal with the Mona Lisa and a light bulb. I liked being able to select a picture and have an e-mail sent to you. That was unlike anything I have seen before—clever, neat. (MOS exit interview)

> They don't show you that on Nova [*Infrared* area]. That's pretty good. (MOS interactive observation)

> G8: I liked the Mona Lisa picture and the window one [at the infrared area]. (MCFTA exit interview)

> B8: There was this thing you had to push, and you could see the black holes. (MCFTA exit interview)

Telescopes, Astronomers, and Where Do We Fit In? Video

Midland visitors made frequent references to the telescopes and information about astronomers and their roles. Several visitors also reflected on the questions raised in the *Where Do We Fit In*? video. Boston visitors mentioned these components less frequently.

> Chandra—I liked them explaining how they choose what things are going to get studied. How she gets her results back, and the limitations of it. (MCFTA exit interview)

> I think it's interesting to hear the astronomers talk about why they became astronomers. My son wanted to be an astronomer from the time he was four. They are saying the same thing. (MOS exit interview)

> This is great. *Why?* Because I'm gonna get a picture sent to my e-mail. (Interactive observation)

> The video interviews were a nice introduction to the exhibit because it asked the questions that you yourself have asked. When you go around the exhibit you appreciate the people who have been working in this field, trying to seek the truth. (MCFTA exit interview)

> The comments about how we fit into the universe by artists, [video wall] that was interesting . . . Just to hear from different people with different backgrounds and their comments about [how] we fit into the universe. (MOS exit interview)

Dark Matter/Dark Energy, Alien Life, and the Big Bang

Dark Matter and *Dark Energy* particularly intrigued Boston visitors, more often than those in Midland.

> That "What is the universe really made of?" room over there, I found that fascinating. On what is dark matter and dark energy, and how is that similar or different. (MOS exit interview)

> I have an interest in astrophysics . . . I have always wanted to see [a cloud chamber] in action. I have seen some photographs and text on it, but I have always wanted to see it working. (MOS exit interview)

> B8: The *Dark Matter* exhibit. That's passing through us right now. If it were visible it would be right there. (MCFTA exit interview)

A large number of MOS visitors were also interested in the possibility of alien life in the universe and some talked about components in the *Alien Life* area.

> I was fascinated with the one asking, "Are we the only one out there?" with the forward movement of astronomers. I'm wondering if we will ever find out, the mysteries of it all. (MOS exit interview)

Others visitors cited the *Big Bang*-related components, especially in Boston.

> G10: I liked the *Big Bang* and the *Albert Einstein* part because it shows how space stretches throughout time. I enjoyed the visual thing where you put your face in it and it showed the galaxy. I didn't know that there was all that stuff in the sky, like there is other life. Now I know more about the world and beyond. (MOS exit interview)

Other Components

Visitors, particularly in Boston, talked about other components as well, reflecting the broad range of interests of our respondents and *CQ*'s ability to provide for these interests.

> I think the *Milky Way* exhibit right here was interesting. I thought it was good how the young man explained things. There was a young man in there giving us a little Milky Way lesson. (MOS exit interview)

> I liked that lightening thing. I didn't know that when you put your hand on it, it would turn colors. (MOS exit interview)

> The video we saw on the interconnectedness of everything in the universe was really interesting [Rhythms of the Cosmos]. I had learned that before, but it was interesting about the interconnectedness about the universe and everything in it, including the atoms and particles and things.(MOS exit interview)

> I really liked the video with Walt Whitman. That was really peaceful. (MCFTA exit interview)

Many MCFTA visitors described the Hubble pictures, which were supplemental to the exhibition and not present in Boston, as highlights of their visit to *CQ*.

> I liked the pictures; it's amazing how beautiful they are. (MCFTA exit interview)

> The Hubble, what it's been able to achieve. The images are incredible. (MCFTA exit interview)

A few Midland visitors had more global responses to the question, possibly because of the impressive Hubble images.

> The sheer size of the cosmos is just overwhelming . . . Normally the naked eye can't appreciate what space is all about; this demonstrates that there is a

> lot more than one sees with the naked eye. It makes one wonder if there is life other than here, in outer space. (MCFTA exit interview)

> When I saw the universe in 3D [is what stood out] . . . There aren't any words. I think I get a connection through a feeling.. . . . Maybe I'm feeling a connection with God. (MCFTA exit interview)

Problems

Visitors also talked about what didn't work, particularly in Boston, and what they found frustrating. (Much of this data came from the interactive observations). At the *Infrared* component, visitors often approached the wall without noticing the console that had directions for the remote control, the infrared camera, and other activities. (The layout in Midland prevented this problem. Also, there was often a docent stationed here.)

> I walked in next to the display. I had to figure out this [console] was here, and then figure out to sit down. Maybe if they had lines or footprints so you'd know where to walk. I just turned the corner. I could use a cue to "sit here." (MOS interactive observation)

Visitors were also confused by the *Spectrometer* and frequently left this component in frustration.

> I don't get it . . . (MOS interactive observation)

Finally, in the *Mauna Kea* area, visitors were confused by the *Images from Mauna Kea* when they used a magnifying glass to look for spiral galaxies.

> OK, this text is talking about the picture on the right. These things [on left] are not in this picture, but it's presented as if they might be. They put two separate ideas in one place. (MOS interactive observation)

Note: The most detailed reactions to individual components were obtained in the interactive observations. These visitor comments are included in depth in Appendix B of this report.

3–7 Days Later

Almost all of the visitors from both sites who were interviewed 3 to 7 days after their visit identified particular components of *CQ* that still "stood out" for them and/or positive aspects of their visit to the exhibition. Interactive components were mentioned most frequently at both sites—the *Cosmic Kitchen*, *Infrared* area, *Fly Through the Universe*, *Black Hole, Control Telescope,* and *Multiwave Viewer*/*Night Sky.* In fact, interactive components were almost the only parts of the exhibition mentioned by Midland visitors when asked what they remembered most.

> I enjoyed it very, very much. Each one of the exhibits . . . the *Cosmic Kitchen*—it was just unique; I thought it was wonderful.
> (MOS phone interview)

> I did like the infrared camera. That was kind of neat. It was a nice demonstration of the spectrum of light that people can't see. It is right in front of them. There was the window that was transparent with infrared light. That was kind of neat. (MOS phone interview)

> B10: I liked the *Cosmic Kitchen* program, and the interactive game where you looped the probe into the black hole—I like video games—and I liked launching the space shuttle and go through the universe.
> (MCFTA phone interview)

> My son, he sat down with the infrared camera and he was fascinated about where the remote showed up in that mirror—the remote beam. All that stuff and where he was able to look at the different wavelengths; it showed the difference, viewing different things with the different wavelengths. That was pretty impressive. (MCFTA phone interview)

Other features mentioned in Boston included interviews with scientists, computers, the timeline (*Cosmic Calendar*), stars, *Rhythm of the Cosmos, Spectrometer*, bronze model of the galaxy, history of science, *Ride Through Time,* telescopes, *Wall of Galaxies*, audio tours, and the "thought-provoking questions."

> When you walk in, I think there is a bronze model of the galaxy and you can feel it, and I really liked that . . . I just liked feeling the galaxy. I know it sounds so weird, but it was a neat way to get the shape of the galaxy.
> (MOS phone interview)

> I was very interested in seeing stars that are so many light years away. We're seeing things that are really 4 million years old, something like that; we're not seeing it as it is in our timeframe. (MOS phone interview)

> One thing I remember reading about was the history of science part.
> (MOS phone interview)

> What I do remember reading is stuff about telescopes. (MOS phone interview)

> I did enjoy the live quotes from several of the researchers . . . the questions about what is their biggest question or how did they get into astronomy.
> (MOS exit interview)

> I guess what I noticed is that . . . one of the goals was to pose thought-provoking questions and not necessarily answer them, and I liked that.
> (MOS phone interview)

Like those interviewed on the day of viewing, several of these MCFTA visitors also reported that the Hubble pictures were the highlight of the exhibition.

> The photographs were the most impressive part. (MCFTA phone interview)

A few visitors did not identify anything that "stood out" during their visit, or were less enthusiastic about *CQ*.

> I don't really remember that much. To be completely frank, I wasn't that into it. I remember some of the displays in the back that had audio; it was really loud, too loud in fact. I did like the infrared camera. That was kind of neat. (MOS phone interview)

> It wasn't, compared to the rest of the museum, a highlight for us . . . because a lot had to be read . . . We were in and out quickly and a lot of it was his age. (MOS phone interview)

> I don't like to see so many computers at MOS. Maybe a couple of interfaces with a computer. You could sit at home and do that. If you're there with a large group of people, the seats are taken. (MOS phone interview)

> No, I guess not [nothing stood out]. (MCFTA exit interview)

6–9 Weeks Later

Evaluators conducted another set of interviews 6 to 9 weeks after respondents' museum visits. Twenty out of 23 MOS visitors had some memory of *CQ*, while all of the 13 MCFTA visitors were still familiar with the exhibition. The overall reaction from both sets of respondents was highly positive but significantly different.

For the MOS visitors, the most memorable single component was the *Cosmic Calendar,* followed by planet-, star-, and galaxy-related parts of the exhibition. The *Multiwave Viewer*/*Night Sky*, *Infrared* area, *Black Hole* area, and the *Fly Through the Universe* components were all mentioned by a few visitors each. Other areas cited were the *Spectroscope, Alien Life*, *Big Bang* information, *A Ride Through Time,* and the *Cosmic Kitchen.*

> I was most impressed by the timeline, that series. My life is the last fraction of a second of Dec. 31st . . . The infrared camera was informative—I'm a retired chemistry teacher; I had trouble with the spectroscopy one—it's right up [my] alley, and some of the mechanisms weren't working . . . (MOS phone interview)

> I remember seeing stars; you could locate stars and look at them in different ways, ultraviolet and X-ray. I remember looking at different light—how

> different they are, and seeing how stars looked different under different lights, and an exploding star, something like that. (MOS phone interview)

> I think when you go into the left there was an exhibit where you press the buttons and they give you the history of time since the big bang. And I thought that was very well done, easy to understand and it gave a sense of the enormity of time and all that good stuff—just the expansion of matter since the big bang and timeframes. That was what I remember the most. (MOS phone interview)

> There was a little place where you could take a rocket ride up into space and that I could remember being very interesting. (MOS phone interview)

Several other MOS visitors were focused on the needs of their small children.

> There was something where you could sit down with two big screens, [*Multiwave Viewer*/*Night Sky*] . . . They [two eight-year-olds] liked playing with gadgets [laughs]. They were more interested in [hands-on] and I was more interested in the things along the wall, but the kids liked the gadgets and noisy things. They liked the booth—we walked in and it started [*Cosmic Kitchen*]. (MOS phone interview)

> It doesn't ring a bell. Basically I was following my four-year-old around. He was wandering from place to place. (MOS phone interview)

About one-quarter of those interviewed from the MOS, when asked for additional comments, said that they would like to see the exhibition again.

> If it is still there, I would love to go back and spend more time there and really look at it. (MOS phone interview)

For visitors to MCFTA, the *Cosmic Kitchen* and the *Black Hole* components continued to stand out for the most people. In addition, several visitors talked about other interactives, including the *Infrared* component, and other stations that involved looking at light.

> The movie they set up [*Cosmic Kitchen*], because the kids really enjoyed the audio. (MCFTA phone interview)

> [I] enjoyed the *Black Hole* exhibit, also the *Infrared* . . . you can visualize what's happening even though elements are not seen by the naked eye. I thought the exhibit was exemplary hands-on. (MCFTA phone interview)

> I liked the hands-on [components]. We came back and took our grandchildren. We've been back twice . . . (MCFTA phone interview)

> I had my two little boys with me and they really enjoyed it, as well—seeing things about space. It was interesting about the computers—how you could go to different stages of space, look back at the Earth; it was almost like being out there. That was really interesting. (MCFTA phone interview)

Other visitors were impressed by the Hubble pictures and the moving images projected onto a high-definition screen within *CQ* (not at MOS).

> What I liked most was that plasma screen with all the different programs 20–30 minutes long that animated and explained the Hubble pictures with the high-definition screen. I liked that best because of the great information. (MCFTA phone interview)

Two visitors were interested in the observatories and getting e-mail pictures of space from the *Control Telescope* component.

> For my son, the best part was being able to e-mail a picture of a system to himself. He loved it. We saw some other images that were linked to NASA. My son chose a system from, I think, the Hubbell. (MCFTA phone interview)

> I learned a few new things, about what the spectrum of light was and the . . . telescopes, like the ones in Hawaii and how they connect to computers and how they could send it up . . . (MCFTA phone interview)

A few visitors did not recall specifics about *CQ*.

> They had stuff about stars and planets, I don't really remember it. (MCFTA phone interview)

INTERACTIVE OBSERVATIONS

The interactive observations provided visitors with the opportunity to "think out loud" about and interact with the various components of *CQ*. The exhibition stimulated questions for many visitors as they went through the gallery. They were impressed by the displays and computer graphics of the interactive components and enjoyed the hands-on aspect of *CQ*, making comments like "cool" and "awesome" as they manipulated the controls. Other visitors responded to the pictures and art displayed in the exhibition, and found other images to be interesting, such as those in the *Cosmic Calendar*.

> It's amazing [*What's Beyond*]; it just keeps going further and further . . . beautiful graphics. (Interactive observation)

Several interactive observation visitors appreciated the *Cosmic Kitchen*, including the female gender of the central character.

> It was a good summary of time since the creation of the universe, and a nice analogy between recipe and cooking. And it's nice using a real character and

> having her be a girl—as a father of two girls who is interested in science. Until recently, girls haven't been fostered in science. (Interactive observation)

Visitors often shared their own experiences and ways they connected to the exhibition, referring to things they'd learned in school, or things they'd seen or heard about. *Cosmic Questions* also stimulated questions for many visitors; questions often related to what visitors were reading about or watching.

> [This] thing says our sun will run out of fuel in five billion years. At what point would life on Earth not be sustained? (Interactive observation)

> How can they theorize what was here before the big bang? How do they know?" (Interactive observation)

Interactive observation visitors often commented on the vast size and scope of the universe and how small we are. Most felt that the exhibition did a good job of explaining and showing our place in relation to the scale of the universe.

> I like this—something [I can] understand. 14 billion years is harder to wrap your mind [around] than one year. (Interactive observation)

> F13: I really feel small. I'm like this person in the museum, in the town Boston, in the state, in the country, in the world, in the universe. (Interactive observation)

VISITOR SUGGESTIONS

Visitors at both museums made a variety of suggestions, with hardly any repetition of ideas.

MOS

General suggestions included having a clear pathway through the exhibition; a more interactive room with holograms; more on local asteroids and comets; a hard 3-D model of the universe; tying the exhibition into an astronaut activity; and having an introductory adult video for the exhibition. Visitors also suggested even more visual information on the timeline for those with limited English; something to "capture the flavor" of the way scientists really work by including controversies among them, and showing more about how data is collected and used.

> Maybe having more of the instruments, so that somebody could really see how astronomy is actually done. Most people think of telescopes, but a lot of it is done with electronics. There could be more of that kind of thing. Sometimes it's hard to see how scientists draw their conclusions. That connection between the instrument and the data could be more easily

> explained . . . What's the direct parallel between what I'm manipulating and what is the relationship and why is the data important? (MOS exit interview)

Other visitors suggested a layout to mirror the Milky Way; more on the issue of time, and a chance to comment into a video camera on the way out of the exhibition, perhaps to be shown on the Web site. Several visitors suggested more publicity for *CQ*; they found little information about *CQ* and some MOS staff were not familiar with the exhibition.

MCFTA

At the MCFTA, some visitors wanted better signage and a clear path linking the two sections of the exhibition. (The two sections were eventually joined.) One wanted a picture of a super nova remnant. Another suggested an audio track at the *Infrared* area to add to their understanding. Also, one visitor wanted a greater focus on how the elements were created and humans' history in the universe.

> I think that was one of the things that was missing. The only thing that involved people and how people arrived in the universe was the apple pie, and that wasn't very long. The bit where they start talking about how all the elements were created, they didn't talk about fusion . . . it might have explained where all the elements came from . . . that might have been more relevant, instead of just stars, apple pie. It didn't explain how the atoms were created. (MCFTA exit interview)

RESPONSES OF CHILDREN

The children who agreed to be interviewed at both museums shared almost uniformly favorable reactions to *CQ*. (About half of the exit interview respondents in Midland were children under the age of 18, as most visitors to the MCFTA were in family groups. In Boston, about one-third of the exit interview respondents were children. A majority of all children interviewed were under 14 years of age.) Even some of the younger respondents—boys and girls 6 to 12 years old, had questions about the universe and identified new learning. Several children in this age group mentioned the big bang, and were curious to know when "time started." Most children of all ages reported that they learned something new in *CQ*. They talked about the big bang, black holes, dark matter, galaxies, the vastness of space, stars and light.

> G8: I didn't know anything about black holes, that time stops when you get near them. (MCFTA exit interview)

> B15: I liked how they talked about the different wavelengths, and how there's so much other besides visible light. (MCFTA exit interview)

> B9: How the universe is created . . . it started with the big bang. (MCFTA exit interview)

G9: I learned that the stars are going to explode some day and I thought they were going to live forever. (MOS exit interview)

G10: I liked the space and Albert Einstein part because it shows how space stretches throughout time. (MOS exit interview)

Many younger children—particularly in Midland—reported that they enjoyed the *Cosmic Kitchen*. They also identified interactive components as highlights of the exhibit, including *Fly Through the Universe, Multiwave Viewer*/*Night Sky,* the *Static Ball,* the *Infrared* component and the *Black Hole* area.

G17: The kitchen. I've never seen an exhibit like that before. (MOS exit interview)

B11: It was good, especially the apple thing. (MCFTA exit interview)

G8: I liked the things where you pressed the button and it talked and you held it up to your ear. (MOS exit interview)

B7: I liked the black hole. Trying to get into the black hole. (MCFTA exit interview)

G10: This thing's cool [*Multiwave Viewer*/*Night Sky*]. You find something, you can make it visible. (MOS interactive observation)

Older children (13–17) also enjoyed the interactive portions of *CQ*. They raised questions about the big bang and the structure of the universe. They were also interested in seeing the inside of a black hole and exploring space, including visiting the planets.

G15: I thought there was a theory about the big bang expansion and in the future, retraction. I wondered if there would be a retraction. (MOS exit interview)

G13: It was a good metaphor to compare everything to a kitchen. (MOS interactive observation)

B13: [I want to] go through the universe or make something that can go through it. (MCFTA exit interview)

B13: It showed me a lot about black holes . . . I didn't think it was hot near a black hole, that matter traveling into a black hole is at the speed of light. I found that interesting. (MOS interactive observation)

B13: I knew time and space distortion happened, but it's nice to see it . . . (MOS black hole interactive observation)

> G13: Oh my gosh, that's a galaxy map. That's amazing.
> (MOS interactive observation)

Some children, like many adults, talked about how "small we are." Many had questions about black holes and other aspects of "what's out there."

> B10: What black holes were and what they did . . . was there a big bang, what are the details of it? (MOS exit interview)

> G9: The question I had is why can't we get a picture of the galaxy . . . and I got an answer that it's too far away. (MCFTA exit interview)

> G10: I was just wondering if the big bang was the beginning of time or something earlier or later was the beginning. (MCFTA exit interview)

> G12: I don't really know how big the universe is. (MOS exit interview)

Most children surveyed wanted to explore space—some to visit other planets, while others hoped to visit stars or black holes.

> G8: I would definitely explore other galaxies and learn about space.
> (MCFTA exit interview)

> G9: I would build a big space ship and float around and see stuff . . .
> (MCFTA exit interview)

> B10: Really go into a black hole. *Why?* Because it sounds interesting, kind of like the Bermuda triangle. (MOS exit interview)

Several of the children we interviewed made reflective comments and developed their own "big questions," like those below.

> G9: I wondered how big it must really be if I am only one out of a million parts of the universe because not even the planets are a big part of it.
> (MOS exit interview)

> B13: What happened before the big bang? What's on the other side of a black hole? (MCFTA exit interview)

> B10: It made me think of how the universe even got here and the big bang. All the stuff that's happened since the big bang; all the stars exploding and dying. (MCFTA exit interview)

C: VISITOR REFLECTIONS, LEARNING, AND QUESTIONS

REFLECTIONS ON THE THREE BIG QUESTIONS

Cosmic Questions presented visitors with three "big questions": "What is the universe like?" "Was there a beginning to time?" and "Where do we fit in?" While most of our visitors did not notice the entrance sign with these questions at the front of the exhibition gallery or inside the exhibition itself, most respondents did say that they were thinking about some of these themes as they went through *CQ*.

> As I look at them now [the three questions], those were all answered as I walked through. If I had read them as I walked through, I would have thought about them a little more. (MCFTA exit interview)

At the Museum of Science in Boston, 78% of exit interview respondents asserted that the exhibition helped them to think about one or more of these three questions, and only 6% said that the exhibition did not have that effect on them. (16% had no answer for that question.) At the Midland Center for the Arts, 74% of exit interview respondents said that the exhibition helped them to think about these questions, while only 3% said that it did not. (23% did not answer that question.)

What is the Universe Like?

According to their responses during exit interviews and comments during the interactive observations, visitors gave considerable thought to the nature of the universe while in the *Cosmic Questions* exhibition. They were often struck by the size and scale of the universe.

> That first thing where he was zooming in and out—I was realizing how vast it was. (MOS exit interview)

> G9: It helped me know what the universe was like because I didn't know it was so big. I didn't know there were as many stars . . . It made me really think about it. (MOS exit interview)

> That's incredible! [Looking at universe in 3D] What it represents . . . each little dot represents billions of stars. It must be what infinity is like. (MOS interactive observation)

> I guess a lot has changed since I learned about it in school. When I was learning, it was just the planets. But now it's universe upon universe. (MCFTA exit interview)

> It gave you a good feel of how the universe is, and our little piece is just a small speck. You don't usually think about that very often. (MCFTA exit interview)

> The reason I didn't appreciate [space science] before the last few years is that I would see a picture of exploding stars, but didn't see them as real. I'm beginning to understand the models better. (MOS interactive observation)

Others were prompted to think about a variety of details about the nature of the universe.

> It gave a lot more information based on actual facts than I've ever seen before. (MOS exit interview)

> It helped to answer some of my questions about all of the planets and the solar system. (MOS exit interview)

> F17: It just kind of explained what the universe was made of. (MOS exit interview)

> I thought about the curvature of space-time, around the *Black Hole* exhibit. It showed some models of limits of where space and time break down. (MOS exit interview)

> It seems much more colorful than I imagined, because when you stand down here you just see black and white. (MCFTA exit interview)

> Of course, because I see the descriptions of how far these bodies are so it tweaks me to try to imagine how far is 400 trillion light years. (MCFTA exit interview)

> I learned today that there is an observatory in Hawaii. It's significant to learn where they are located in our own country. (MOS interactive observation)

Many visitors found themselves still wondering about what the universe was like as they left *CQ*.

> I'm still trying to understand what [black holes] are. I'm not sure I can get my head around them yet. (MOS interactive observation)

> Are there other planets like ours? Is there another galaxy similar to ours? If there are other galaxies, what are they like? I hadn't previously thought about them in depth. (MOS exit interview)

> Is it the same everywhere? Could you go to different parts of the universe and would they be different . . . fundamentally? Does it look the same everywhere? (MOS exit interview)

> G13: How did oxygen get inside the stars? How did the stars get all this stuff? (MOS interactive observation)

> G10: I just was wondering if there are huge galaxies that are billions and billions of light years away. And if there really are aliens somewhere in the universe. (MCFTA exit interview)

Some visitors in both museums (although more often at the MCFTA), said that thinking about the nature of the universe made them think about God.

> Is there a greater power out there that governs this? (MOS exit interview)

> I'm speechless . . . I believe in God. I believe God put all this here. I see the beauty of what he or she did. I don't try to understand it, but you see what's here. It's like magic. (MCFTA exit interview)

Was There a Beginning to Time?

Visitors also thought about issues and questions related to the beginning of time. They often wondered about what may have come before the big bang, and about an end to the universe.

> I knew about the big bang, but I never thought of how it all began, how the cosmic ooze all got together . . . If it all had a beginning, then it all must have an end. I hadn't thought of that. (MOS exit interview)

> I was concentrating most on the beginning of time [of the three questions] . . . I love the shape of space-time. They compare Einstein's ideas with the current ideas of today. (MOS exit interview)

> B10: I read the big bang one. That was interesting and made me start thinking about the beginning of time . . . I don't know if there was a beginning to time and that's kind of scary. (MOS exit interview)

> It definitely makes you think about the beginning of time, because we watched the video and looked at the computer images . . . I can agree with some of it, but how can they know this if they were not around? (MCFTA exit interview)

> I've come to the realization that humans think in a linear fashion. I think there is another dimension. There is another way to explain and describe time that we have no idea of. (MCFTA exit interview)

> I understand space-time fabric, but not enough to apply it. (MOS interactive observation)

A number of visitors, especially in Midland, brought up the topic of religion when discussing their experience in *CQ* in relation to this question.

> For beginning of time, it's the question of creation vs. evolution. If you believe in creation, you know what the beginning of time was, from the Bible. (MCFTA exit interview)

> This is an interesting question—What's before the big bang? Maybe religion will find an answer. (MOS interactive observation)

Where Do We Fit In?

Finally, visitors also found themselves wondering about their place in the universe—both as individuals and as part of humanity—and how they "fit in." For many, their thoughts concerned the relative size of humans compared to the vastness of the universe.

> That is so immense, you know; where do we fit in? Actually, I have more questions and things going on in my mind now than before. (MOS exit interview)

> The first one about the Milky Way made me think about where we fit in. You know what a tiny speck we are in the whole scheme of things. (MOS exit interview)

> My amount of time in the grand scheme of things is a fraction of it and it is daunting to think about. (MOS exit interview)

> It makes you think. We're not even an atom in all this. People think we're the be all and end all, and we're not. (MCFTA exit interview)

A number of visitors were prompted to think about the possibilities of other life in the universe.

> I enjoyed looking at the pictures of other landscapes. It does make you wonder about what else is out there and how significant we are in the whole universe. (MOS exit interview)

> That's the question that really struck me—Where do we really fit in? Are we the only life form? Are there any civilizations outside our galaxy? (MCFTA exit interview)

Some were struck by the similarities of the chemical make-up of all matter in the universe.

> I liked . . . that we are made of the same chemicals that were made at the beginning of time. (MOS exit interview)

> B14: It makes you think about everything is the same and nothing is different because we're all made of the same thing. [In *Dark Matter* room, looking at wall of objects.] (MOS interactive observation)

Finally, visitors also shared their thoughts about various philosophical issues, including religion.

> Where would I be if there wasn't a universe? (MOS exit interview)

> We're a speck of dust; mankind is so insignificant. But it seems that everything fits together. We are an integral part of the cosmos. Without mankind, the cosmos would be meaningless. There would be no one in the world to understand it or pay attention to it. (MCFTA exit interview)

> "Where do we fit in?" Yeah, right where God wants us to. (MCFTA exit interview)

VISITOR LEARNING

A majority of visitors at both the Museum of Science and the Midland Center for the Arts reported that they had learned something new while visiting *Cosmic Questions*, when questioned during our exit interviews. At the MOS, 69% of visitors said they had obtained new information, while only 19% said they did not. (12% did not answer this question). At the MCFTA, 86% learned something new, 5% said they did not, and 9% did not answer.

Though there was considerable overlap between MOS and MCFTA visitors in terms of the topics discussed, there were also significant differences in terms of visitor responses. The following table presents the range of responses for the two museums in order of their relative frequency.

Table 6
Learned Something New

MOS	MCFTA
Dark matter/dark energy	Black holes
New learning—no specifics	New learning/no specifics
Black holes	Stars
"Everything"	Chandra/Hubble/telescopes
Vastness/relative size	Galaxies/Milky Way
Galaxies/Milky Way	Hubble pictures
Stars	"Everything"
Alien life	Light spectra
Big bang/creation	Infrared
Infrared	Vastness/relative size
Chandra/Hubble/telescopes	Space exploration
Hydrogen/other elements	
Light spectra	
Relative scale in time	
Different cultural and spiritual perspectives	
Observatories	
Space-time and expanding universe	
Don't know/not sure	

Black Holes and Dark Matter/Dark Energy

At both museums, black holes were an area of new learning for a large number of visitors. At MOS, this was true even though many of those who were interviewed had not been to the special component specifically about black holes.

> The information about the black hole was the most current stuff to me. I hadn't heard about the radiation that it emits, that time stops at the black hole. (MOS exit interview)

> You don't realize that the wind around a black hole is millions of miles per hour. That is really an incomprehensible fact. The millions of miles per hour struck me. I can't imagine what millions of miles per hour of wind would be. (MOS exit interview)

> Black hole . . . It was interesting to see the temperature and how fast [it goes]. It's theoretical, no one's ever come out, but it's interesting. (MOS exit interview)

> I didn't realize there were so many black holes. (MCFTA exit interview)

> B6: I learned about black holes and if you get too close you can get sucked in like a suction cup. (MCFTA exit interview)

> G13: I didn't know that time stopped at the edge of a black hole—we played that game—and that it was so hot. (MCFTA exit interview)

At the MOS, but not the MCFTA, many visitors also spoke about new information they had learned about the existence and features of dark matter and dark energy.

> I thought dark matter was science fiction, not reality. (MOS exit interview)

> The fact that there is all this matter that is not made up of atoms, which we always thought was the building block of life. I have always heard about dark matter and always thought it was made of the same building blocks of the elements. (MOS exit interview)

> B8: I thought it was kind of cool because I didn't know atoms had that big of trails that they left behind, because atoms are small. (MOS exit interview)

> B8: [I learned] that they just discovered dark matter. (MCFTA exit interview)

> I hadn't been aware of dark energy. I'm teaching astronomy to kids and I didn't know. (MCFTA exit interview)

Galaxies and the Vastness of the Universe

At both institutions, visitors reflected on the immensity of the universe, the vast distances in space, and new information about our galaxy and other galaxies.

> G10: I learned a lot—about some new scientific research that they just discovered. How big the galaxy really is. (MOS exit interview)

> G12: How tiny we are—on that thing right there [points to Milky Way]. It doesn't feel like we are that tiny. (MOS exit interview)

> [I learned about] the enormous distance to the edge of our solar system, and then galaxies and then other galaxies. That even Star Trek, the Next Generation, when going warp 10 or the speed of light, gets you nowhere in the vastness of space. (MOS exit interview)

> I didn't know that the galaxies are arranged in a non-random arrangement in the universe. They are plastered together, many galaxies. (MOS exit interview)

G13: They had a lot of names of galaxies that I hadn't heard of before. (MCFTA exit interview)

I knew about the Milky Way . . . I didn't realize there was more outside that galaxy. It just goes on and on. (MCFTA exit interview)

Stars and Light Spectra

Many visitors also talked about stars, and were especially struck by the idea that "we're made of the stuff of stars."

Well, how things were made, how everything started, that everything really started from the stars; I didn't realize that. (MOS exit interview)

I learned a lot, that there are so many more stars than you know about, and that they are constantly exploding. Every single day those stars are exploding; that's new to me. (MOS exit interview)

G10: I [I learned] that you have stardust in your teeth. (MCFTA exit interview)

Others talked about light spectra—particularly infrared light—and several made the connection between light spectra and learning about stars.

I guess the different spectrums of light. I wasn't as familiar as where they are along the continuum as regular light. (MOS exit interview)

I never realized the difference between gamma, X-ray and UV. (MOS interactive observation)

I learned stuff in [the demonstration] about light and how they measured distances. (MOS exit interview)

B17: Looking at the different nebulae through the different wavelengths. (MCFTA exit interview)

There were some other levels of perception that are not seen by the human eye; I wasn't aware of all of that. (MCFTA exit interview)

Telescopes

Many visitors commented on the Hubble telescope, the Chandra mission, and the Hawaii observatories when talking about what they had learned.

I would say some of the different projects going on with the Hubble telescope with the X-ray telescope and the map. It was all grouped together with the

> Hubble—some kind of project that took pictures with the universe. That was interesting. (MOS exit interview)

> The Chandra stuff. I didn't realize that was up yet. (MOS exit interview)

> One thing I learned is there's another telescope going up in 2010. (MCFTA exit interview)

> I haven't been familiar with what NASA is doing when it comes to observing the universe, all their satellites . . . It's amazing. They are very sophisticated. That they only use a small amount of energy to power Chandra. (MCFTA exit interview)

Some visitors also talked about space exploration and expressed an interest in what scientists will discover next.

> A lot of visual aids and explanations, like the observatories, which I think gives a lot of visual impression to what your thoughts are [that was new]. There's so much more being developed every day, it's hard to keep up with it all. (MCFTA exit interview)

> I also didn't know that they have the Hawaiian observatory; I didn't even know that existed. That was really fascinating. (MOS exit interview)

Big Bang, Einstein's Theory, and the History of the Universe

As noted earlier, there were differences in the physical set-up and pathways through the exhibition at the two museums. Therefore, some components that were placed in a high-traffic area at the MOS were in a less conspicuous location at the MCFTA. For example, the *Cosmic Calendar*- and *Big Bang*-related components were in the center of the main exhibit gallery at the MOS. At the MCFTA, these components were located in a smaller and darker room, off the main gallery. The *Big Bang* and the *Expanding Universe* were cited as areas of learning by many more visitors at the MOS than at the MCFTA.

> G10: I liked the *Big Bang* and the Albert Einstein part because it shows how space stretches throughout time. (MOS exit interview)

> It's an expanding universe, isn't it? I knew that before, but I'd forgotten. (MOS exit interview)

> I picked up how they know there was a big bang because they found galaxies speeding away and light without a source. (MOS exit interview)

> The explanation of the big bang theory . . . I knew about the big bang, but I didn't know about the theories connected to it. (MCFTA exit interview)

> [I didn't know] that theory that the universe is expanding out, instead of going together. (MCFTA exit interview)

Boston visitors also talked about what they learned from the *Cosmic Calendar.*

> Scale of the life of the universe. How we fit into that. December [on the *Calendar* display]. (MOS exit interview)

> The length of time it's taken for the whole thing . . . that was interesting. (MOS exit interview)

> It was neat to see the chemicals: carbon, gold from the stars. (MOS exit interview)

Alien Life

Although visitors at the MCFTA indicated an interest in the possibility of other life forms in the universe, they did not cite *Alien Life* as an area of new learning, while many visitors at the MOS did.

> I'm really into the universe, so I've seen every angle, but I hadn't seen much on life on other planets. That was new to me. (MOS exit interview)

> I didn't realize that scientists had actually discovered in recent years that there are other solar systems besides our own. I don't know if solar systems are the right term, that they might support life, that they had evidence of it. (MOS exit interview)

General New Learning

Finally, a large number of visitors said they had learned something new without providing specific in-depth information.

> I probably did, but everything was just kind of flashing. It is very attractively set up, user-friendly. (MOS exit interview)

> G16: I haven't learned any of this stuff in a long time. (MOS exit interview)

> Actually, there was a lot that was new to me, but I can't be specific. (MCFTA exit interview)

> All of it was kind of new. It's been a while since I've been out of school . . . It's a refresher course. (MCFTA exit interview)

No New Learning

Most of those who said they didn't learning something new from the exhibition cited their amateur or professional involvement with the topics, recent schooling, or a recent visit to a similar exhibition as reasons. However, other visitors with similar backgrounds did identify new learning within *CQ*.

> Not really. I have always been interested in astronomy. It's almost a hobby. (MOS exit interview)

> I knew most of it. I read a lot. I watch a lot of science channels. (MOS exit interview)

> Pretty much most of the stuff I know already; but then again, what I do is selling astronomy software. So it is my background. (MOS exit interview)

> B15: It's not really a whole lot new. I've had a lot in school. It's more fun than in school. (MCFTA exit interview)

> We saw it in Chicago already. (MCFTA exit interview)

QUESTIONS RAISED BY THE EXHIBITION

On The Day Of Viewing

> B13: It makes you wonder; yes, it did. (MCFTA exit interview)

The *Cosmic Questions* exhibition raised new questions for many visitors or stimulated them to think about their existing questions. At the Museum of Science, 56% of those interviewed reported leaving with questions. At the Midland Center for the Arts, 68% said they left wondering about topics related to the exhibition. Thirty-two percent of visitors in Boston and 13% of visitors in Midland said that they were not leaving with questions. (12% of those interviewed in Boston and 19% in Midland had no response.)

The tables below show the relative frequency of the types of questions reported by visitors. This data is influenced by two factors. First, many visitor questions fell into overlapping categories as classified by the evaluators; second, it was not always apparent when the visitor was asking a new question or identifying a pre-existing question that had been "triggered" by *CQ*. We have separated these questions in the tables according to our best understanding of that distinction, but will integrate the types of visitor questions in our discussion below.

Types of new questions provoked by *CQ*, in order of frequency:

Table 7
New Questions Provoked by *CQ*

MOS	MCFTA
Alien life	Alien life
What's out there	Religious/spiritual
Religious/spiritual	Before the BB/what started universe
Before the BB/what started universe	Expanding universe/ Einstein's theory
Technology used to explore space	Stars/what's out there
Big bang	Technology used to explore space
Size/vastness of space	Black holes
Black holes	Size of universe
Expanding universe/Einstein's theory	Age of the universe
End of the universe/what's beyond	

Types of pre-existing questions of *CQ* visitors, in order of frequency:

Table 8
Pre-Existing Questions of *CQ* Visitors

MOS	MCFTA
Alien life	Alien life
Before the BB/what started universe	Before the BB/what started universe
What's out there	Space exploration and technology
Size/vastness of space	What's out there
Technology used to explore space	Black holes
Big bang	Stars
Spiritual questions	Size of the universe
End of the universe/what's beyond	Spiritual questions
End of universe in time	
Black holes	
Space and time	
Expanding universe	

Alien Life

Visitors at both museums wondered most often about the existence of other life in the universe. While for most it remained an open question, some seemed certain of the

existence of other life forms somewhere in the universe, wondering only about their nature.

> Are we alone in the universe? I liked that. I think it's an interesting question. (MCFTA exit interview)

> You wonder about extraterrestrial life. There's no way to answer that. Usually when you come across a space exhibit, that's something that you think about. (MOS exit interview)

> I like the pictures of the [alien] worlds . . . (MOS interactive observation)

> Are we alone in the universe? Is there any evidence at all that there is other life? And I'm just wondering about the steps that have been taken so far in science towards researching that. (MOS exit interview)

> I guess my questions now are more, I feel certain that there are other planets out there that have life on them. Are there people on them? And what is their life like and what do they do? And what else are we going to learn through all of the observation going on now? (MOS exit interview)

> TV says aliens have been captured. I want to know if that's true. (MCFTA exit interview)

For some, questions about other life in the universe were closely related to spiritual and religious topics.

> What role do we play here? It's very clear that we can't be the only thinking creatures in this universe; there have to be others. How do they react in their thinking? Are we the only ones given free will by God, or not? Of course that causes all the problems. Is God experimenting with us? (MCFTA exit interview)

Stars, Galaxies, Planets/ "What's Out There"/Vastness of Space

Stars, galaxies, planets, and a general interest in "what's out there" formed the basis for many visitors' unanswered questions. Some questions were short and very specific.

> They say our sun is a small star. What is a big star? (MOS exit interview)

> I wanted to know, were there just stars in certain places. (MOS exit interview)

> The stars die. What is the temperature when they start dying? (MOS exit interview)

> I'd love more information on what we do know about planets in other solar systems. (MCFTA exit interview)

> B9: How many stars are in the galaxy? (MCFTA exit interview)

> B10: [I want to know] how the great red spot on Jupiter got there. How it is; is it dangerous to go in and see? (MCFTA exit interview)

Other respondents left with more complex questions.

> Are there other planets like ours? Is there another galaxy similar to ours? If there are other galaxies, what are they like? I hadn't previously thought about them in depth. (MOS exit interview)

> What's the speed of gravity? Like if you have the Earth orbiting the sun, and the sun suddenly disappeared, does the Earth fly off immediately or after 8 1/2 minutes? (MOS exit interview)

The exhibition prompted many visitors to wonder about the size and vastness of the universe.

> G17: I don't really like to think about it because it's so big it makes you crazy, how large it is. Numbers like 12 billion light years are off-putting because you have no way of understanding how far that is. (MOS exit interview)

> I always wondered how large the universe was . . . You look at the stars and you see the black and the lighted stars and you wonder what's behind that. (MOS exit interview)

> G8: I just was wondering if there are huge galaxies that are billions and billions of light years away. (MCFTA exit interview)

Others expressed a more general curiosity about the universe.

> What's beyond the universe? (MOS exit interview)

> I always wonder what's out there. (MCFTA exit interview)

Several visitors had questions about the future, in particular, of our sun.

> G8: I wonder if the sun will ever explode. (MCFTA exit interview)

> B8: What will happen after the sun turns into a supernova? (MCFTA exit interview)

Religious/Spiritual Questions

Many visitors were inspired by the exhibition to think about religious or spiritual questions. In addition to specific religiously-based topics, questions included

philosophical issues such as the reason for and purpose of human life, as well as musings about the universe as a whole.

> Why are we here? (MOS exit interview)

> The questions I have are more philosophical. How did this all get here? And what are we supposed to do now that we are here? Things that don't have easy answers. (MOS exit interview)

> If you can think of the universe as a person, it may be something that is also trying to exist on its own. Its body undergoes these changes . . . Does the universe have a mind? If the universe is some sort of a person, is there another universe with a different set of factors? What's the bigger concept? (MCFTA exit interview)

Some visitors saw the universe as evidence for and proof of the existence of God.

> You could say that someone or something started it. The universe keeps expanding and we're still safe. (MOS interactive observation)

Especially in Midland, where the *Where Do We Fit In*? video was seen by more visitors than at the MOS, respondents were spurred to consider many larger issues while watching the video interviews. Visitors were stimulated while listening to the interviewees answer questions such as: *Was the universe designed for us? What's the relationship between faith and science? What about God? Where do you find meaning?*

> The video interviews were a nice introduction to the exhibit because it asked the questions that you yourself have asked. (MCFTA exit interview)

> The type of questions that were asked in the video interviews . . . It makes you ask those questions. From the back of your mind, maybe you've asked those questions before, but you haven't really thought about them until you [see the video]. (MCFTA exit interview)

Others had specific questions about religious topics, like the existence of a "greater power," what will be left after the "millennium" comes, the relationship of the *Cosmic Kitchen* story of the beginnings of the universe to the Bible, and questions about God-given human traits.

> Is there a greater power out there that governs this? (MOS exit interview)

> I am wondering how it is all going to come together when it is the Millennium . . . When it all comes together, how it is really going to end, and what is going to be left? (MOS exit interview)

> I wondered about the *Cosmic Kitchen* and how that relates to the Bible. I wondered what my pastor would say, how you can have both, dual beliefs, how you can make both things work for you. (MCFTA exit interview)

One visitor, originally from Britain, spoke about conversations indicating that *CQ* had prompted some in Midland to question theories about creation.

> Midland is a fairly small town. There are a lot of churches. While at the exhibit, I could hear people questioning the story of Genesis vs. the exhibit which presents the universe unfolding in terms of billions of years . . . They were questioning some of the theories. I wanted to pass that along. I've had discussions with people at work [from Britain] . . . So the exhibit did get these people thinking. (MCFTA phone interview)

The Big Bang and Before/Expanding Universe/Einstein

A number of visitors left the exhibition wondering about the origins of the universe and what happened before the big bang. For several, these were familiar questions.

> The creation of the universe—How did it all begin so long ago? Not a new question, but the exhibit inspires that. (MOS exit interview)

> Well, before we were here is my question . . . Is everything dark or is there other life that anybody knows? (MOS exit interview)

> I am still asking what was before the big bang. (MOS exit interview)

> What really started the universe? (MCFTA exit interview)

The big bang-related components of the exhibition prompted some general questions about that phenomenon.

> I just wanted to know what created the big bang. (MOS exit interview)

> M10: Was there a big bang? What are all the details of it? (MCFTA exit interview)

> I don't fully comprehend the big bang and all that. (MCFTA exit interview)

Visitors also left wondering about the expanding universe, Einstein's space-time theory, and Einstein himself.

> It makes me think more about the whole concept of Einstein's space-time and seeing it as a 3-dimensional model. I'd be more interested to read about that in the future. (MOS exit interview)

> Why is the cosmos still expanding? Where's it going to go? (MOS exit interview)

> Will the universe expand forever or will it collapse in on us? I think they think it will expand forever. (MOS exit interview)

> I keep wondering how Einstein got his ideas. (MCFTA exit interview)

The End of the Universe and Time

A number of visitors wondered about the end of the universe, often in terms of time.

> If it all had a beginning, then it all must have an end. I hadn't thought of that. It's all gone on for 18 billion years. Will it go on for another 40 billion? (MOS exit interview)

> I have trouble comprehending that something can't end, even though I understand infinity. It is one thing to have a number that goes on and on, but it is another thing with three-dimensional space. (MOS exit interview)

> G8: I'd kind of like to know if the universe would ever end. (MCFTA exit interview)

Time was also a topic of interest to other visitors.

> Is time, can you call it some sort of traveling in circles? Can you go back in time, change the future? What happens to time and space in a black hole or after a black hole? (MCFTA exit interview)

> What happens at the end? You die? What does time do? (MOS interactive observation)

Black Holes

Black holes were of interest to many visitors, and the exhibition prompted a number of questions.

> It didn't explain black holes very thoroughly. I want to know if things are sucked in, where do they go? (MOS exit interview)

> Since the black hole is following matter, when will the black hole stop doing this? Will the black hole stop swallowing matter? What is the life span of a black hole? What will happen? Maybe someone knows this, but I didn't see it in there. (MOS exit interview)

> B13: What's on the other side of a black hole? That's a new question, I don't really think about the universe. (MCFTA exit interview)

> G13: I was wondering who thought up the idea of black holes, where Einstein got the idea. (MCFTA exit interview)

Telescopes, Observatories, and Other Technology

Many visitors were also left with questions relating to the telescopes, observatories, and other technology portrayed in *CQ*.

> What else are we going to learn through all of the observation going on now? What are we going to learn from that? (MOS exit interview)

> It was neat to see the exhibit about Hawaii. I looked at those men. How does anyone want to be one of those people? It's scary. It could blow up. (MOS exit interview)

> The Hubble deep space image, the big, wide shot of galaxies in one photo—how long did they have to expose the image? Have they ever tried to see past that distance, great as it is? (MOS exit interview)

> [I wonder] if there are any more telescopes out there. We know of Hubble; now we've seen this display on Chandra. (MCFTA exit interview)

> G13: I like the technology. I want to learn more about the technology they use in space. (MCFTA exit interview)

No Questions

Many of those who stated that they were not leaving the exhibition with questions gave particular explanations for their responses. Some realized that they needed more time to assimilate their experience.

> Actually, I didn't have much time to think about new questions. (MOS exit interview)

> No new questions yet. We haven't had a chance to absorb the information. (MOS exit interview)

Others were simply overwhelmed by *CQ*, and some found the topic hard to understand.

> It's really overwhelming. (MOS exit interview)

> To be honest, it's so far beyond me . . . when you don't understand things, you can't come up with intelligent questions. (MCFTA exit interview)

Some found it difficult to have questions that they knew were unanswerable.

> It's difficult for me to have any questions. A lot of theories are unfinished. The answers have not been found. (MCFTA exit interview)

A number were parents who were busy following children around.

> I don't get to read the stuff . . . I'm following them. (MCFTA exit interview)

Finally, some simply were not interested in the topic.

> I'm not really interested in it. It doesn't interest me at all. (MOS exit interview)

> No [questions]. I'm just doing a general visit . . . I have different interests. (MOS exit interview)

Lingering Questions

> Since I saw that exhibit, I've been more curious to read more about that subject. (MOS phone interview)

3-7 Days Later—Museum of Science

At the Museum of Science in Boston, where 23 visitors were interviewed by phone 3–7 days after viewing the exhibition, over two-thirds of respondents reported wondering about some type of "cosmic question" since seeing the exhibition. *CQ* prompted many visitors to think about topics they had wondered about before, and for some it created new queries. Topics referred to most often were:

- **The big bang and before the big bang**

  > [A pre-existing question is] whether or not the big bang actually happened, how it was possible, how life developed. We talked about everything, every end of the spectrum, when we'd go to each exhibit, we'd discuss it. (MOS phone interview)

- **Religion and the creation of the universe**

  > God creating the world versus the scientific side of it. (MOS phone interview)

- **Questions relating to time**

  > When I've talked to astronomers before, they tell you that when you work in astronomy, you have to develop a different concept of time. The 24-hour clock is a totally different sense of time than when you look at a galaxy billions of light years away. You have to do some kind of switch. [That's what I've been wondering about since seeing the exhibit.] (MOS phone interview)

- **Alien life**

> Most of the questions had to do with, is there life out there? That, of course, is still a question. I've just had to think about that for a while. (MOS phone interview)

- **The exploration of space**

> What is the next step in terms of exploration? I know right now there's a limit to the information we can get, but what could we still find out through travel or satellites going further out? (MOS phone interview)

- **Other types of questions**

Other visitors wondered about infrared light; planets and what they looked like in earlier time periods; our place in the universe; the evolution of planets and humans; the possible creation of other universes; and the use of wavelengths to observe the universe.

> I wonder a little more about whether there are other universes being created at the moment. What's to stop us from thinking it could be happening in other places? (MOS phone interview)

> I found myself wondering about the make-up of a lot of the planets, and about what they might have looked like at another point in time. (MOS phone interview)

> To some extent, it's the topic of what is observable and what is not, and how you can use indirect evidence to figure out what exists. It was from the area with the different wavelengths. Certain things cannot be observed directly. I was thinking about that. (MOS phone interview)

- **No questions**

A few of those visitors who had no questions shared comments. One respondent talked about being preoccupied with his own life. Another wondered if she might have questions if she saw *CQ* again.

> Honestly, no real questions in mind. I've been bogged down with my own personal day-to-day stuff. (MOS phone interview)

> No, not right now. Maybe if I went back. (MOS phone interview)

3–7 Days Later—Midland Center for the Arts

At the Midland Center for the Arts, 12 visitors were interviewed by phone 3–7 days after seeing the exhibition. Unlike in Boston, less than one-fifth of these visitors had questions remaining from their visit to *CQ*. The topics included:

- **Religion**

> I go back to the concept of a creator. It's not hard for me to imagine God could create the Earth and the people in it and the universe. But when you think of the galaxies and the amount of matter and energy, it's staggering and awe-inspiring to think that what's out there was created. What kind of a creator could do that?
> (MCFTA phone interview)

- **Other planets like ours**

> I guess I have more of the sorts of questions that the scientists are having, such as, are there other planets out there more like ours? And what might the ramifications of that be? (MCFTA phone interview)

- **Dark energy/fossils/big bang**

> B10: Things like exactly what is dark energy, and exactly what were the fossils that people found in the timeline . . . and what they found out about that, and what caused the big bang.
> (MCFTA phone interview)

- **No questions**

Of those who reported having no questions spurred by *CQ*, some gave explanations. One visitor stated that it "reinforced" the knowledge and attitudes he brought to the exhibition, while a second respondent thought that his Christian perspective predetermined his beliefs. Another visitor said that she went through with a child and didn't look closely for herself, and one respondent said that she doesn't typically ask questions of a "cosmic" nature.

> No, nothing new. I guess it just kind of reinforced my opinions and feelings about it. (MCFTA phone interview)

> No, not specific questions . . . basically all my beliefs in that come from my Christian perspective, and I enjoyed looking at pictures of awesome creations. (MCFTA phone interview)

> [No] I was there with my grandson so I was just casually perusing the exhibit. I didn't spend enough time. There is a lot there and you need to spend a lot of time to get the full picture . . . I feel like I skimmed over the surface as I walked through. (MCFTA phone interview)

> I'm not really much of a cosmic-question-type person.
> (MCFTA phone interview)

6-9 Weeks Later—Museum of Science

Eighteen out of 23 visitors who were called 6–9 weeks after their museum visit in Boston had clear memories of the exhibition; of these, two-thirds indicated that they had wondered about topics related to the universe since seeing *CQ*. It was not clear which topics and questions were specifically related to seeing *CQ*, but at least a third of respondents' queries were definitely motivated by their experiences in the exhibition, and many of the others were at least influenced by *CQ*. Visitors wondered about topics such as:

- **Philosophical issues**

> [*CQ*] posed a lot of philosophical issues I was debating with a friend. What I brought home was questioning the premise of the big bang theory . . . It sort of sparked me. After seeing that exhibit, it made me ask more questions about what the universe really is, the meaning of it, the theory of it. It brought out more questions, it didn't really answer too much. I liked it. I wanted to see it again, but it had left.
> (MOS phone interview)

- **Religion**

> I teach religion. I am not a fundamentalist and I do believe in evolution. It has been a big thing we have talked about in our religious community, how to do a more cosmic approach to religion.
> (MOS phone interview)

- **Personal relationship to the universe**

> It brought up a few questions and I'm still curious about them. I thought it did a good job in making you think about man's place in this universe. (MOS phone interview)

- **Black holes**

> I have a particular curiosity with the physics and the gravitation of black holes, whether or not the universe can be thought of as us being on the inside of an enormous singularity or a singularity that we can't see the edge of. (MOS phone interview)

- **Big bang and the expanding universe**

> Related to God and the creation of the universe—as the universe expands, there's still gravitational force. Will the universe collapse and there will be another big bang? Maybe it's a process that happens

over and over again . . . I wonder if that's the heartbeat of God?
(MOS phone interview)

- **The earth's future**

  Will Earth slow down enough to pull us into the mass of the sun, or will the sun reduce its mass significantly enough to throw us out of orbit into space? (MOS phone interview)

- **The space program**

  I'm wondering how much more we can explore with the space program being cut back. (MOS phone interview)

MOS Visitor General Curiosity About "Cosmic" Topics

These visitors were also asked if they "tend to think about issues related to space and the universe" on a daily basis. Approximately half stated that they do, while about a quarter said that they think about these issues at times, and another quarter not at all. Those who think about these issues frequently often read magazine articles, talk with their children about the topic, like to watch the night sky, and think about it in relation to God and religion. For those who think about these issues less often, the topic is triggered by "prompts" like the *CQ* exhibition, looking at the night sky, and readings.

When you're in day-to-day [life], you don't focus on larger issues, but when you see an exhibit like that, it really makes you think about things.
(MOS phone interview)

I do. It's hard not to when you look at the stars. You always wonder.
(MOS phone interview)

The older I get, the more I want to know about possible close calls and what else is out there. (MOS phone interview)

[I think about] the vastness of it, how we fit in with it all. I think it leads to a deeper understanding of religion. (MOS phone interview)

A couple times a week, at least, I keep up with the current topics. I am interested in space exploration and different satellites that are currently out there gathering information and plans to go to Mars at some point.
(MOS phone interview)

It is an area that I have always been interested in. By trade I am a biochemist, so I am interested in stuff normal people don't think about, like when they come back from outer space, do they bring microbes with them?
(MOS phone interview)

6–9 Weeks Later—Midland Center for the Arts

When visitors to the Midland Center for the Arts were interviewed 6–9 weeks later, they still reported fewer lingering questions than MOS visitors. Only 38% indicated that they had lingering questions from their visit, and for many, these questions were very vague.

> Well, yes, I think so. I think we always do discuss it; it stimulated our curiosity. (MCFTA phone interview)

> That's a really good question. Nothing pops to the top of my mind, but I know [my family has] talked about it. (MCFTA phone interview)

A few visitors did report specific questions resulting from their visit to *CQ*. One person wondered about what will be seen when the technology exists to look back beyond 12 billion years, and also what new principles of physics will result from this technology. The exhibition made another person wonder about the future.

> I've always had questions about what they're going to see when they can look farther back. The Hubble can see back about 12 billion years, and the big bang happened about 15 billion years ago, so my question is, what will they see when they look back even farther? The other question is, what new laws of physics will we come up with based on what's out there because our interpretation of things is always changing based on what we're looking at out there? (MCFTA phone interview)

> To a certain degree, yes. The exhibit is thought provoking. It allows one to conceptualize what may occur in the future beyond our lifetime. (MCFTA phone interview)

MCFTA General Curiosity About "Cosmic" Topics

These visitors were also asked if they think about issues related to space and the universe in their daily lives. Half responded that they think about these issues frequently. Several of these visitors referred to religion in their responses.

> Usually in a religious context If there's life out there, what are the religious implications? We believe God is out there. (MCFTA phone interview)

> [I often think] a lot about experiments they're doing on the space lab and the space station and the new things we're learning that do affect us day-to-day—new materials, crystals, medicines. To me there's a huge benefit in terms of everyday-life in terms of innovations . . . Every once in a while I think about religious questions and speculations about how we came to be, stuff like that. (MCFTA phone interview)

> I sort of just read the headlines that I get on Google's news section . . . If there are articles that appeal to me I'll read them, like the progress of the space shuttle or the upcoming Mars explorer adventures . . . I'm not into

> astronomy per se. The only stars I know are the Big Dipper and the Northern Star. (MCFTA phone interview)

D: CHANGES IN MENTAL PICTURE

3–7 DAYS LATER

> That's one thing that changed, my realization that there's a whole lot more than you actually see with the naked eye. (MOS phone interview)

Visitors from both museums were called 3–7 days or 6–9 weeks after their visit to *CQ* and asked if their mental picture of the universe had changed as a result of viewing the exhibition. Of those queried within a week of their visit, approximately half from both museums stated that their mental picture of the universe had changed. Their comments fell into the following categories:

- **Vastness of the universe**

> I think what really hit home for me was the whole thing with the light waves and how little we actually see that's out there. (MOS phone interview)

> I think it gave me a broader feel for what is out there, which in turn makes you think about what more is out there that hasn't even been discovered yet. (MCFTA phone interview)

- **Existence of dark matter and black holes**

> I guess the thing that changed was prompted by the discussion of the kinds of matter that can't currently be described. My mental picture before that was that everything consists of matter that can be described. (MOS phone interview)

> I used to think a black hole was one-dimensional, like a circle. But I learned that it's a sphere. I learned about dark energy. I had no idea that it existed. (MCFTA phone interview)

- **Possibility of alien life**

> I remember seeing a strand of DNA that was interwoven with the boundary of the solar system. I never really thought of the possibility of any form of life beyond Earth and the solar system, or as likely. (MOS phone interview)

- **Warmth of universe**

  I always thought of it being cold, individual light or stars, just in terms of the coldness of it. But it was interesting to me how they explained the gasses and the heating of each of the elements.
  (MOS phone interview)

- **Shape of universe**

  Now I think [of the universe] as more of a top, because of that bronze thing that you could feel in the beginning of the exhibit.
  (MOS phone interview)

- **New images of the universe**

  I have added new pictures. There were things I had never seen before . . . a picture of a spiral galaxy, and I had never seen that before. It was a very cool shape. (MOS phone interview)

  I am really left after having gone to the exhibit with this one particular picture that I saw over and over again in a few places, of all the swirling galaxies . . . So now in my mind that is what I picture.
  (MCFTA phone interview)

- **Expanding space**

  I saw the part where Einstein was talking . . . and he was explaining how the universe was expanding. That gave me a new perspective, but I can't explain it. (MOS phone interview)

- **More reality**

  It put more of a real spin on it. Before, a lot came from movies and entertainment. So seeing Chandra and learning about different telescopes and discoveries made through time, I feel better informed . . . [Now my mental image] is not just fantasy, it's not just science fiction. (MOS phone interview)

6–9 WEEKS LATER

It's not a neat little box anymore. (MOS phone interview)

Almost one-half of visitors from both Boston and Midland who were interviewed 6–9 weeks after seeing *CQ* also reported that their mental picture of the universe underwent changes as a result of their experiences there. Their comments included the following:

- **New images of the universe**

  I had a little clearer picture of what it looked like, the make-up of [the universe]. (MOS phone interview)

  I was able to see what the planets looked like a lot better. Now I know what they look like and I know a little bit about them. (MOS phone interview)

  I think it broadened my mind to the tangibility there are other solar systems in the galaxy. (MCFTA phone interview)

- **Vastness of the universe**

  It reinforced the fact that things are far apart from each other because there are things that gave proportions. It made you think how far away everything is. Students sometimes ask, "Do you think someday when I am still alive will they be going to the stars?" I think, well, maybe planets, but stars are far away. (MOS phone interview)

  I think looking at the exhibit gave you an idea of where you are in the universe. It also showed how big it is and how much more there is to do, and how we're just studying a little bit of it. (MCFTA phone interview)

- **Complexity of the universe**

  I've just come to the realization [the universe] is much more complex [than I had thought]. (MCFTA phone interview)

- **Possibilities of alien life**

  It gets you thinking there could be life out there. (MOS phone interview)

- **Expanding space**

  [Before seeing the exhibit] I just thought of it as expanding space. Now's there's a theory . . . It's sort of like an expanding balloon, and you're an ant on the balloon, and there's no epicenter of the big bang. One of the questions I had, if there was a big bang, you could find out where the epicenter was. But the analogy was if you were an ant on a balloon, there is no epicenter, everything would just be moving away from you. (MOS phone interview)

- **Relationship of universe to everyday life**

  When they showed the apple pie baking, rays of light were cooking it. It shows that everyday life has something to do with the universe. (MOS phone interview)

NO CHANGES IN MENTAL PICTURE

A minority of respondents to the short and long-term follow-up interviews who reported that their picture of the universe had not changed gave explanations with their answers. These visitors cited a reinforcement of their existing beliefs, significant prior knowledge about the topics covered in the exhibition, and a preoccupation with children or grandchildren during their time at *CQ*.

> [My mental image] was more confirmed and strengthened. You could see the vastness of multiple universes or galaxies. That fits with what I've learned from religion. Of course we're all looking for confirmation of our beliefs. (MCFTA long-term phone interview)

> I thought it was interesting, but I've run across most of the information there at various times before. (MOS long term phone interview)

> Not really with two small children. If I was on my own, it might be different. (MOS short term phone interview)

E: PERSONAL, RELIGIOUS, AND SPIRITUAL REFLECTIONS ON *CQ*

PERSONAL RELATIONSHIP TO THE UNIVERSE

On their way out of the exhibition, visitors were asked, "Did [*CQ*] help you to think about your relationship to the universe?" The majority of respondents answered in the affirmative—60% in Boston and 64% in Midland. In Boston, 26% of those interviewed reported that *CQ* did not help them to think about their relationship to the universe, while 15% from Midland said that it did not. (14% of those in Boston and 21% of those in Midland did not answer this question.)

Visitors at both sites frequently spoke of feeling small in relation to the universe, both in terms of size and time, as a result of experiencing the *Cosmic Questions* exhibition.

> We are truly insignificant except through our own identity and ego. We are a speck of dust. (MOS exit interview)

> It makes you feel quite humble when you consider the sheer size. Earth's place in the Milky Way. You realize you're a tiny part of the Milky Way. The Milky Way is a small part of the universe. It's hard to put into words. The more you think about it the smaller you feel. (MOS exit interview)

> It made me think that time is very relative. We're here such a short time we have to make the best of our time. (MOS exit interview)

> When you look at it, it makes you feel pretty insignificant. Like it said, the sun will burn out in a billion years and that's one of a million suns. It makes you wonder why you have to do your homework at all.
> (MCFTA exit interview)

> G10: It made me feel really tiny. Because there are billions and billions of light years, and I'm a little speck in the world, let alone in the universe.
> (MCFTA exit interview)

While many visitor comments about the small size of humans in relation to the universe had a negative connotation, many others were positive. Some referred to the helpfulness of putting human concerns in a much larger perspective, or the importance of humanity. Many visitors spoke about feeling part of something bigger than themselves, often in conjunction with comments about feeling small.

> It's reassuring. I feel very small, but I also feel like we're an integral part of all this. I'm tired of hearing that we're the superpower of the world. We're not, but we have a place here. (MOS exit interview)

> Understanding how much of a past we have behind us puts more weight on the possible futures . . . And if we can make decisions that can affect the whole universe . . . it puts more responsibility on our decisions because we are affecting not only ourselves but something that was before us.
> (MOS exit interview)

> Not really so much my place, but maybe the whole role of the human race as a body of people . . . when I think about space, I imagine an entire planet rather than just myself. (MOS exit interview)

> It's just a sense of awe in being part of it. We're just a speck of it but we're an important speck and we're part of all of it. (MCFTA exit interview)

> When you think about the universe, you think about the tiny piece everyone is. But we're all connected, too, like the hydrogen we're made up of was created billions of years ago. When the Native Americans talked about how everything is part of everything, they had it right. When you think about space and the universe, that really rings true. (MCFTA exit interview)

> F8: It makes you feel like you're in a safe place and you're protected.
> (MCFTA exit interview)

Several visitors at both locations also talked about God, religion, and large philosophical issues when describing their personal relationship to the universe.

> When I think about the universe I think about God. We are one of God's creatures. (MOS exit interview)

> I didn't sit in very long, but I did see the one section of the exhibit with the mini-theatre about, "Is the universe speaking to us or with us?" What sort of message am I supposed to be carrying out as my place in the universe? Are we doing the right things as a human species to sustain our way of life, and what could be changed? (MOS exit interview)

> [It makes me think about] where we fit in to all of this. That God allows us to be a part of this, I think it's awesome. (MCFTA exit interview)

Visitors also commented on the implications of being made from the same elements as stars.

> I think the most interesting part was to show that all the elements come from stars. Interesting because you don't think of being made of material that has this huge history. That was the biggest cool thing for me. It is humbling in a way. The atoms have been in a million things before and will be in a million things after. It's not something you usually think about. (MOS exit interview)

> G13: I thought it was interesting in the movie, they talked about stars giving birth and what we're made of . . . and that hit me. We're made of the same thing as stars. I thought that was interesting because you never would think that. (MCFTA exit interview)

Others spoke of space travel and space exploration as they thought about their personal relationship to the universe.

> We should be exploring the universe because the Earth is getting crowded. We should be looking, in general. There is limited resources on Earth and we should plan ahead. (MOS exit interview)

> B10: It's kind of hard to explain, because I know lots of stuff about space. I was thinking about me becoming an astronaut when I'm older and going out into space and exploring Jupiter because that's my planet. (MCFTA exit interview)

Visitors at MOS also reported that *CQ* made them think about their relationship to the universe in terms of possibilities and hopes for other life in the cosmos.

> I thought about someone in another galaxy at a museum thinking about us, doing the exact same thing in a parallel universe. (MOS exit interview)

> It just came to my mind what I had heard, that it would be too sad if we were the only ones out there in this huge space. (MOS exit interview)

Several of those who reported that the exhibition had not prompted them to think more about their personal relationship to the universe, referred to their belief that such a

relationship is not possible. Some discussed their feelings about the overwhelming size of the universe, our inability to see more of it, or the inertness of the universe.

> G10: There is, like, a never-ending universe and I don't even think of myself as part of it really because first you think of humans, then planets, then stars, and it is hard to imagine all that is happening around you. (MOS exit interview)

> I don't think I have [a place] in the universe. It's too big. (MCFTA exit interview)

> B15: I don't think there really is a whole lot of relationship yet, because we can't do anything except observe. If we could travel faster than light, we could see some of the galaxies. (MCFTA exit interview)

> I'm not sure . . . We live in it, but I'm not sure I have a personal relationship with it. It's not a living thing. (MCFTA exit interview)

Another visitor felt that it required a particular type of person to be philosophical.

> No, not really. I don't know that I'm the right person to ask that question of. I'm not a philosopher. I'm a fact-finder. (MOS exit interview)

Finally, one visitor verbalized a need for more time to digest the experience of the exhibition.

> No, [no thoughts on that topic] yet. Maybe I will driving home. (MOS exit interview)

RELIGIOUS/SPIRITUAL COMMENTS

About 10% of MOS visitors and almost one-quarter of visitors in the MCFTA exit interviews discussed their belief in God or a higher power. The majority of these respondents were comfortable with the exhibition and did not express major conflicts between science and religion, including those who identified themselves as creationists. However, a number did share questions that the exhibition prompted for them.

> If you accept on faith, in the beginning . . . God created the heavens and the Earth, how much clearer can that be? It had to start sometime, but that does not preclude the evolution, which is so beautifully demonstrated in your exhibit. (MOS exit interview)

> I believe in the theory of the Earth being created by God, and I believe in science, and it's possible to believe in both. It's interesting to tie them together. (MCFTA exit interview)

> I believe in creationism. To imagine that God created all this, and has from infinity on out, I think it's just awesome. (MCFTA exit interview)

Several visitors wondered about the intersection between religious and scientific theories related to the creation of the universe.

> Where would I be if there wasn't a universe? If there really was a big bang or a supreme being—which theory is right? Kind of makes you wonder. Did God really make heaven and earth? (MOS exit interview)

> I kind of struggle. If you read the Bible and you come to one of these things, I tend to go with the simplistic Bible view. I'm comfortable with that rather than trying to get into the whole science thing. (MCFTA exit interview)

> I want to know how it started and if its tied into the concept of creator, and how it is, not from a religious but from a more spiritual perspective. (MCFTA exit interview)

One visitor discussed how he reconciled his religious faith with scientific theories during a follow-up phone interview.

> One thing I could tell you, I'm a Christian, and I have my views in relation to that. I don't personally have a conflict with the theories, but I go with a personal creator and not an accidental creation. I don't have a problem with big bang, but I believe in a pretty literal interpretation in Genesis, but I don't necessarily think the seven days was literal. I'm not well-enough informed in physics to reconcile seven days with literal interpretation. It doesn't make a lot of difference to me personally. (MCFTA phone interview)

A few respondents talked about how their faith gave them a sense of security and control in the face of a vast universe. Others saw evidence of God's power in the information and images of the universe, including the Hubble pictures that were not shown in Boston.

> It made me feel really glad there is a God to make sense of all of this. Otherwise it would be scary if there wasn't a higher power in control. (MOS exit interview)

> Pulling back from Washington, there's so much out there, and it's so pretty and intricate and big. It made me think about the power of God. (MOS exit interview)

> [I am in] awe that God can create such a magnificent universe. (MCFTA exit interview)

> I'm speechless . . . I believe in God. I believe God put all this here. I see the beauty of what he or she did. I don't try to understand it, but you see what's here. It's like magic. (MCFTA exit interview)

> I guess that God thought so highly of us, that he placed so much emphasis on us. (MCFTA exit interview)

Some visitors reported that they disagreed with some of the concepts presented in *Cosmic Questions*, which conflicted with their religious beliefs.

> G16: I don't agree with a lot of the stuff. I'm a Christian. I don't really agree with the stuff in a year [timeline]. I wonder how they came up with it . . . (MOS exit interview)

> Maybe there was a big bang, maybe there was creation. I hope so [that there was creation], so I whizzed by that. (MOS exit interview)

> I don't really believe in it. We're here to look at a Christian college. (MOS interactive observation)

> Most of it I didn't like because it's evolution and I'm a creationist all the way. Some of it was pathetic . . . I just think they shouldn't teach evolution or the big bang when they don't have solid evidence for it. (MCFTA exit interview)

In Boston, while the majority of visitors did not make overt references to God or a higher power, a significant number of respondents did ask questions or make comments that could be considered "spiritual." Visitors asked questions about "what's out there" and "why are we here" and were interested in considering possible answers to those "big questions."

> Where do we fit in? This is more of a philosophical question that I am always thinking about as I go through museums like this. (MOS exit interview)

> I liked the way it . . . talked about spirituality with the wall of thought . . . It is nice to see different perspectives on what this all means and of ideas of how God fits in to it. (MOS exit interview)

Several Midland visitors also talked about their spiritual perspectives in relation to the cosmos.

> I believe we are created by the same love force, God, that created the universe. Even though we are small, our being here has meaning. Sometimes exactly what is clear, and sometimes it's a mystery. (MCFTA exit interview)

> Most of my life I've been a spiritual searcher. It confirms that the real question is, what is my relationship with God and my fellow man, with what I do and say. (MCFTA exit interview)

One visitor, over a month after his visit to the exhibition, appreciated how the video interviews showed science being used in the service of the search for spirituality.

> I did think it was interesting that the first diorama talked about those heady, moral, ethereal questions about space and religion. I thought that was an interesting beginning to the whole exhibit. You usually thought of the topic as a cold, calculated scientific methodology. But that idea of using science to answer bigger questions opposed to the science being an answer in itself. It was science being used to answer larger questions. (MCFTA phone interview)

Note: More visitor comments about religion and spirituality are included throughout the report.

F: SPECIAL AREAS OF EMPHASIS

DIVERSE CULTURAL AND HISTORICAL POINTS OF VIEW

While most visitors did not comment on the diverse cultural, historical, and spiritual points of view included in the exhibition, those who did notice cultural and historical references found them to be an important part of their *CQ* experience.

About one-third of our respondents from each of the museums shared diverse perspectives that they had noticed within *CQ* when specifically questioned during follow-up phone interviews less than a week after their visit. Visitors also talked about the varying historical and cultural points of view presented in the exhibition during some of the exit interviews and interactive observations at MOS. These visitors appreciated this aspect of *CQ* and often wished for more.

> They talk about how other cultures view the universe—multicultural examples, art—but there was a heavy emphasis on astronomy and science. I wish there was more about how other cultures see the universe, their whole understanding . . . both ancient and modern. (MOS phone interview)

> I did like that they brought out the Chinese proverb. It was kind of in the corner; I think some people may have missed that. I liked having both those points of view. One was more personal, the other seemed like an older historical idea. I liked the different perspectives. I like to see diversity. (MOS phone interview)

> I liked the supernova historical [information] from the year 1054 from Chinese and Mexican perspectives. (MOS exit interview)

> One thing I remember reading about was the history of science part . . . it would be cool to see the stuff about the past thoughts of the universe and geocentrism could be included near the front, because it seemed like the

> history of science stuff was banished close to the back.
> (MOS phone interview)

> B10: I noticed that the Chinese were really interested in astronomy and that people a long time ago believed that the "paintings in the sky" were what God was telling them. (MCFTA phone interview)

> I find it very intriguing to look at how our perspective has changed . . . like when I tell my students that people thought the Earth was flat . . .
> (MCFTA phone interview)

A number of visitors commented on the video, which presented several people from different ethnic, racial, and professional backgrounds, including a playwright and a painter whose works were part of the exhibition, the Vatican's astronomer, and a Native American storyteller and physicist. Each was asked to answer a series of questions, such as *Where do you find meaning? Was the universe designed for us?* and, *What's the relationship between faith and science?*

> [I liked] the video with the different poets and astronomers. I think it's helpful to have different rhythms in taking things in. (MOS exit interview)

> The comments about where we fit into the universe by artists, that was interesting . . . just to hear from different people with different backgrounds and their comments about how we fit into the universe. (MOS exit interview)

> It's impressive . . . a learning experience. The little video was interesting . . . Because it talks about things people question—the relationship between science and spiritual life or faith. They don't give you answers, it tells you the differences and sameness. (MOS interactive observation)

> He [scientist in video] looks Native American. What struck me is he comes from where they honored what we destroyed—here's one [person] in our generation [who is] still seeking that. (MOS interactive observation)

> G11: I liked that they have people speaking ["Where Do We Fit In?"]. I liked the fact they had people speaking to the Bible. (MCFTA exit interview)

UNDERSTANDING THE WORK OF ASTRONOMERS

At both the Museum of Science and the Midland Center for the Arts, visitors reported an interest in the work of space scientists and the tools they use to explore the universe. In both exit interviews and in follow-up phone interviews, visitors were specifically asked about what they had learned related to how scientists explore the universe. Respondents talked about their interest in scientists' work and new learning related to scientists' tools such as the infrared component, the Chandra and Hubble telescopes, and light spectra at

both sites. However, there appeared to be differences in what stood out in relation to these tools between the sites. For example, more visitors commented on the Chandra, Hubble, and Mauna Kea areas at the MCFTA than at the MOS.

MOS

Over one-third of MOS respondents reported that they learned something new about how astronomers do their work during our follow-up phone interviews within one week of their visit.

> [I liked] the part that talks about how astronomers use different light waves to see different things. It really brought home the point of how limited our sense of vision is when looking at the universe, and how astronomers have had to use other devices to understand the universe, not just our sense of sight. (MOS phone interview)

> They explained in [the exhibit on the telescope] how they set it up and all the different people that it takes to take a viewing, and that they come from all over the world. That you don't just walk up to a telescope and look into it. ((MOS phone interview)

> The thing I liked in particular was the fact that they had pre-recorded interviews with real scientists . . . (MOS phone interview)

Several visitors said that they had prior background in astronomy and came to the exhibition with significant knowledge of the subject, which focused their interest on particular topics.

> I have to say I don't come with a clean slate. My father is an astronomer and he came with me. He actually learned something . . . One thing that was very interesting for us was the part that talks about how astronomers use different light to see different things . . . (MOS phone interview)

> The questions about how they [researchers] do their work were not as interesting as the questions about what is their biggest question or how did they get into astronomy. I think it's because I had prior knowledge. (MOS phone interview)

About a third of the MOS phone respondents, when asked directly, stated that they had not learned new things about the work of scientists from the exhibition. Those who did not learn anything about this topic were not interested in the these aspects of *Cosmic Questions*, didn't notice those parts of the exhibition related to the work of astronomers, or approached *CQ* with large amounts of prior knowledge.

> We didn't look at everything. I can't think of anything that indicated about how astronomers do their work . . . or about what their life is like. (MOS phone interview)

> I did not learn anything new. I was a space engineer before I retired. I've seen those things in other contexts. But I still thought it was a good presentation.
> (MOS phone interview)

> I didn't learn anything about astronomy; I wasn't interested in that.
> (MOS phone interview)

Other visitors talked about what they had learned about the work of space scientists during interviews conducted as they were leaving the exhibition. New information about observatories, Chandra, and the Hubble were mentioned most often.

> [I learned about] the telescopes where the observatories are.
> (MOS exit interview)

> [I learned about] some of the different projects going on with the Hubble telescope, with the X-ray telescope and the map . . . Some kind of project that took pictures of the universe. That was interesting. (MOS exit interview)

> I would say it's [*Explore Mauna Kea*] interesting. I would like to know what each [observatory] is looking for. (MOS interactive observation)

> I learned that Chandra had to use battery power when eclipses happen.
> (MOS exit interview)

> Looking at what is going on in space at the moment is new [to me], the different projects, like the information about current labs in space.
> (MOS exit interview)

> I learned stuff in [the demonstration] about light and how they measured distances. (MOS exit interview)

MCFTA

More than half of MCFTA visitors interviewed in follow-up phone interviews shortly after their visit to *CQ* said they had learned something about how scientists do their work. Several respondents talked about how astronomers make new discoveries in space, and what they had learned about those discoveries..

> B10: Yes, I did; it was very interesting. Like how, before they figure out if there's life on other planets, they have to figure out if a planet or star is close enough to the sun or if there's enough of the things needed for life.
> (MCFTA phone interview)

> There were a couple of areas on how they were scanning small areas of the sky for galaxies that were very far away, and I didn't know how much work went into that, and I hadn't read about that before.
> (MCFTA phone interview)

> Definitely, but it's been a couple of days. I don't know if I could cite anything specific for you. (MCFTA phone interview)

Several visitors were fascinated by the Hubble pictures that were added to *CQ* at the MCFTA.

> It was interesting to realize the photos were composites of different techniques—using X-rays and infrared to get a clear view.
> (MCFTA phone interview)

A few other phone respondents didn't focus on this aspect of the exhibition or had previous background in this subject.

> I guess I really didn't look at it from that perspective. Other than I was impressed with how much they have learned about the universe and what is out there and how much I don't know. (MCFTA phone interview)

> I don't know if I can answer that question. That's not what I was looking for… (MCFTA phone interview)

> No, it was just looking at interesting photos of different stars.
> (MCFTA phone interview)

> Because I already had some background, not a whole lot, but more depth about what they do. (MCFTA phone interview)

MCFTA visitors exiting *CQ* volunteered a wider variety of information about their learning related to the work of space scientists than similar visitors at MOS.

> [I learned]about the astronomers. They don't even know what they're going to find and what they're looking for. (MCFTA exit interview)

> I didn't know that there was a special tool scientists use to see new stars.
> (MCFTA exit interview)

> I didn't know you could tell the age of stars by the gasses.
> (MCFTA exit interview)

> [I learned from] some of the things they did looking at objects through one viewing source, and then another, like looking at the sun through different light sources. Looking at the sun through the naked eye, but using X-ray and ultraviolet, you see other things. That was fascinating.
> (MCFTA exit interview)

> I've been following the Hubble pictures pretty closely. The X-ray imagery, I didn't know about that. There were some other levels of perception that are not seen by the human eye. I wasn't aware of all of that.
> (MCFTA exit interview)

G: MAGICAL POSSIBILITIES

> Oh God, I would travel through space. I've always wanted to do this . . . Just to see what is out there and life on other planets and try and understand what they understand and make meaning out of all this. (MOS exit interview)

At both the MOS and the MCFTA, a large majority of our visitors were interested in exploring the cosmos. When visitors were asked, "If anything were magically possible, is there anything new you would like to do as a result of seeing this exhibit that you hadn't thought about before?" most visitors responded that they would like to actively explore space, as noted in the following table:

Table 9
Magical Possibilities and Dreams: Relative Frequency

MOS	MCFTA
Space travel	Space travel
See a black hole up close	See a black hole up close
Content to stay here on Earth	Immerse myself with knowledge
Telescope-related	Become an astronaut
Immerse myself with knowledge	Find aliens
Find aliens	
Big bang-related comments	
Go into the future	

In both institutions, our respondents were fascinated by the idea of personally seeing the planets, stars, and other aspects of the universe. Their curiosity about the cosmos is reflected in the following comments.

> If anything were possible, I would love to be transported or travel though the universe. I'd love to see the solar system and Milky Way. Seeing that first hand and not through the telescope pictures, that would be awesome. (MOS exit interview)

> I would like to see the birth of a star, the whole process. How it was born, how it dies, and what happens when it dies. (MOS exit interview)

> I'd like to go to another planet. Any one will do. The exhibit . . . provoked those thoughts. (MOS exit interview)

> G10: Well now I want to visit everything that they talked about in there. (MOS exit interview)

G8: I would definitely explore other galaxies and learn about space. (MCFTA exit interview)

B8: Explore all the other galaxies we haven't found out about yet . . . and stand on Saturn's rings and land there. (MCFTA exit interview)

Black holes proved to be a source of fascination for children and adults alike.

I guess go to the center of a black hole, but that is impossible . . . alright, if anything is possible that would be it. (MOS exit interview)

B13: I'd like to see a black hole and exploding stars, or supernova. (MCFTA exit interview)

B8: Probably go into a black hole, because it had a question mark in the middle of the screen and I'd like to find out about it.(MCFTA exit interview)

Several visitors wanted to become astronauts and visit the space station.

G16: I would want to go to the space station . . . In Washington D.C. a few years ago, I watched a 3-D movie on an Imax thing about the space station. And I was looking at it over there [points to exhibit with space ship across from *Cosmic Questions*], they have a model of it. It's all the countries working together and it would be cool to see how it works. (MOS exit interview)

It would be interesting to travel around space like an astronaut . . . If there was no issue of time, I'd like to go to a nearby galaxy to see if it is there. If there was no issue of time, because it takes the light how many million years to get there? . . . (MOS exit interview)

I would like to be an astronaut. It's a dream for me at my age. (MCFTA exit interview)

Several MOS visitors and a few MCFTA respondents said that they were content to stay here on Earth or were more focused on issues and problems on our planet.

I'm more interested in our planet and how it's developing. Our universe here on Earth. Changes that are happening here environmentally. (MOS exit interview)

I probably wouldn't go into space. The whole blackness is kind of intimidating. I'd rather explore Earth more. (MOS exit interview)

If I could do anything I wanted, I'd do nothing . . . lay in the grass and look into the night sky and think about why it's called the Milky Way. (MOS exit interview)

> I'd actually worry about something here instead of something out there; there's a lot of earthbound problems that need to be taken care of.
> (MCFTA exit interview)

> I'm pretty happy sitting here on Earth. I don't need to go out there.
> (MCFTA exit interview)

A number of visitors at both sites spoke of wanting to become more knowledgeable about topics in the exhibition, including travel into the past. A few Midland visitors were especially interested in answers to religious and philosophical questions.

> I would like to have universal knowledge. I would like to know all the answers to what we don't know yet. (MOS exit interview)

> I would go back to college and get a degree, without having to take any tests. I would like to know more about the scientific world . . . I need to know some more information . . . I wish I were a scientist. (MOS exit interview)

> I guess I would really study the stars, you know some deep learning about what I suppose the planetarium will give me as an overview. Somebody will teach me which star came first. All this in much more detail. (MOS exit interview)

> I would like to go back in time to the first people to build a theoretical model. Sit with them. Listen to their thoughts. Probably Babylonian. I thought about it when I saw the history of astronomy. (MOS exit interview)

> I think it would be neat to either go up in space or just be more knowledgeable and have a large enough telescope to look at different planets. The college where I work at, you can go in there and look through the high-powered telescope, but I never have. (MCFTA exit interview)

> No boundaries? I'd like to be able to talk to God, and ask what is the meaning of all this creation. I'd like an answer to that question.
> (MCFTA exit interview)

> I'd like to go galaxy hopping. Then I would have a rendezvous with God.
> (MCFTA exit interview)

Visitors also expressed an interest in using the tools of scientists—such as the Mauna Kea telescopes and Chandra.

> I would love to be able to be one of the people that is constantly observing what is going on in the sky and I'd investigate other solar systems and galaxies . . . to work at the observation station in Hawaii. How fascinating it would be to watch and see things change over time and to see it and be what you do all the time. (MOS exit interview)

> It would be interesting to get a high-powered telescope and observe night sky, observe changes, things you can't see. (MCFTA exit interview)

Several respondents at both institutions were interested in finding other life forms in the cosmos.

> Go galaxy to galaxy; visit all—see if other people have more technology than we do. (MOS exit interview)

> See alien cultures. (MOS exit interview)

> Find out if there's other life out there on other planets. (MCFTA exit interview)

Finally, several MOS visitors wanted to see the big bang, events preceding the big bang, and to look into the future of our universe. Some of these visitors wanted to see the physical limits of the universe.

> To go back in time to see what was before the big bang. Go to the edge of the universe where it's supposed to end . . . and see what's on the other side. What was 15 billion years ago?! (MOS exit interview)

> Witness the big bang. I'd like to go forward 50,000 years. To see what happens to us. (MOS exit interview)

Approximately 11% of visitors at the MOS and less than 3% of MCFTA visitors said that they didn't have any dreams/desires related to space or the universe. (About 6% of MOS visitors and 12% of MCFTA visitors did not answer this question.)

H: ADDITIONAL THEMES

Many visitors at both museums made general, positive comments about the exhibition that reflect the overall enthusiasm experienced by a wide range of visitors.

> Of all the other exhibits I saw, it was by far the most interesting. (MOS phone interview)

> It wouldn't have been my first choice, but once we got in there . . . I could have stayed an hour. (MOS phone interview)

> I liked the way it was put together. It was very simple for my brain. (MOS exit interview)

> It's cool to see things in this exhibit that are often left out. These are more sophisticated, and presented in a way that doesn't sacrifice detail for giving information to the public. (MOS exit interview)

> It's awesome, mind-boggling. We will come back. (MCFTA exit interview)

> G9: It was really cool, that you can look at everything and know it's around us. (MCFTA exit interview)

> For him to come home and tell his sisters that they need to go see [*CQ*], it must have impressed him. And he said he wanted to go back, so we will. (MCFTA phone interview)

Others commented on particular overarching aspects of *CQ*, such as it's interactive nature, thought-provoking features, "up-to-date" quality, and accessibility.

> I really enjoyed it. I liked the hands-on activities. I think that's how people learn the best. (MCFTA exit interview)

> The thing is that it gets you thinking about the questions it asks. (MOS exit interview)

> I was surprised how up-to-date it was. Very cool . . . It's cool to see things in this exhibit that are often left out. (MOS exit interview)

> I graduated from Gallaudet University . . . [the exhibit] is good because you can read . . . it's good for deaf people. (MOS exit interview)

Some visitors were uninterested in the interactive components, but found other aspects quite interesting.

> The best part were all of the quotations from many people. They meant a lot to me. The interactive stuff doesn't compel me. (MOS exit interview)

A number of visitors made comments about age-related issues—that *CQ* was especially good for children, that it was good for both children and adults, or that it was not good for one age group or the other. One felt that the presentation was either "too simple or too complicated" in various parts.

> There are lots of different levels of stuff. I have my four-year-old granddaughter with me and some appeals to me and some to her. (MOS exit interview)

> I just thought it was really interesting, very educational, especially for my kids to see all this stuff. It gives them a better perspective than in school. (MCFTA phone interview)

> This is nice for kids but it's not interesting for adults. It's like a toy; it doesn't give me new information. (MOS exit interview)

> My brother is 7 and he was too young for it. (MOS phone interview)

> I felt the information was either too simple or too complicated. It was grade-school-level or for actual scientists, and I couldn't find a comfortable level for learning. (MOS phone interview)

A few visitors said that the exhibition was too hard to understand, or simply not interesting enough.

> Pretty high-tech. This stuff is way over my head, I just go by it. The computer stuff was [too difficult]. [I] couldn't spend a lot of time trying to figure it out. (MCFTA exit interview)

> I thought it was almost kind of empty . . . It looks bare. It sort of didn't hold my interest even though some of it is interactive. (MOS exit interview)

Finally, two young women spoke about the potential impact of the exhibition on their future plans.

> F16: I thought it was pretty amazing. My friend and I spent hours there . . . We talked about how we both want to be doctors . . . but after seeing this we thought, you know what, I'd like to go to space on the side. How it would be possible to do that as a career. It changed our thinking on how possible that is. (MOS phone interview)

FINDINGS PART TWO: VISITOR REACTION TO CONTENT IN RELATED ACTIVITIES

AT MOS: PLAY, DEMONSTRATION, AND PLANETARIUM SHOW

At the Museum of Science in Boston, *Cosmic Questions* included four separate but interconnected components—the main exhibition; a play entitled *Girl Meets Boy*; a live demonstration, *The Real Time Machine*; and a planetarium show, *Journey to the Edge of Space and Time*. The play and demonstration were created specifically for the *Cosmic Questions* exhibition. The planetarium show was updated to complement *CQ*. Each of the three presentations took place on a daily basis, all at sites within the MOS, but at some distance from the exhibition hall. Live presenters told audiences about the *CQ* exhibition in the main gallery and encouraged them to see it, but the main exhibition offered little information about the other, related activities.

PLAY SURVEYS—*GIRL MEETS BOY*

The Museum of Science developed a play to complement the experience of the *CQ* exhibition hall, *Girl Meets Boy*, which was usually presented twice a day on a stage at the other end of the museum. According to surveys filled out by 84 visitors over the course of several weeks, audiences generally enjoyed the play, and identified a range of things that "stood out" for them, including the acting, the comedy and story, and the impact of the ideas presented.

Personal Connection to the Universe

The first question asked visitors if they "thought about their personal connection to the universe" while watching *Girl Meets Boy*. Over three-fourths said that they had; the following responses were typical.

> Yes, in terms of both science and the insights of the arts. (MOS play survey)

> Yes, it brings up philosophical questions while not presenting answers or "judgments." (MOS play survey)

> Yes. I think the questions about why we are here and how we feel so small make me think about my purpose. (MOS play survey)

Questions

The evaluators asked visitors what else they would like to know about the universe after seeing the play. Over 80% of our respondents had additional questions. The most common questions were related to stars—their birth, death, and formation; questions about the big bang and the beginnings of our universe; and questions about our expanding universe, space, and time.

> I've heard about the telescope that can "see into the past" and I'd like to know more about it. (MOS play survey)

> The facts and ideas about time vs. space in relation to the stars. The idea that the further out a galaxy is, it reveals a younger moment in time. (MOS play survey)

> So many things—I want to help my kids find the "answers" that I can guide them to. (MOS play survey)

What Stood Out

Visitors were also asked what "stood out" in the play. They enjoyed the mix of art and science and the performances in the play, as well as the questions it raised.

> The excitement of the questions and the questioning, and how the answers aren't always what they seem. (MOS play survey)

> I loved the vision of someone's life and the choices we make. (MOS play survey)

> The dilemma between the theists/creationists and the evolutionists. (MOS play survey)

One visitor offered a suggestion about the age range of the play.

> Excellent play and acting! This is focused primarily on adolescents and adult vocabulary and learning style. Perhaps the program should note that. (MOS play survey)

Motivation to See *CQ*

According to survey responses, only about 10% of audiences had seen the *Cosmic Questions* exhibition. After viewing the play, almost all of these respondents reported that they planned to see the *CQ*.

> The dialogue was perfect! I am now so inclined to visit the exhibit in connection with this play. This play was my first step. (Play survey)

DEMONSTRATION SURVEYS—THE REAL TIME MACHINE

Survey responses from *The Real Time Machine* demonstration were generally positive but brief, and much of our data appeared to come from school groups. Most of the respondents who had not visited *CQ* (75%) intended to view the exhibition after watching the demonstration.

New Learning

Over three-quarters of visitors who attended the demonstration said that they had learned something new. Their responses ranged from a simple "yes" to complex answers and fell into a broad range of categories.

Many visitors (about 1/6 of those responding) said they had learned about light, wavelengths, and gasses. Some said they had learned about the lengths of different spectra, and that different gasses give off different light.

> How to identify gas, universe expansion, how to measure distance, sky is not dark. (MOS visitor survey)
>
> Microwave is a kind of light. (MOS visitor survey)
>
> I learned that hydrogen and helium are not solid lights. (MOS visitor survey)
>
> Gasses have different light patterns. (MOS visitor survey)
>
> Different light spectrum; light travels faster than sound. (MOS visitor survey)

Several visitors reported that they realized they were "looking into the past every day," and realized light was used to measure distance. Other popular visitor responses included learning about time and space, aspects of the big bang, and stars.

> The red shift demonstration was very interesting. I now understand how we can view the remnants of the big bang. (MOS visitor survey)
>
> Everything inside you is a star. (MOS visitor survey)
>
> The Earth got cold after the big bang. (MOS visitor survey)
>
> Names of stars in the Big Dipper. (MOS visitor survey)

Questions

After seeing the demonstration, more than half of our respondents wanted to know more about a wide range of topics. These included aspects of the big bang and light—including how ancient light can be seen—and questions about how scientists see and explore gasses.

> How scientists find out about gasses on the moon and planets. (MOS visitor survey)

> Everything. The whole subject of the big bang is totally fascinating.(MOS visitor survey)

> Detailed explanation of the big bang theory. (MOS visitor survey)

> I would like to know more about helium and hydrogen. (MOS visitor survey)

Several visitors were interested in how light travels, the size of the universe, and wanted to learn more about stars.

> I want to learn more about stardust. (MOS visitor survey)

> How big is the universe? (MOS visitor survey)

MOS PLANETARIUM SURVEYS

Survey data collected from the planetarium were somewhat limited and appeared to include a large number of responses from school groups. Eighty surveys were collected on five different days at the planetarium, although many surveys were only partially completed. Of those filling out the surveys, about one-third had seen *CQ*, while about two-thirds had not. About half of the respondents who had not seen *CQ* planned to go to the exhibition.

Questions

Planetarium visitors who had seen *CQ* were asked if they had any questions about the universe. About one-fourth of these visitors had questions or were wondering about topics related to the universe, such as black holes, the beginning of time and how the universe came to be, whether space ends, alternate universes, life on other planets, and the expanding universe, as reflected in the following comments.

> The meaning of the big bang, black holes, time travel. (MOS planetarium survey)

> Yes. Does time have a beginning, an end? Why? (MOS planetarium survey)

> Why do new moons occur at night if they are between the Earth and sun? (MOS planetarium survey)

About one-third of visitors who had seen *CQ* and the planetarium show said *Journey to the Edge of Space and Time* had helped them to reflect on their questions.

> Yes, it helped answer how we found out about galaxies. (MOS planetarium survey)

> Yes, a moving visual of the big bang theory. (MOS planetarium survey)

After watching *Journey*, almost 60% of our respondents wanted to know more about various topics related to space and cosmology. Many of these visitors had questions about black holes—how they function, what happens to time, and their features.

> Black holes and how we are studying them. (MOS planetarium survey)

Other popular topics included the possible existence of alien life in our universe or other universes; questions about matter, anti-matter, and dark matter; and curiosity about the features of space, including other galaxies, and space exploration/new discoveries.

> Quasars, dark matter. (MOS planetarium survey)

> Where can I get an update as we develop new theories? (MOS planetarium survey)

> New discoveries, recent research. (MOS planetarium survey)

> Yes—other matter and possible laws. Computer reconstructions of big bang. Could life exist on non-circular orbiting planets? (MOS planetarium survey)

Spiritual/Religious Issues

A few visitors commented on spiritual/religious issues. One respondent disagreed with the premise of *Journey* and the big bang theory.

> Yes, [I want to know] more about spiritual life. (MOS planetarium survey)

> You assume the world was created through a "big bang" theory—you mention creation—creation implies a creator. Analogy! If there were all the components to create a watch sitting in a random pile, can you expect all those pieces to assemble themselves and function as a watch? Please read account in Genesis One in the Bible. (MOS planetarium survey)

AT MIDLAND CENTER FOR THE ARTS: DEMONSTRATION AND PLANETARIUM SHOW

The Midland Center for the Arts presented the various "pieces" of *CQ* in a format different than at the MOS. In Midland, the MCFTA presented several *Science Sunday* lectures connected to *CQ*, including *The Real Time Machine*, a program featuring the *Hall of Ideas* traveling planetarium, and a program for children entitled *Our Amazing Universe*. They also sponsored several evening lectures on related topics. The *Journey to the Edge of Space and Time* planetarium show was presented at the Delta College Planetarium in Bay City, Michigan, about 10 miles from the Center. The play, *Girl Meets Boy*, was not presented in Michigan.

DEMONSTRATION SURVEY: THE REAL TIME MACHINE

New Learning

Evaluators surveyed visitors attending *The Real Time Machine* demonstrations that were held at the MCFTA in April 2003. More than 100 visitors attended the three demonstrations presented on one afternoon. Most of our respondents learned something new.

> That there is light we cannot see. (MCFTA visitor survey)

> I learned how to measure the distance to a star. (MCFTA visitor survey)

> The explanation of the big bang is easier to understand. (MCFTA visitor survey)

> How elements were formed from H and He. (MCFTA visitor survey)

Questions

The survey asked visitors if they would like to know more about anything after seeing the demonstration. More than half had questions on topics including stars, the shape of the universe, the cause of the big bang, the future of the universe, and space travel.

> How old are the stars? (MCFTA visitor survey)

> Donut shaped universe? Is the universe cyclical? What about entropy in these new models? Is it just an intermediate stage before a new cycle begins? (MCFTA visitor survey)

> What's next for our universe? (MCFTA visitor survey)

What caused the big bang? (MCFTA visitor survey)

Is it possible to get to any other galaxies? (MCFTA visitor survey)

Presentation

MCFTA visitors were asked to comment on the presentation. Those respondents who made comments all said that they had enjoyed the show, and most of those who had not visited *CQ* said they planned to see the exhibition.

Very good demonstration! Very informative, and it held the kids' attention very well. (MCFTA visitor survey)

Nice presentation—did a good job of explaining it to the children. (MCFTA visitor survey)

Excellent! We are SO enjoying these talks! Thank you for bringing all these people to Midland. Bring more! (MCFTA visitor survey)

Even visitors who had a background or previous information on this topic enjoyed the presentation.

Even if I knew a lot of the materials covered, they sounded brand new and interesting. Great creative visual aids. Very well-thought-out examples. (MCFTA visitor survey)

[I] liked the techniques of demonstration. (MCFTA visitor survey)

DELTA COLLEGE PLANETARIUM SURVEY

One hundred-fifteen total surveys were filled out on seven separate days at the Delta College Planetarium in Bay City, Michigan, about ten miles from the MCFTA. However, many of the surveys were only partially completed. Of those filling out the surveys, about one-third had visited *CQ*. Among those visitors who had not seen *CQ*, more than two-thirds planned to visit the exhibition.

Questions

More than three-quarters of visitors to both the planetarium and *CQ* reported questions about the universe when asked by the survey. While some did not provide specific answers, others listed questions and topics, such as: our insignificance, our place in the universe, current technology, current happenings in the universe, the shape and boundaries of the universe, and what came before the big bang.

The shape of the universe. ((Delta planetarium survey)

> What is in the boundary between galaxies? What was before the big bang? ((Delta planetarium survey)

> What we see are "ghosts." They existed way back when. What is really [happening] now? (Delta planetarium survey)

Other topics raised by visitors included black holes and dark matter; other universes and solar systems; the future of the universe; the size of the universe and the probability of other life forms; and how much more will we learn in our lifetime through space exploration, both manned and unmanned.

> How big is it? How do we relate? Can there possibly be other human life? (Delta planetarium survey)

> What are black holes, beyond what we know? What is dark matter? Will we ever answer these questions? (Delta planetarium survey)

These same visitors were asked if *Journey to the Edge of Space and Time* helped them to reflect on their questions. A majority of our respondents wrote that it had. The following comments were typical:

> Yes. Fascinating. Makes one realize how little we know. Must be a Creator—not happenstance. (Delta planetarium survey)

> Some—it put many things [size] into perspective. (Delta planetarium survey)

> Yes. Our current knowledge is limited but expanding. (Delta planetarium survey)

> Somewhat. I have a better perception of the universe's size. But are there other universes? Seeing *Journey* helped me understand the *Cosmic Questions* better. I want to visit *Cosmic* again and then visit *Journey* again. (Delta planetarium survey)

All visitors, both those who had visited *CQ* and those who had not, were asked if they were interested in learning more about particular topics. More than 60% wanted to know more about a range of topics, including black holes and dark matter; other galaxies; stars; creation; different views of the sky—for example, a view from the southern hemisphere; different seasons; and the sky ancient explorers used for navigation.

Religious Topics

A few respondents cited the role of religion or faith in their view of the universe or felt that the planetarium show did not give a complete picture of creation.

> More of all creation, space-time and my (man's) eternal existence (God). (Delta planetarium survey)

> Not everyone shares the view that there was a "big bang." There is a creator. He is God, the evidence we see around us is that it couldn't of happened without one Creator. It was disappointing to hear that all the show was based on nothingness. (Delta planetarium survey)

A few visitors questioned the big bang, or described it as a theory rather than fact.

> I think they should present not only the big bang (which should be presented as a theory not fact) but also the creation by God as recorded in the Bible. (Delta planetarium survey)

> How do you know the big bang happened? (Delta planetarium survey)

Overall Comments

Finally, visitors were asked to comment on *Journey.* Most of our respondents made positive comments, such as the following.

> This show did a good job in describing black holes, as much as we can understand at the time. (Delta planetarium survey))

One visitor wanted to know more about dark matter.

> Describe how astronomers know dark matter is there, not just that it is there. (Delta planetarium survey)

Several Michigan visitors described the show as "excellent," "great," and "educational." One wrote the following:

> The best part of the show was hearing children sigh, saying "amazing," 'wow," "cool," and hearing adults giggle like little children . . .

FINDINGS PART THREE: IMPLEMENTATION AND SUPPORT OF THE *CQ* EXHIBITION

Many resources and additional components were mobilized to implement and support the main *Cosmic Questions* exhibition. The developers and museum staff provided or organized training for staff and volunteers working with the exhibition. Volunteer interpreters and docents enabled visitors to experience and understand the content of the exhibition more fully. In addition, at the Museum of Science, demonstration staff supported *CQ* with daily live presentations of some of the more challenging concepts, and actors humanized many of these concepts through their performances. A planetarium show also complemented the exhibition, on-site in Boston, and ten miles away, but jointly promoted, in Michigan. Also, some MOS staff prepared materials to travel with the exhibition. This part of the report covers topics related to those who worked to implement and support the main exhibition—their roles, assessment of their effectiveness, visitor feedback received in the course of their work, and challenges they faced. This section also includes the personal impact of *CQ* on these individuals who worked so closely with the exhibition, and their suggestions for its improvement.

TRAINING

TRAINING FOR MOS STAFF AND VOLUNTEERS

In Boston, staff and volunteers were taken on guided tours by one of the creators of the exhibition, Mary Dussault, and provided with extensive written materials. Two training sessions were set up for volunteers and were presented by exhibition developers and an astrophysicist. Staff were encouraged to attend those sessions. In addition, staff were also invited to a series of seminars on scientific topics for several months before *CQ* opened, attended various brown-bag lunch discussions, and had easy access to the exhibition developers. Most felt that their training was essential to their ability to work with the exhibition.

> The content was a bit daunting, but with support from CfA, we built up our base of knowledge. (MOS staff)

MOS Staff Training

At the MOS, museum administrators from several departments were in need of training, including those responsible for the interpretations and the interpreters, the demonstration

and the demonstrators, the play and the actors, and the teachers' workshop and guide, as well as those responsible for museum programs in general and this program in particular. Also, those doing the demonstrations, interpretations (mostly volunteers), and acting also required preparation for their roles. They all relied heavily on Mary Dussault and Erika Reinfeld, Education Specialist for their understanding of the exhibition and its goals, as well as for ideas on how to reach those goals.

> Mary held several meetings with the museum staff to explain what she hoped the museum exhibit would do . . . .I think Mary did a really good job answering our questions . . . The best was Mary's description of the exhibit, written materials, mock-ups, slides, lots of different media . . . Mary has done a good job of making complicated ideas easy to understand, accessible, and attractive. (MOS staff)

Staff also appreciated seminars with professionals in the field, which gave them another place to ask specific questions about exhibition content.

> One of the things I found most valuable was being able to talk to an expert in the field. (Demonstration staff)

Administrators also made use of each other after their initial orientation.

> We then met as a *Cosmic* team with representatives for each of the six pieces and talked about how to build on the message of the exhibit. We had about a half a dozen meetings and understood our individual directions. Then it became more decentralized and we worked with Mary at CfA to develop our own projects and we reported back to each other. (MOS staff)

> Any time there was anything on the news, the staff would e-mail it to me, so we would keep up-to-date with all the new information going on. I learned a lot by people sending me Web pages, and I always read them. (Demonstration staff)

One person talked specifically about the helpfulness of the "human component" of her preparation and all of the different people available for consultation.

> In addition to books and articles, the Internet, those traditional places, people are a great resource. The planetarium staff here, we consulted them quite a bit, the CfA folks, the lectures and seminars . . . Those of us developing the programs also met with Mary and Erica . . . It was really useful to bounce ideas back and forth. The human component of learning was really important. (MOS staff)

In addition to receiving training, MOS staff also wrote training materials, with help from the developers of *CQ*, for use by other museum staff and volunteers, both locally and at other sites hosting the exhibition. The staff used Mary Dussault and other experts, as well as Web materials, to enable them to do their work.

> We did a ton of Web research and put together a binder. Mary would put some information before us and we trusted her, and we got suggestions from the cosmologists. We were looking for articles and resources that were . . . the level of a college course. (MOS staff)

MOS Volunteer Training

Specific training was designed especially for the volunteer interpreters, to which all staff were also invited. Volunteers appreciated the thoroughly-written materials, the two evening programs—one with an astrophysicist and one with the exhibit developers, and the guided tour, even though many of those interviewed were already quite familiar with much of the exhibition's content.

> There was a wonderful package they gave us . . . [It] was absolutely astonishing. (MOS interpreter)

> I personally have a fair amount of background in the subject matter so I didn't require that much in the way of training and resources, but there was plenty available. Some were about recent advances I didn't know as much about . . . The second evening was more useful, training with the exhibit designers. (MOS interpreter)

Like the staff, interpreters also enjoyed collaborating with their colleagues.

> We also talked a little bit, brainstorming—What can we do here? How can we demonstrate that? That's part of our usual work. The weekend volunteers are mostly professionals . . . We have science or engineering backgrounds and we love to discuss things. (MOS interpreter)

One of the staff members who conducted demonstrations felt that the training provided was not accessible enough. This person wanted the training sessions and training materials to be easier to access, both in terms of the time they were offered and the amount of copies available.

> There were training sessions that were held at night and I was not able to get to them. We were supposed to have a video, but I never got it. There were booklets, but we had to share, so I didn't use them as much. I used a little section of the packet but I had to photocopy it . . . I didn't get enough training . . . I think they should have had more binders . . . Maybe putting it online would have helped. (Demonstration staff)

Training for "Girl Meets Boy" Actors

The actors involved with *Girl Meets Boy* undertook their own training process to prepare both for acting in the play and for answering questions that might be posed by audience members after performances. This training involved the playwright, program

coordinators, stage manager, and the exhibition designer. Those involved with the play from the beginning received more thorough preparation than those who joined the cast later.

> I was lucky since I was there from the beginning. I got to speak with Mary and [ask] any questions, so I got more science background than [the cast] who came later . . . At first I was just saying words, but after that I understood more. I'm not an astronomer, but . . . we had the opportunity to speak with Mary and ask questions . . . and repeated answers back to Mary in our own words to make sure we understood. (Actor)

> During the rehearsal process between Kathryn and Melinda and Dan, we could ask questions about things we didn't understand in a way that was great to learn. (Actor)

One actor also talked about doing research on the Web.

> [I also did] a little Web searching on my own, mostly sites for children and basic astronomy. (Actor)

Another actor described the blending of art and science presented in the play and summarized his learning process.

> I could understand the poetry part, but I knew little about the science. There were a lot of technical terms in the play. But for me, the neat part was marrying the art and the science . . . My character didn't understand the science, but Melinda [the playwright] and Seth, our stage manager this summer, gave us information and we'd sit and talk about it in rehearsal. (Actor)

One of the administrators responsible for the play related his high opinion of the actors and their ability to ask for what they needed.

> The actors here have self-selected themselves because they enjoy science. They have gotten comfortable with science and with saying "I don't know." We have people who will educate themselves. (MOS staff)

TRAINING OF MCFTA STAFF AND VOLUNTEERS

At the Midland Center for the Arts, an institution committed to integrating arts and science in one building and within exhibits wherever possible, three administrators had important responsibilities in relation to *CQ*. In addition, volunteer docents were used to offer extra information and support to visitors, and substitute teachers were hired to provide guided tours to school groups. The administrators all received an orientation and some training for their roles during visits to Boston, which they found useful and

informative. These administrators also appreciated their access to the exhibition developers and MOS staff whenever necessary.

> When I went to Boston, Mary spent an afternoon with us, guiding us through the exhibit, explaining what they had tried to accomplish with it. In general, we were extended far more information and explanation than we would normally have had with an exhibit. (MCFTA administrator)

> I was also trained by the staff [at MOS]. I received all the booklets and guides related to it, the docent guides. They [gave] me the demonstrator guide . . . The people from Boston who had already had the experience with the exhibit . . . it was easy to talk to them and learn what they did and how they did it. (MCFTA administrator)

MCFTA docents were oriented to the exhibition, either by Mary Dussault or Joe Kchodl, the Interim Director of the Hall of Ideas at the MCFTA. They used the written materials developed in Boston, and relied on their own backgrounds and interests for their work with *CQ*.

> We met with Mary Dussault, all the interpreters and the guides. We must have spent two hours. We met again and she went over the interactive things, and the things we could pull out, like the spectrometer, you can attach a light there . . . We got a booklet that went into more depth. (MCFTA docent)

> The biggest thing is, astronomy has always been my hobby . . . I'm a member of the local astronomy club, and I subscribe to two astronomy magazines and *Science News*, so that's the main things. (MCFTA docent)

However, one of the docents interviewed felt that the volunteers were not given enough time to learn about the exhibition before visitors arrived.

> We had just three days to see it [before it opened to the public], and Mary was available all three days, but she had her schedule too . . . We had so many questions, we spent 20 minutes asking Mary questions at the first station . . . We had about 18 people there, and everyone had their own questions. (MCFTA docent)

This group also used each other's knowledge, the Internet, and other written sources to increase their knowledge of *CQ*'s content.

> We all talk amongst each other. [The other volunteers] often have a lot more experience, they go over a lot of the things. A lot of us have an interest. We'll check online and look up more things. (MCFTA docent)

> I go on the Web and pick up tidbits. I picked up a book by Sagan that I already had and I read the text of Hawkings' BBC series about the history of time. (MCFTA docent)

CQ VOLUNTEER INTERPRETERS/DOCENTS

> At the entrance where they have the tactile model of the Milky Way, one interpreter liked serving as a "cosmic guide," helping visitors with where they are in the universe. A real interesting orientation at the beginning of the exhibit. (MOS interpreter)

Administrators at both museums agreed that the presence of live, human resources available to help "interpret" *CQ* was essential for many visitors to fully experience and understand the exhibition. However, the interpreter/docent programs at MOS and MCFTA differed in a number of ways. In Boston, volunteer interpreters most often presented predetermined interpretations using materials developed for that purpose; they worked inside or directly outside the main exhibition hall, while sometimes making themselves available within the exhibition to talk with visitors and answer questions. In Midland, docents rarely presented additional materials, almost always circulating within the exhibition to interact with visitors about different components and answering general questions. The MOS interpreter program is well-established, large, and able to provide extensive support to the volunteers, who are often graduate students, working professionals, or retirees. At the much smaller MCFTA, *CQ* is only the second exhibition which has used docents, who are almost entirely retirees (many are former professionals from Dow Chemical), and its support and training capabilities are much more limited.

MOS INTERPRETERS

The volunteer interpreters interviewed from the MOS were excited about *CQ* and thought very highly of it. They enjoyed learning about and explaining the "big ideas" presented in the exhibition. For most, it was a welcome chance to immerse themselves in new areas of science or to explore more fully an area they were already familiar with. Almost half of the interpreters who were offered the possibility of working with the exhibition decided to do so, which was considered an unusual and extremely high percentage.

> Our interpreters see a lot of exhibits come through. More so than others, I thought they had a lot of good things to say about this exhibit in terms of the rich content and opportunities for visitors. (MOS staff)

> I joined the MOS interpreters just to work on this exhibit . . . I'm interested in the whole process of the creation of the universe and the creation of stars, our galaxy, and the creation of life. I thought this would be a good way to improve my knowledge and presentation skills at the same time. (MOS interpreter)

> We pitched this to 80 interpreters, hoping we could wrestle 5 or 10, because it was such a daunting exhibit. We ended up with 30 or 40 there. (MOS staff)

The MOS staff in charge of the interpreters felt that the exhibition provided an excellent opportunity to meet that group's needs for continuing education.

> [Interpreters] found the topic engaging, with good solid science. It was a topic they had to get up to speed on, too . . . *CQ* offered them a subject where they had to do their homework. This idea of a lifelong learner, this was particularly helpful for that. (MOS staff)

Interpreter Role

Interpreters at the Museum of Science presented relatively agreed-upon interpretations with prepared materials that were developed to supplement the exhibition, or were available as general resources in *CQ*. They often used carts to display their materials, and located themselves in a variety of places, both inside and directly outside the exhibition hall. Although their particular interpretations were specific to this exhibition, their general types of interactions with visitors were standard at the museum.

> The interpreter mode [on the spectroscope] was my favorite. I think I tried them all. There was one on the spectroscope, one on gravity probe b, one on modeling expansion, one we called *Our Place in Space* or *Put the Universe in Order*. There was one we called *Building Blocks*; it was mostly an atomic structure interpretation. (MOS interpreter)

> [I spent] about half the time being a resource, talking to [visitors] about what they were looking at, and about half the time doing interpretations. (MOS interpreter)

The volunteers often felt that their presence was useful, and sometimes necessary, helping visitors to get a full understanding of the material presented.

> I think [the interpretations] provided an important link in their understanding of the way the universe works . . . People I talked to got an understanding they would not have received otherwise. (MOS interpreter)

> I'm afraid when the exhibit was built, they hoped that was information people would be able to get just from the exhibit, you wouldn't need people around. My experience was just the opposite. It was necessary to have relatively aggressive people around to talk to people about what they were looking at. (MOS interpreter)

Self-Assessment of Effectiveness

The interpreters felt their presentations were often, but not always, successful in engaging visitors and explaining the scientific concepts behind some of the components. They cited several factors that influenced the effectiveness of their work—the number of visitors in the gallery, the ages of the visitors (a presentation or component could be "too high" or

"too low"), and their location within the gallery. Although many interpreters were observed actively interacting with visitors, others were seen sitting alone with interpretations for long periods without making a visible effort to engage visitors, or when the exhibit gallery was empty.

> I don't think there was ever a time when someone would come up and speak first. If you wanted someone to ask you a question, you had to ask someone if they had any questions, and maybe more . . . I can't emphasize enough how unnatural it feels and how necessary it was . . . Always people were surprised and happy for the attention. (MOS interpreter)

> The right age level was not so old to be jaded but old enough to understand what you're talking about—7th, 8th, and 9th grade—there is a tendency for their attention span to be 15 seconds, but they have enough of a background to feel like this is cool, and are not so busy trying to look old.
> (MOS interpreter)

Several described their work within the spectroscope and the infrared areas, where they felt they were effective.

> The areas where I felt like I was being most effective were the infrared camera and the interpreter mode on the spectroscope, both having to do with talking to people about both science and technology . . . You could talk to people about both the instrumentation and the stuff you could figure out with it. That was an area where you could go from talking about basic science and then give examples that related to some of the most exciting, newest scientific discoveries, without having to teach them about complicated science. (MOS interpreter)

> Most of the time when I walk up [to the infrared camera area, kids] were pointing the camera at each other to see each other on TV. I would have to walk up and say, "Look at this window, you can't see through it." Then someone would go behind and they would see them. They would not discover it on their own, but it was very easy to point it out to them and they would get a whole new level of interest. (MOS interpreter)

One new interpreter was quite impressed with the high quality of the work of his colleagues.

> As a novice interpreter, I was really astounded by the capability and knowledge of the other interpreters. They are a classic bunch.
> (MOS interpreter)

Interpreters' Feedback on Visitors

Interpreters enjoyed their interactions with visitors, and were in an ideal position to gather visitor feedback about the exhibition. Many reported observing a high level of interest on the part of visitors.

> Unlike some other presentations I have done, I had the impression that people coming to this exhibit were willing to spend some time learning things. Some people spent as much as ten minutes playing around and doing things. That's unusual. (MOS interpreter)

Different interpreters were surprised by both the low level and the high level of basic knowledge demonstrated by *CQ* visitors.

> I learned that people weren't starting from the base level of knowledge that I expected them to be. People usually didn't have as much as I expected. One of the parts of the exhibit that seemed to work very well when I was there and could talk to people about it was the infrared camera. I was surprised at how basic I had to start when talking about infrared light . . . I thought [adults] had at least a vague understanding of what light is. Usually I was wrong. (MOS interpreter)

> I was surprised by the knowledge people brought to it. When I was doing the ordering of the pictures of the objects, a little girl not as high as the table placed them all immediately. It just blew me away. The interest that people have and their knowledge is quite surprising. When they don't, they are usually happy to learn. (MOS interpreter)

Interpreters also described the types of questions and information visitors were interested in, including the timeline, the ability to measure distance using light, cosmic expansion, and questions about time.

> The cosmic questions [from visitors] were about time. I didn't get as many cosmic questions as I was expecting. (MOS interpreter)

> People were interested in the idea that you could use spectroscopy to measure how far away an object was. (MOS interpreter)

> I think they got the idea that there is electromagnetic information that we don't get from our eyes . . . I think it depended on the age. When we move into the cosmic expansion and the Doppler red shift, that was a tough one. It is easy for us, I know it, but it was a big jump. That was the least successful, the most challenging. I would say 50% of visitors got something more than the basic science and the range of frequency. The cosmic question, "What do we do with this information?"—most understand that we can use some information from the light and the composition of the stars, 70% got that; less than 30% got, "What does it tell us about cosmic expansion?" (MOS interpreter)

Challenges

Volunteers at the MOS described some challenges they faced in doing their work. During periods when attendance was very low, volunteers found it hard to stay "focused." The technical problems of some of the components frustrated many volunteers; components

that were hard for visitors to understand, even with their help, also frustrated them. Knowing how or when to approach visitors was difficult for many volunteers. Finally, the majority struggled with matching their explanations to the level of visitor understanding.

> I found it was difficult to make people understand the spectrometer . . . I don't think they understood what they were doing with those buttons.
> (MOS interpreter)

> There is a trick to pitching things at the right level. It can be tricky to explain something to a five-year-old and use the same equipment to explain something to an adult who might have a science background.
> (MOS interpreter)

MCFTA DOCENTS

Similar to the MOS, MCFTA volunteers liked the exhibition very much and appreciated the chance to work with it. *Cosmic Questions* is only the second exhibition at the Center to use volunteers to aid the museum experience. Almost all of the docents are retirees.

> I really love it because I always was fascinated with the heavens. Like the kids say, it's awesome. I read up on it in books, and every time I go there, I see something I missed. (MCFTA docent)

Docent Role

In Midland, docents usually stood near one of the exhibition components and offered to explain the topic to visitors, or walked around the exhibition gallery and waited to be asked a question. Sometimes they also acted as a guide, helping people to notice different parts of *CQ* that they might have missed.

> Here we go over and explain how displays work or help people if they have questions . . . We act a bit as a guide. Like people come through and sometimes miss this area [the room with the *Cosmic Kitchen*] or walk by, and if you stop and tell people what it does, they get interested, like the *Cloud Chamber*. (MCFTA docent)

Like the MOS interpreters, these volunteers also felt that visitors often needed them to fully appreciate the exhibition.

> A lot of times if they read the text on display, they'd know what I'm talking about, but they're more receptive to listening. (MCFTA docent)

MCFTA docents tended not to use the materials sent from Boston and used by MOS interpreters. They said that their museum did not lend itself to those kinds of interactions, and they did not have rolling carts for displaying materials, as in Boston.

One of the docents also felt that the majority of the volunteers did not feel knowledgeable enough about the interpretation devices to use them.

> We haven't used the extra things because there isn't a steady flow of people . . . .Most of us don't feel comfortable bringing out [the props] Some of the older volunteers . . . [feel] I'd rather not take out anything I don't understand and try to explain it to somebody else. (MCFTA docent)

Another docent spoke of wanting to use more of the props from MOS.

> I wish this venue was set up to use all of the props that came, that are sitting unused in the back room. We were really looking forward to using the spectroscope and all of the rest of the stuff that Mary showed us, and nothing is happening. (MCFTA docent)

One of the docents, with help from Mary, developed a tool for teachers to use with their students, to demonstrate the concept of a light year and the lack of a center of the universe. Another made up a probe with a small radiation emitter from a smoke detector to use with the cloud chamber.

> It's a way to explain the concept that we don't really have a center of the universe, we don't know where it is. (MCFTA docent)

Self-Assessment of Effectiveness

The Midland volunteers noticed their contributions to visitors' museum experiences, citing visitors' increased understanding of the content presented in *CQ* and return visits.

> I see people begin to understand [the spectrum when I explain it]. The spectroscope is tough, because people push the star buttons but don't read, and there's a delay there. If you can sit them down and go to the spectra of six lights and have them guess one, that works well for kids . . . I don't know how long they retain it, but nine times out of ten [visitors] say thank you. (MCFTA docent)

> I thought at times I did some good. People were quite receptive to what I had to say; plus the personal contact and friendliness helped too—I think people responded to that. Several of them came back, even some out-of-town people came back because they really did enjoy it. (MCFTA docent)

Docents' Feedback on Visitors

At the MCFTA, which is a relatively small museum, it is rare for a visitor to the building not to spend time visiting all of the exhibitions, or at least viewing the new or special exhibitions they have not seen before. Hence, almost all those who entered the building spent some time viewing *CQ*. According to the docents, the overwhelming majority of visitors had positive reactions to the exhibition. Some of the docents also spoke

specifically about visitors' awe; learning about the electromagnetic spectrum; and a minority who did not like the exhibition.

> We've only had very positive feedback from everybody really; not one negative person. (MCFTA docent)

> I don't think they ask that many questions. I just think everybody is in awe about what scientists can predict and how many billions of light years things are away, and there are so many besides ours, and it's awesome. (MCFTA docent)

> Most people don't understand the whole electromagnetic spectrum, and [the *Multiwave Viewer*/*Night Sky*] explains it well. (MCFTA docent)

> Some are overwhelmed, but aside from some fundamentalist Christians who were here, everyone enjoys it . . . I've seen a few people walk in and walk out, but that's not the majority. (MCFTA docent)

Challenges

Midland volunteers cited technical problems, a lack of information, and a general feeling of intimidation in relation to the exhibition.

> We had a lot of bugs when we started and some of the computers lock up, but we call the maintenance team and it works fine. The *Black Hole* was a nightmare for the guys who maintain it and it was frustrating for the docents. (MCFTA docent)

> There are some exhibits, like the *Cloud Chamber*, I'd like to know how it works. It seems to be using something different and [the docents would] all like to know how it works. (MCFTA docent)

> Well, I suppose the exhibit is so awesome, you wonder what it's all about, really. (MCFTA docent)

Deciding how and if to approach visitors was also an area of concern.

> I did my best, but some of them knew more than I did, because there are so many scientists here. You have to be tactful. If the man wants to explain it to his family, we let them do it. (MCFTA docent)

DEMONSTRATION STAFF FROM *THE REAL TIME MACHINE*

At the MOS in Boston, museum staff presented a daily live demonstration in support of *CQ*, further explaining some of the concepts involved. One of the Boston staff traveled to

the MCFTA to conduct an afternoon of similar presentations for one of their *Science Sundays* that complemented the exhibition. The demonstrations were developed over time to present information and concepts closely related to the exhibition but not fully covered by it.

> We feel it's important not just to give people information, but the process of science is very important to us here. We wanted that in the demonstration—How did we come to those ideas? The other thing that is important is [deciding] which things work well as demonstrations. Some things can be done well in an exhibit and [others] can be done well by a live person; it can be very different. We chose things that would complement the exhibit, concepts that could use a live person to help get them across.
>
> (Demonstration staff)

Like others working with *CQ*, demonstration staff thought highly of the exhibition and enjoyed their work with the demonstration and the challenge it provided them. They were planning to find ways to continue it.

> I thought [the exhibition] was surprisingly good . . . Many times I feel like I can get the gist [of an exhibit's content] in about an hour. I was really impressed. I went back several times. (Demonstration staff)

> Those of us involved in the demonstration program were talking about these huge ideas. People found themselves dealing with cosmology. I can't remember anybody saying, "I don't understand this enough; I don't want to do it." Everybody got excited about it. (MOS staff)

> It was a lot of fun to work on it. After the exhibit closes, there is an open slot [for a demonstration]. This is one people really like doing. I think people will continue to do it, which is unusual. Usually people are tired of it, but they want to continue doing this one. (Demonstration staff)

SELF-ASSESSMENT OF EFFECTIVENESS

Demonstration staff were mostly pleased with the effectiveness of the demonstration, including its ability to keep the interest of many relatively young children. They reported a high level of interest on the part of many visitors, and often fielded questions during and after the presentations.

> I've had people come up to me and say it was the best show they've ever seen at the museum. I've had some pretty tough questions. I've been with people for about half an hour after the show . . . People walk away still talking about it. (Demonstration staff)

> One of the most encouraging things about the demonstration was, I was expecting young children and their families to head for the hills. But they stayed, and you could see young children paying attention through the

> program, not being disruptive. There were enough visually intriguing things for the young children. (Demonstration staff)

> Most gratifying was when you have younger kids between 5 and 7, when they come up and say, "Wow, that was neat" . . . .There are times when families with young children left the show because it was not reaching the younger children. They would stay for the refraction glasses . . . but I would lose people in the period when I would explain the concepts before the next demonstration. (Demonstration staff)

The staff continued working on the demonstration as they presented it, and felt that their effectiveness increased as time went on.

> We changed a lot of our explanations of the expanding universe. I think at the end we were doing a better job of explaining that to people. (Demonstration staff)

DEMONSTRATION STAFF FEEDBACK ON VISITORS

Visitor questions to the demonstration staff often concerned light, such as patterns of light, invisible light, and light shifts.

> They don't realize that different elements give off different patterns of light. They think it's cool. People really like looking at light. When you talk about light shifting, they can get confused. Having them go from looking at light to understanding how light changes takes a little bit of work. (Demonstration staff)

> The concept of invisible light—elementary age kids, this is something that they sort of knew; that concept stuck with the elementary kids. (Demonstration staff)

Visitors were also very interested in big bang-related topics, including religious-based questions about the creation of the universe and the certainty of scientific knowledge about it.

> There were a great many things they had not realized in the evidence for the big bang . . . [They said] that they had learned things that they hadn't known before. (Demonstration staff)

> I had a youngster ask me, "You said that the universe started with the big bang, but my teacher or mother . . . said that God made the universe. Which is it?" My answer was, scientific evidence said the big bang started the universe, but we don't know where the big bang came from. A lot of people ask big-bang-related questions. Was there space or time before the big bang? If the big bang resulted in the expansion of everything, how come we are seeing light? Isn't that light moving away from us as well, shouldn't we not see it? (Demonstration staff)

> We got folks from a creationist bend who would want to argue about it. They would try to emphasize that a lot of it was theoretical and I would emphasize that a lot of it was based on hard research. Sometimes we have to go over what a theory is. The perception is that a theory is just a guess. A theory is the best we know based on good evidence. I didn't have any knock-down, drag-out fights, but just people who had questions about where we were coming from. They would say, "You don't know what was there before the big bang," and I would say, "No we don't." That was enough for them.
>
> (Demonstration staff)

CHALLENGES

Demonstration staff were pleased to be working with content related to *Cosmic Questions*. However, most felt challenged to master that content well enough to present a program and be ready to answer visitors' questions. They described the difficulty of reaching visitors of all ages and scientific backgrounds with scientifically accurate information in a short period of time.

> My background is biology, so it's a stretch for me, which is a lot of fun . . . One of the most challenging things [is] for my understanding to be complete enough to give that information back to folks. Initially, being comfortable enough with the material myself was the biggest challenge.
>
> (Demonstration staff)

> There are so many topics, so many different ways to go; [a challenge was] keeping our demonstrations short enough, because there are so many different topics you can talk about. (Demonstration staff)

> Some of the things are hard to explain because I don't understand them that well. Thinking about the world in other dimensions that we can't perceive, people get frustrated. And it's hard to explain to them, which as educators, we would really like to do. It's much easier to explain how a plant grows than what happened in the first couple of seconds of the big bang.
>
> (Demonstration staff)

ACTORS FROM *GIRL MEETS BOY*

The Museum of Science hired a playwright, Melinda Lopez, to create a play based on some of the content contained in *Cosmic Questions*. Focusing on the relationship between a female astronomer and a male poet (first during college and again at a college reunion many years later), the play contrasts different ways of thinking about and relating to the universe, while also including a large amount of scientific information.

SELF-ASSESSMENT OF EFFECTIVENESS AND ACTORS' FEEDBACK ON VISITORS

All the actors interviewed, and the supervisory staff, reported that the play was well-received by visitors and that the process of implementing the play was relatively smooth. According to the actors, the play often succeeded in providing visitors with a different "entry point" into the content of the exhibition, through the joining of science and art. Also, the actors told their audiences about the exhibition and encouraged them to see *CQ*.

> I think science and art are a good team. Good art doesn't have to give answers, but you're doing the play and then you have a concentrated exhibit to give [visitors] the information they need, and they have the play that triggers that hunger for information. (Actor)

> I think many would have walked by the exhibit if they hadn't seen the show. We talked to them and told them there's all kinds of neat stuff and you should check it out. (Actor)

One actor felt that the play "humanized" the content of the exhibition, helping visitors feel related to the universe.

> The visual timeline on my arms [in the play] . . . seemed to bring it in perspective for a lot of people. It seemed to humanize the exhibit . . . .It's easy to feel unrelated to cosmology and the larger universe. I think the play . . . made people think of our place in the universe. Being physically made up of stardust makes one tied into the stars. (Actor)

Feedback given to actors indicated that audiences, including children, enjoyed the play and appreciated its dramatic and scientific content.

> I heard a lot of people who really appreciated the debate of head vs. heart and who understood that struggle personally, and appreciated it being dramatized and thinking about it more. Many people were affected and surprised by the concept we are really made of stardust. My in-laws came to see the show and were in tears afterward. (Actor)

> One woman saw the play several times and said it was great that you could take a scientific topic that was complex and could be daunting, and make it entertaining and enjoyable. (Actor)

> It surprised me how much kids sat still and really listened. The concepts are so high-level for many kids . . . but they sat in a trance for most of the show. I was surprised by that. (Actor)

Some actors also reported that *Girl Meets Boy* stirred questions for some visitors that they weren't always able to answer. Also, some feedback indicated that the play encouraged viewers to reflect on their place in the universe.

> In terms of content, it got them thinking about it. They have all the facts [in the play], they want to go out and make their own opinions. It jogged their mind a bit. (Actor)

> I definitely had one or two [people] ask about the big bang theory, and how much it was proven. . . . I had a couple ask something like, "Was it all real?" (Actor)

> We'd answer [scientific questions] if we could, but we'd encourage them to go to the exhibit. (Actor)

> A lot of comments focused not on science, but it made people think about their place [in the universe]. (Actor)

CHALLENGES

Challenges faced by the actors included peripheral noise from the area near the performance stage, covering a lot of scientific content in a short period of time, and being knowledgeable enough to answer visitor questions.

> From a science perspective, we were under pressure to keep it short . . . [The play] may have left people wanting to get a replay for certain concepts; it might have gone a bit quick. (Actor)

> I was a little worried about getting [answers to questions] right . . . A reference packet for actors might have been helpful. (Actor)

PERSONAL IMPACT ON MUSEUM STAFF AND VOLUNTEERS

Most of the staff and volunteers who were involved with *CQ* reported that the exhibition impacted them personally and left them thinking about some aspects of it. In addition, many of these individuals had a strong interest in some part of the content of *CQ*, which made their involvement with it especially satisfying and significant for them.

> I think about it all the time . . . I learned a lot, about the cosmos, stars, distance. (MOS interpreter)

> I had the great pleasure of studying these things a little better because I needed to do the preparation . . . My first love in science was astronomy, in middle school; then I decided to go into chemistry instead . . . For me it was coming back to a field I had to leave behind. It was a wonderful feeling. (MOS interpreter)

> Keep in mind that I am trained in astrophysics. I was thrilled with it. (MOS staff)

> I really love it because I always was fascinated with the heavens.
> (MCFTA docent)

The exhibition left many staff and volunteers with a sense of awe and a new awareness of the cosmos and their place in it.

> [*CQ*] rekindled the awe and wonder of the universe in which we live. We opened the weekend that the Columbia was destroyed . . . The tragedy we had experienced was offset by the totality we could see in this exhibit.
> (MCFTA staff)

> It's corny—I look at the stars very differently because of what I learned in the exhibit . . . The stars that are visible constitute an incredibly tiny sense of space, and it was constituted in the gallery in a way I could understand.
> (MOS staff)

> The biggest thing is this concept that people figured all this out. I knew that, but I don't think it was a part of me as it is now. (MOS staff)

> I just marvel at the universe and God's creation. That's my personal belief.
> (MCFTA docent)

Many who worked with the exhibition increased their interest in and knowledge of astronomy and cosmology.

> I'm more apt to pick up an astronomy article. (MOS staff)

> I learned a lot. Before the project, I didn't know much about black holes or speed of galaxies in space. (MOS staff)

> [I'm left with] a general sense of amazement at the speed of the collection of new information. Ninety-two extra solar planets were discovered while I was working [with the exhibit]. Learning about things billions of years old and trillions of miles away is mind-boggling. (MOS staff)

> I know I'm using the Internet more to find astronomy-related sites, and it's firming up my resolve regarding having access [to], if not owning, a telescope. (MCFTA docent)

> I didn't realize there was so much astronomy in the different wavelengths . . . I notice things in the newspaper more, like I saw that the map probe found the microwave remnants of the big bang, and I went on the Web and made copies for teachers, so I notice a bit more . . . It heightened my awareness of what's out there. (MCFTA docent)

Some enduring topics of interest, especially to the demonstration staff at the MOS, concerned the vastness of space, dark energy and dark matter, red shift, the question of time before the big bang, and the possibility of alternate universes.

> [I'm left with questions about] the expanding universe. I have questions about time . . . I don't understand whether time existed or not before the big bang; the non-existence of time and the expansion of space, how to make that register . . . And of course what else is out there that we don't know about. As the universe continues to expand, what happens if the temperature keeps dropping? Alternate universes is something I also have questions about . . . I didn't know about a lot of these things, so I didn't have questions about them. (MOS demonstration staff)

Interpreters also spoke of their love of transferring some of their knowledge and interest to visitors.

> If all the planets line up, if everything works out right, how incredibly satisfying it is to connect with visitors, to give them a glimpse of what science really is and what we're finding out. (MOS interpreter)

Finally, those at both museums were extremely pleased to have their institutions sponsoring such a high-level exhibition on these topics. In addition, several MOS staff and volunteers, interviewed mostly after *CQ* had left, voiced their wish for the exhibition to stay at, or return to, the museum.

> I love it. It's great. I'm thankful that it is here, that I have a chance to see it. (MCFTA docent)

STAFF AND VOLUNTEER SUGGESTIONS

> I guess I would say that people at [other] museums shouldn't be scared of the topic. (MOS staff)

INTERPRETER AND DOCENT VOLUNTEER SUGGESTIONS

Interpreters spent a good deal of time within the exhibition and interacting with visitors at both museums. As a result, many identified some challenges within *CQ* and made some suggestions for improvements to the exhibition. Several of the recommendations concerned specific components, logistical issues, and the training and use of interpreters.

Components

- ***Spectrometer***

  When I first saw the [*Spectrometer*] exhibit, I thought, hey, this is cool. This is really a good set of activities. It has three challenges. It's in the right order. It's demonstrating some cool stuff. Then when I spent a few months in there, I never saw a visitor interact with that spectroscope in the way it was intended, even if I gave them assistance, without the interpreter mode . . . That was really frustrating, because I thought this was really cool, this will get through to people, and I was totally wrong. (MOS interpreter)

  There's a spectroscopy part that allows the interpreters to hook up a light pipe so they can direct light from an object in their hands into the spectroscope. To access that, you have to open the machine with a key. It would be nice to make it easier to do and less error-prone. Sometimes that would break down and have to be fixed. Interpreters liked to be there. (MOS interpreter)

- ***Cloud Chamber***

  The cloud chamber worked like a dream, but it had so much ambient life, you have to cut down on all the lights and have it in a darkened room. It's an expensive machine and people didn't get too much out of it. (MOS interpreter)

  My only disappointment was that when the *Cloud Chamber* exhibit . . . was installed, there wasn't enough information that I could get my hands on. I would have been in heaven to do something about that. (MOS interpreter)

- ***Black Hole***

  Most people using [the black hole] didn't really know what they were supposed to do, or what was the black hole, because there was a star in front of it. Maybe don't let them pilot it but have the motion always go in the same track. A lot of people were tying to go in the wrong direction. (MOS interpreter)

  I may not be able to point to anything that was factually untrue, but I can't imagine someone coming away [from the black hole component] with an accurate understanding of what we do and do not understand about black holes. After the first couple of times I tried to talk to visitors there, it was so frustrating I didn't go back. (MOS interpreter)

- ***Ride Through Time***

  I was working right near [the *Ride Through Time* component]. I ran through it and it got set back to the beginning a couple of times.

- ***Universe in 3D***

  There was a beautiful 3D picture of galaxies through space near me. I'm not sure people understood what they were looking at. Most people looked quickly and walked away. It took me a while to adjust to what I was looking at. Once you spend the time to get adjusted to it, it really was fascinating. It would be nice if people could be helped to understand what they were looking at. (MOS interpreter)

- ***Gravity Probe***

  I never ever went around the *Gravity Probe*. That part could have used some interpretation . . . Unless you had the connection with that exhibit, it made no sense to have it inside the exhibit.
  (MOS interpreter)

- **A variety of components**

  The spectroscope has a 15-second delay when comparing spectra, and visitors often think it's not working. At *Images of Mauna Kea*, the overhead light reflects off the magnifying glass, so it's hard to see the spiral galaxies. There's a typo error in *Night Sky* on the Crab Nebula screen. It says 1045 instead of 1054. *Night Sky* should go from quiet mode to wake-up mode by locking on the home area, so this is a familiar place for everyone. There should be a movement sensor for the *Cosmic Kitchen* so that the narration isn't on constantly, even when it is empty. (MCFTA docent)

- **Introductory panel**

  That gorgeous picture in front completely blocked the entrance. We lost a lot of visitors because of that. We were going to move it ourselves. It blocked the entire view to the exhibit. That should never happen again. (MOS interpreter)

Helping Visitors Through the Exhibition

- **Map of the exhibit**

  For those of us who got training, we understood that the exhibit was divided into major areas—our place in space, time, etc., but I don't think it was clear to any of the visitors who went through that there was an intended sequence to the exhibit. I'm not suggesting arrows on the floor, but a quick overview at the beginning, a little map, what

you can expect to see in the exhibit. There was a little map that we got; why not put that under a piece of Plexiglas? (MOS interpreter)

- **Guided tours**

I don't think people are used to the idea of having live human resources wandering around museum exhibits. Like art museums, you either get organized tours or walk through yourself. Maybe people would be more comfortable if there were guided tours. (MOS interpreter)

- **Advice for docents**

Do your homework, make sure you understand the material. There are times people ask me questions and I say, "I don't know," but if you keep saying, "I don't know," you lose [their] interest . . . .Enjoy what you are doing, be willing to listen . . . It's important to listen as well as talk. Wear comfortable shoes. (MCFTA docent)

Friendliness makes a lot of difference. (MCFTA docent)

Training

- **Training by science educator**

It is way too easy to go over people's heads without even realizing it. The amount of feedback you get directly from visitors is pretty limited. If they don't understand, they don't tell you, they just nod and leave. You probably need someone who is a professional science educator, with the emphasis on educator, to explain to people what you can expect of visitors. (MOS interpreter)

- **Information about each station**

[It would have been helpful if] we could have had a handout that had a picture of each station and a brief description of each station and objective of each that would have been a primer for us when Mary got here . . . [so that] she could deal at a different level. (MCFTA docent)

Additional Suggestions

- **Materials for teachers**

My wife is a middle school science teacher . . . When I saw what Mary had [interpretations], I thought my wife would like it if one of these tubs could go to her class. (MCFTA docent)

- **Covering all the interpretations**

> Without a specific plan of what to cover, we came up with a division of labor that was agreeable to everyone, but we didn't look to see if we were leaving out something important. It would pay to spend a little time identifying what kinds of interpretations you will do and make sure you cover them all. (MOS interpreter)

MOS DEMONSTRATION STAFF SUGGESTIONS

MOS demonstration staff made the following recommendations related to these daily live presentations.

- **Include live presentations**

> I couldn't stress enough that the live presentations add to the value of the exhibit as a whole, conveying concepts in a linear, logical manner . . . Presentations and interpretations add an interactive element that is simply not as possible in a stand-alone exhibit.
> (Demonstration staff)

- **Talk with specialists**

> I would recommend that all of the live presenters . . . talk to a specialist in the area, if possible, an astronomer . . . One of the things I found most valuable was being able to talk to an expert in the field.
> (Demonstration staff)

- **Keep demonstrations unscripted**

> We don't have a script . . . Each educator teaches in a different way and teaches best that way. We don't want to lock them in. That also allows for demonstrations to be improved or have a slightly different twist to it. There's a lot of room for creativity . . . Each institution has a different mission statement, goals, and resources. We wanted to leave flexibility so each institution can adapt for themselves, pick the outlines that work best for them. (Demonstration staff)

- **Demonstrations in the main exhibition hall**

> I think it might be helpful for the *Cosmic Questions* exhibit . . . to have a station there [for demonstrations done by staff.]
> (Demonstration staff)

GIRL MEETS BOY ACTORS' SUGGESTIONS

The MOS actors also had a few suggestions for other sites using the play, concerning promotion and timing of the performances, linkage to the main exhibition, and reference materials for the performers.

- **Promotion**

> Promote it especially to junior high and high school audiences who will understand it a lot more. (Actor)

- **Timing**

> It would be good for a lot of schools. One thing that happened for us was we often performed shows when schools were on their way out, so . . . the timing is key . . . During the week it could have been planned around school groups. (Actor)

- **Location and linkage to the main exhibition**

> We were very far from the exhibit, so it was hard to make a linkage. There should be something in the exhibit that talks about the show. (Actor)

> If you really wanted to connect the exhibit and the play, it would be nice to have a space near the exhibit . . . The exhibit was tucked in a corner. I walked by it four times and I didn't know what it was! But two people on stage arguing, you're going to notice it, so it would be beneficial to have both near each other; you get a double whammy. (Actor)

- **Reference sheet**

> [The actors need] a reference sheet of general ideas, something we could glance over so we're confident of any questions we might be asked by the audience. (Actor)

ADMINISTRATOR SUGGESTIONS

Administrators at both museums had a number of recommendations for institutions that will be hosting the exhibition in the future; these concerned promotion, volunteers, the additional components, training, and installation issues.

- **Internal promotion of all parts of the exhibition**

> There could be something in the exhibit that talks about the show [*Girl Meets Boy*]. (MOS staff)

> People had trouble finding [the main exhibit from the planetarium] because we're on opposite sides of the museum. Or put stars on the floor or something. You need to cross-promote both ways between the two venues. (MOS staff)

- **Use interpreters**

> I would encourage [other museums] to have interpreter programs. They add a lot of richness to the experience, especially with this topic. It helps visitors to talk about it with someone who knows about it. (MOS staff)

> It requires an interpreter, and the need for that cannot be downplayed . . . It dramatically benefits from even having one or two interpreters wandering around. I've been up there watching a lot. For a lot of people afraid to ask a question, an interpreter can [see what they are wondering about and] step in. I think that vastly enhances the experience. It can run by itself, but for the best experience, no. (MCFTA staff)

- **Include live presentations and play**

> They should be sure to figure out haw to have sufficient staff, not only to interpret the exhibit, but also for the live presentations and the play. These add tremendous value to the exhibit. (MOS staff)

- **Don't feel overwhelmed by number of products**

> We produced a lot of products. Don't feel overwhelmed or that you have to do everything all the time. (MOS staff)

- **Add images**

> Depending on the installation space, consider images, not just ours, to enhance the exhibit . . . The interactives leave you wanting to be awed . . . Especially if you don't have a planetarium right there . . . After you've heard those astronomers speak to you, you just want to look up at the stars. (MCFTA staff)

- **Use local expertise to help with training**

> I would invite [other museums] to draw upon their regional expertise. If we didn't have researchers from Harvard getting up to speed, we wouldn't have been able to produce what we produced . . . I'd encourage them to work with those folks for training, content, and resources. (MOS staff)

- **Do your own research**

> I urge them to have fun with it. It seems like a daunting and challenging topic, but it really offers a lot of great science once you

> get into the research. We have made a lot of materials available to other museums, but I know I get a better understanding when I'm doing my own research. I would urge them to start exploring on their own. (MOS staff)

- **Teacher input into design of professional development**

> Get some initial teacher input on the design of the professional development experience. Perhaps . . . surveying the teachers in the middle and high school grades on the best format and best time. (MOS staff)

- **Installation issues**

> It was way overbuilt in terms of the heft . . . They did have some shipping crate problems. They will have to build new crates for some of them. One move and the boxes were busted apart already. (MCFTA staff)

> From an installation standpoint, we were not allowed to begin without their technician at the site. We feel we could have gotten a lot more done. Even when he was here, he personally had to direct everything. They have to let go a little bit and let us do our business. (MCFTA staff)

> Aztec needs to let [Mary] get more involved with the people doing the work. (MCFTA staff)

EDUCATOR INVOLVEMENT

In order to support educator involvement with the *Cosmic Questions* exhibition, both museums sponsored symposia for teachers. Also, staff at the Museum of Science produced a teachers' guide to complement *CQ*, which was available as the exhibition traveled to Michigan.

MUSEUM OF SCIENCE

> I sincerely hope they have more workshops like that. (MOS teacher workshop participant)

Overall Reactions

The developers of the Cosmic Questions exhibition—the Harvard-Smithsonian Center for Astrophysics—in conjunction with the Museum of Science, presented a two-day professional development workshop for educators in November 2002. The goals of the

workshop were to familiarize a group of teachers with the content of the exhibition, and to allow the developers to "pilot" the professional development piece of *CQ*. An early version of the teachers' guide was given to participants for use in their classrooms. In December 2002, evaluators conducted a series of interviews with educator/participants from the workshop.

The four (out of seven total participants) from the MOS *CQ* teacher symposium who were interviewed had very positive responses to the workshop. They found it to be useful, informative, and relevant to their classroom teaching. Respondents reported a strong feeling of connection between the participants and found the presentations interesting.

> I totally loved the workshop. The things that I loved the most were the presentations by the various area scientists on research. I found that immensely helpful. Plus the opportunity to meet with the people who designed the exhibit, to hear what they hoped to accomplish. It helped to orient me when I went in to view it and when I went to orient my students.
>
> (MOS teacher workshop participant)

> I'd recommend it to everybody and I'd sign up myself [if they did it again]. All of the stuff from the workshop I'll continue to use and I'll spread it around, and I've been back to the exhibit several times—three times since the workshop . . . Mary and everyone else did an amazing job.
>
> (MOS teacher workshop participant)

> Mary was incredibly warm and Roy was amazing. And the guy who presented on light and spectrograph. He mentioned work on children's misconceptions about science concepts and I went on the Web to look at his work, and it definitely changed the assumptions I made about what students did.
>
> (MOS teacher workshop participant)

In addition, all the interviewed teachers had shared information from the symposium with their colleagues, and all said they would recommend the workshop to their peers. They especially liked the hands-on nature of their learning experiences, and appreciated the applicability of the activities to a wide age range.

> When I went back to school, I told them they missed one of the best workshops. Very informative instructors, and we brought information to each other. It was a win-win situation; you couldn't walk away without learning and knowing the exhibit, and everyone was asking questions. We had hands-on, and we were like the children and they were the teachers, and we got different ways of working with the children. I said if it happened [again], we should have a professional day and everyone should go, I felt that strongly about it.
>
> (MOS teacher workshop participant)

> Absolutely [would recommend the workshop], because it really gives you a good foundation. I felt that the information was information that could be

> used across the grades. It built teachers' background knowledge and there were enough of a range of activities, or the activities had enough of a range in them, so you could use them for elementary or high school classes.
> (MOS teacher workshop participant)

Although several teachers commented on the small size of the workshop and wished that their colleagues could have benefited from the information provided, one teacher enjoyed the "intimacy" of a small group.

> Unintentionally, the intimacy was amazing because it was a small workshop. The quantity of information and the people I had access to that weekend, was amazing. To have a weekend of time with astrophysicists was amazing. Also because of how generously it was funded, the nice room and food—teachers aren't usually treated that way, and it was nice to share meals with people I was working with for the weekend. (MOS teacher workshop participant)

Impact on Teaching

Teachers reported teaching differently and teaching more about the scientific concepts covered in the exhibition as a result of their attendance at the symposium. The information presented in the workshop affected teachers' lesson planning in their classrooms, giving them more knowledge, understanding, materials, and ideas about how to present more of the content of *CQ* to their students. It increased their confidence and enabled them to focus on the outstanding "cosmic questions" along with the latest scientific theories.

> The presentation of materials in the workshop, and in the exhibit itself, really made me think differently about how much I could teach students, and opened up how complex materials can be presented in a kid-friendly way. I started to teach a lot of new stuff after the workshop.
> (MOS teacher workshop participant)

> The thing that attracted me was the cosmic questions. What I've been exploring in my classroom has been asking big questions that don't have easy answers. That's what *CQ* is founded on, and it gave me more courage to introduce that kind of material to my students—black holes and red shifts and the expanding universe—things I don't understand because scientists don't understand, and it changed my teaching instantly.
> (MOS teacher workshop participant)

PERG evaluators asked participating teachers to comment on their learning of science ideas presented in the workshop. Most of the teachers did identify areas of learning.

> Oh, yeah. Because of the generosity of everyone involved, it made the knowledge seem attainable, so that weekend was a huge developmental leap in terms of my grasp of the content, and then that makes a huge leap in my teaching. I read a few books a week, and now I'm reading books about the universe and scientific exploration. (MOS teacher workshop participant)

> Oh, I certainly did. I first went through on teachers' education night, prior to the workshop. I didn't realize how much information was there. But when they explained it and broke it down [during the PD workshop] it was, "Wow!" there's so much information there. When you go through on your own, you just read some, but when you have it explained, you really want to try the hands-on activities. (MOS teacher workshop participant)

One teacher already had a significant background, but still identified new areas of learning.

> I am a science teacher to begin with, and Earth science and astronomy is my major field, so I went in with a slightly higher background than some of the other teachers. For me, it was just really the exposure to some of the current research, some of the things they are doing with X-ray images of objects, the ability to take images of objects that show the various forms of radiation . . . You can get a whole different sense that this is still a vital energy-emitting object even if it doesn't look like there's too much going on on the visual level. (MOS teacher workshop participant)

Impact on Students

Those teachers who brought their classes to the exhibition found the orientation they received at the symposium to be helpful in designing activities for their students. These teachers felt more prepared for their classroom visits to *CQ*.

> [The workshop] helped to orient me when I went in to view [*CQ*] and when I went to orient my students . . . what their aims and objectives were. I got insights into research projects, what's going on in the field of astronomy. It's not often that I get to hear about the cutting edge, what they were hoping to accomplish with the general public. (MOS teacher workshop participant)

> I was just really prepared for what the exhibit was all about, in a way that I would not have been prepared if I had just previewed it on my own and not had a chance to talk with Mary and some of the other presenters. It helped me to focus on what I wanted the kids to get out of it.
> (MOS teacher workshop participant)

Two teachers who had brought their students to *CQ* reported that these students enjoyed the exhibition and learned from it. They also found that their students left *CQ* with many new questions.

> [My students] enjoyed it. It was a lot. Because it's a work-study program, we had 1 1/2 to 2 hours; we could not do everything that was in there. Their feeling about it was, I thought I was going to answer those 3 questions, now I have more questions I want to find out about.
> (MOS teacher workshop participant)

> It was kind of cool. They had questions before and they found some answers, but they came away with more questions, and I was pleased . . . I asked, "Do you have more questions or new questions?" and they did—tons of questions!

> Everybody had their hands up—everybody had something to say—reactions, opinions, and questions, too . . . Some of them were techno geeks—some questions I couldn't answer, but some went into concepts [bigger questions] and they were totally thrilled with dark matter, loved black holes and supernovae and *Cosmic Kitchen*. (MOS teacher workshop participant)

Other teachers conducted cosmic-related activities in their classrooms. Some teachers described how the exhibition inspired major changes in the relationship of their students and their classrooms to science.

> One part of the workshop that was done about light made me feel my kids need to understand photons, and what's the composition of the universe, and how light is used [to understand the] history of stars. We started reading about the life span of stars and the history of the sun, and it really opened up what I was willing to do with my students and tons of vocabulary. We decorated my room and we put up *Cosmic Questions* trivia for school in the hall because we're reading so much . . . [It resulted in putting] this on the front burner instead of the back, and everyone in school goes by it, and putting Chandra posters on my door, which is next to the office. So that alone gives science a bigger profile in my classroom, and that changes what's happening in my class. My students make jokes about black holes—they understand enough to make jokes. It made a big change. (MOS teacher workshop participant)

> It made so much difference in my classroom. I'm a kinesthetic learner and I got back and I had ideas shooting out of me and went from there. I had many ways of teaching the children, to go beyond the textbooks—and that's what's special about my room. Like the symposium, we get children thinking beyond. (MOS teacher workshop participant)

Teacher Suggestions

Teachers made a few suggestions to further strengthen the workshop. One would have preferred to have more participants, and another wanted more time, especially to cover the topics of dark matter and dark energy. Another teacher suggested providing background information in advance, especially given that some science teachers do not have a background in the field.

> There were a couple of things we didn't have enough time to finish or do. I don't know what the solution would be. I don't know the feasibility of making it a longer workshop. I would have enjoyed a longer workshop, maybe a full two days. The whole field of dark matter and dark energy, we barely got to touch that, and that's one of the really interesting areas in terms of current research. It would have been interesting to hear how they approach it. (MOS teacher workshop participant)

> Sometimes teachers are bumped into teaching science. If there was a little backup information, or when you register say, "Look at this," or "Read about that," so people will have an idea that we'll be starting here and going there,

> so we won't just start with where all the stars are.
>
> (MOS teacher workshop participant)

One teacher raised the issue of bringing moral questions into the teaching of science.

> I think it's possible to talk about how you work with questions in the classroom—a good resource is "Moral Question in the Classroom" . . . It's great. She talks about how this level of discussion in the classroom, how little there is and how teachers stop the probing of big questions in the classroom. That would be an amazing connection, to use that. It talks about the pedagogy of asking big questions. (MOS teacher workshop participant)

Logistical and Implementation Challenges

The administrator who oversaw the development of the teachers' guide and the teacher symposium identified some of the logistical challenges faced by MOS staff. These included the timing of the exhibition and hence the workshop, marketing the workshop to teachers, and the time required to create the guide.

> I think the symposium had an incredible impact on the few people who attended. It was a lot of work for so few people . . . .. I think it could have been the time of year, and maybe the advertising . . . .It wasn't clear in the grant whether we had money to promote it . . . . We would have loved to have had this into the winter an d spring. Obviously we were limited in when we could offer the symposium, because it was there so early in the year. We kept pushing it back. (MOS staff interview)

One challenge was finishing the guide and meeting deadlines while ensuring its accuracy and engaging in a collaborative process.

> Time was the only thing. Folks would have preferred the educators' guide sent to the printer December 1 instead of January 28, but things always take longer. It was an issue of CfA's schedule and their availability. I relied on their review, for scientists to make sure our descriptions were accurate, and the changes went back and forth. That helped the product, but took a long time.
>
> (MOS staff interview)

The writer for the teachers' guide indicated that CfA staff and others were very helpful in developing it.

> I did sit in on meetings with folks from CFA and Irena from the Chandra Observatory—the museum hosted a couple of brainstorming sessions for people working on educational materials—those working on the demonstration, the interpretations, and myself, we sat together and looked at question like, "How do we know the universe is expanding?"
>
> (MOS staff interview)

MIDLAND CENTER FOR THE ARTS

Teachers' Guide

The evaluators were unable to get contact information for the Midland-area teachers who attended a *CQ*-related professional development workshop in Michigan. However, PERG evaluators did receive short survey responses from ten teachers who used the teachers' guide and brought their students to *CQ* at the MCFTA. Most of these instructors taught grades 1–6, and two said the guide was too advanced for their students.

> [I didn't use the guide]. It was quite high-level for most of our students. (MCFTA teacher survey)

Several teachers found the guide useful as an overview and to prepare for the class visit to *CQ*.

> I used it mainly just to refer to and tell my students what would occur. (MCFTA teacher survey)

> Review before the field trip. (MCFTA teacher survey)

Several other teachers used the guide more thoroughly.

> I read it over and followed the suggestions provided. (MCFTA teacher survey)

> I read everything and covered the material with students. (MCFTA teacher survey)

Most of the teachers who used the guide before their museum visit found it to be helpful. They were asked if the guide "enriched your students' experiences." These teachers reported:

> It helped us to focus on what we might see and do. (MCFTA teacher survey)

> They [students] knew what to expect, and we discussed some concepts before we went [to the museum]. (MCFTA teacher survey)

Midland teachers were asked how the guide could be improved. Since many of the teachers taught primary grades, one suggested adjusting the guide for younger children.

> Since my students are so young, it might help to have more and larger pictures. (MCFTA teacher survey)

Another teacher adapted the lessons.

> It was more difficult than my students needed, but I could scale [lessons] back. (MCFTA teacher survey)

Finally, one teacher suggested adding benchmarks to future guides.

> [I'd like] benchmarks and standards for solar system study matched to the exhibit. (MCFTA teacher survey)

FINDINGS PART FOUR: IMPACT ON THE MUSEUMS—BENEFITS AND CHALLENGES

This part of the evaluation report discusses the institutional benefits and challenges that *Cosmic Questions* provided to the two museums, primarily as reported by museum administrators and others who worked with the exhibition. Although a number of items were site-specific, others were similar for both museums.

BENEFITS FOR THE INSTITUTIONS

MUSEUM OF SCIENCE

At the MOS, *Cosmic Questions* achieved the following:

- **Enhanced the reputation of the museum, generally due to the high quality and important content of the exhibition**

> It gave us an example of a really, really good exhibit about the universe. I would like to keep it, frankly. (MOS staff)

> I think it was a great exhibit and I think it did a lot for the museum to have it there. It's pretty much pure science, and it answers an interesting question—"How did this stuff come together?"—the most interesting question there is, I think . . . The museum has good science, and I think this part of it was some of the best. I was impressed by the accuracy, validity of the information. (MOS interpreter)

- **Advanced the main mission of the museum**

> It was an excellent fulfillment of museum promise . . . People pay money to come here to learn science. We have to fulfill their expectations and I think *Cosmic Questions* did that . . . It's one of those exhibits that help us accomplish our mission very well. (MOS staff)

- **Pleased the staff and volunteers with its content of challenging scientific concepts**

> I did have a staff member come down and say this is a really challenging topic and I'm really happy to see we're addressing that. I'm glad to see that it's being done. Other staff members from outside this department commented on that. (Demonstration staff)

> I think the *Cosmic Questions* exhibit was unique. It was asking questions I have not seen around, questions that an exhibit that wants to be more successful with the public stays away from . . . but you are a museum of science, you have a mission to the public, and this exhibit furthers that mission . . . I applaud the museum's willingness to host it. (MOS interpreter)

> I think that the exhibit provided an excellent example of how science touches our lives, affects our lives. Even though cosmological questions may not be of immediate practical importance in most people's work lives, it does concern questions that affect each and every person . . . Cosmology is an area where science has the chance to address some of those issues—How did everything come into being and where is it going? It's an area that ties into philosophical questions that everyone has. It was illuminating to host an exhibit to deal with those questions so clearly and touching on what implications those answers have. (MOS demonstration staff)

- **Increased the knowledge base of staff and volunteers, which will be useful in relation to other exhibitions**

> We found ourselves talking more about models than we have in the past, and the museum is building a new exhibit about making models. It got us more ready for working with that. A few of the people really grew during the development of the program. (MOS staff)

> Since in Science Theatre we insist on a certain amount of research on the topic so that audience questions may be fielded with some assurity, the actors are also increasing their knowledge on scientific subjects. This makes them more "employable" in our viewpoint. (MOS staff)

- **Moved astronomy topics into the main exhibition hall**

> It offered another opportunity to present astronomy, where people could continue their planetarium experience . . . Usually astronomy is limited to the planetarium and many people don't go there, but only go to the exhibit halls. (Planetarium staff)

> *The Real Time Machine* let us experiment with a cosmology presentation outside the planetarium, to expand our repertoire where we don't usually do anything on that topic. Now we are going to continue to do it even though the exhibit is gone. (MOS staff)

- **Provided different ways and more chances to access the content through the thematic approach of the exhibition hall, demonstration, play, and planetarium show**

> A lot of people didn't see *Cosmic Questions* before they saw the demonstration. The show really helped people want to see the exhibit. (Demonstration staff)

I think a lot of people who came to the show wouldn't have gone to the exhibit if they hadn't see the [play]. (Actor)

We could link the program to the exhibit. We could say, "Be sure to see this particular component in the exhibit." It was nice because the show is 35 minutes and . . . there's limited time to spend with visitors. (Planetarium staff)

- **Left behind materials for ongoing use**

We have a traveling planetarium. One of the women who does that is going to use one of the components [from the demonstration] in her program—the radar gun . . . to measure speed using invisible light . . . We wouldn't have developed it if we didn't have the exhibit. (Demonstration staff)

Our volunteers love [the props]. Some of the props are still being used and implemented in other ways. Only a few of the items we were not able to keep here. (MOS staff)

- **Offered an additional high-level resource for teachers and classes**

It really was a great enhancement to our current programming for students and teachers . . . I felt that it brought a lot of strength in astronomy and Earth science ideas . . . It was a benefit because I could promote going to that exhibit in my other programs, because it helped people understand those complex ideas . . . It was an additional resource to offer teachers for their own learning and for their field trips. (MOS staff)

- **Established new working relationships with the playwright, astronomers, Jeff Kennedy Associates (*CQ*'s design firm), and the Harvard-Smithsonian Center for Astrophysics**

The playwright is a very well-known and popular playwright, Melinda Lopez. We'd never worked with her before, and this was an appealing topic to her. It gave us entry . . . My department worked with constituents we hadn't worked with in the past like JKA and CfA . . . We've built relationships with astronomers we can use in the future. (MOS staff)

- **Enabled the funding of high-quality educational materials**

We were able to create a better product, knowing we weren't on a shoestring budget . . . We're printing using beautiful full-color images, and it's so much more powerful as an educational tool . . . So the final product will look very professional. (MOS staff)

- **Assisted fundraising efforts due to the collaboration with NASA and NSF and their reputation for high standards**

  > NSF-funded projects are a stamp of approval, because it is well known [that] it has a rigorous peer review process. So when we are looking for sponsors, it's easier to find a sponsor for an exhibit if NSF has also agreed to fund it. [The developers] also had support from NASA, so they were able to draw on that whole body of resources. When you have cross-agency projects, it brings together the criteria for effective programs for both, and leverages additional funding. (MOS staff)

MIDLAND CENTER FOR THE ARTS

At the MCFTA, an overlapping but different set of benefits were cited by museum staff. *Cosmic Questions* achieved the following:

- **Enhanced the reputation of the museum as a place for high-quality, important, and scientifically-challenging exhibitions**

  > It further enhanced our reputation for doing exhibits at a high level of science . . . It continued us along a path of increasing the level of exhibits and did it in a significant and dramatic way. (MCFTA staff)

- **Provided a good example of a high-level exhibition that integrated science and art, advancing the core mission of the institution**

  > It provides us on the art staff a good example of the nature of things from the science perspective that we can look forward to as we begin to integrate art and science. (MCFTA staff)

  > It was a way for us to fulfill our mission as it relates to science. It provided us a wonderful complement to the Hubble photographs. (MCFTA staff)

- **Established new working relationships with the local planetarium, local university physics professors, the MOS, and the CfA**

  > We loved having the opportunity to reach out to the planetarium which we had no need to reach out to without this exhibit . . . There's a connection between us now because of this exhibit . . . This particular part of Michigan tends to be insular from one small city to another. I hope we struck a blow for regionalism in this kind of work. (MCFTA staff)

  > We've had a totally positive experience working with CfA. Anytime we could work with them again, we'd be pleased to do so. (MCFTA staff)

- **Opened new possibilities due to NASA sponsorship**

  The benefits [of NASA sponsorship] were tremendous. We wanted to embellish the exhibit so we contacted [NASA staff at different sites] and got Hubble pictures, a space suit, transparencies. Because it was NASA-funded, I think they were more likely to cooperate with us. It enabled us to get some great speakers here as well—from NASA, from the Hawaii observatories. (MCFTA staff)

- **Advertising and collaboration led to increased visibility of the museum and planetarium, bringing in new visitors**

  Because of the success of it, it brought people in who may not have visited before, and hopefully we'll benefit by having people come back for other shows . . . It showed us that if we can get the word out, people will come . . . It was the publicity, but also having people who regularly go to MCFTA come here. (Planetarium staff)

  We were well above our average visitorship for the period and we did draw in a lot of people from the surrounding areas. (MCFTA staff)

- **Enhanced the internal teamwork between several of the member organizations within the MCFTA**

  We learned that we really can do a lot as a team. We've always worked by department here, there's always been some territoriality between art, science, performing arts. In these lean economic times, we've learned a lot about bringing those barriers down. Through this, we learned we could really kick ass here as a team. (MCFTA staff)

- **Revealed a maintenance crew eager for new projects**

  We learned that [the maintenance crew] are willing to take on new and exciting projects. We were apprehensive because we thought they would see it as stepping outside of their responsibilities. They loved it. It was more interesting. (MCFTA staff)

- **Provided a good winter activity for families**

  I had hoped this would be a perfect way for families to spend the weekend with their kids . . . in the middle of a cold, grey Michigan winter. And it was. (MCFTA staff)

CHALLENGES FOR THE INSTITUTIONS

MUSEUM OF SCIENCE

Challenges connected to the *Cosmic Questions* exhibit at the Museum of Science were the following:

- **Getting staff and volunteers comfortable with the challenging content of the exhibition**

  > The topic was very complex and there weren't many of us who felt comfortable with the topic at the beginning. There was a lot of catch-up to get enough understanding. (MOS staff)

  > We do not have professional astronomers on staff, so we had the double challenge of becoming comfortable with the topic and vocabulary and research, and then the challenge [of turning] that into the high-quality products we were expected to produce. (MOS staff)

- **Learning to communicate the big ideas to a varied audience**

  > The subject matter is very, very difficult to communicate to the general public . . . The subject matter of *CQ* deals with the broadest questions you can imagine in the world. So communicating this to a family with young children, with teenagers, with the few who have a background in astronomy, fewer in cosmology, is a tremendous challenge. That was the biggest challenge—how to communicate the big ideas behind the exhibit. (MOS staff)

- **Technical problems**

  > Some of the equipment was not working well and the black hole stopped working, which was very important because it was very impressive. (MOS interpreter)

- **Keeping up-to-date with the content**

  > The world of cosmology is changing weekly, it seems . . . It was exciting and shows the dynamism of the research, but that was a product challenge—to make sure we had the latest information. (MOS staff)

- **Space challenges in the main exhibition hall**

  > One of the most inconvenient things, challenging things, was the location of the exhibit—the physical layout and placing of the exhibit, stuck in a corner of the museum. The way it was set up in that space, the introductory panel with the big picture on it looked like a wall preventing visitors from noticing there was an exhibit there. (MOS interpreter)

- **Space challenges for the related presentations**

  I think the biggest challenge was finding the correct space for the play in the museum. An intimate, beautiful piece, but that space is far away from everything . . . and near a noisy exhibit. (Actor)

- **Scheduling issues for the demonstration and play**

  There were internal scheduling issues. We ended up doing the live presentations and play on the same stage. We were running into ourselves because there were so many things happening on the stage. (MOS staff)

- **Challenges using actors**

  If a museum is starting to use actors, they should be cautioned that actors cerate problems, but are a powerful way of educating . . . If you have good actors, they are going to have scheduling problems . . . Actors tend to not know a lot of science, but you want them to be science educators. Museums are not the best place in the world to put on plays. Actors are used to being the reason people come to a place . . . You have to choose your actors carefully—people who will not be affronted if the audience leaves. (MOS staff)

- **Symposium timing, content, and promotion for educators**

  We would have loved to have had this [exhibition] into the winter and spring. Obviously, we were limited in when we could offer the symposium, because it was there so early in the year . . . The challenge was to try to reach all the teachers, that whole marketing piece. Trying to determine what would be a good balance [at the symposium] between content, the experience with the exhibit, and process. (MOS staff)

- **Meeting the high standards, especially for reporting, required by the funding agencies**

  Having been granted funding from both organizations [NASA and NSF], you understand you're being held to a high standard and identified as an organization they can trust to produce high-quality, accessible, accurate products, so there are standards expected in return for their funding you . . . [You have to report] more extensively than for a private foundation. (MOS staff)

- **Providing enough promotion and publicity, inside and outside the museum**

  I didn't see or sense a lot of internal enthusiasm for creating [*CQ*] as a big event. . . . *The Quest* drew a lot of people's attention away, just when it was needed to promote *CQ*. (MOS staff)

> I would have liked to have seen this exhibit get more attention and it was intended to, but we got the Egypt exhibit here at the same time . . . [*CQ*] was going to get more museum-wide attention if it hadn't started at the same time. (MOS staff)

MIDLAND CENTER FOR THE ARTS

At the MCFTA, challenges connected to *CQ* included the following:

- **Training the educational staff**

> It was challenging getting the education staff up to snuff, getting to guide people to what is fascinating about it. (MCFTA staff)

- **Technical issues and problems**

> I think the greatest challenge that we faced [was] a lot of technical bugs [that had] to be worked out . . . I think we're leaving the exhibit in much better shape than we found it, by working out the bugs. (MCFTA staff)

> It required an upgrade in one of our systems . . . It was a challenge to upgrade the system, but it's great because now we have other shows we can run. We had a bit of stress to do the upgrade in a short period of time. (Planetarium staff)

- **Resolving installation frustrations**

> When we could . . . deal directly with Mary, everything went fine. ASTC got in the way of allowing my staff to function, with the very best of intentions . . . Sometimes they would allow three days for something we could do in four hours . . . Once we got over the fact that ASTC didn't need to guard the exhibit against us, we were fine. (MCFTA staff)

> I think we could have been more efficient, especially when you're looking at paying people overtime . . . We wanted to install this exhibit on weekdays, but had to install it on a weekend . . . And that there wasn't a good installation document to work with was a challenge. (MCFTA staff)

- **Space challenges, including size and weight factors**

> The size—we're a fairly small museum, so the size and the weight were of concern. (MCFTA staff)

> We really didn't do a good job estimating the size . . . It's a real tribute to the exhibit that it can stand being split and still be a good experience. (MCFTA staff)

- **Exposed a need to update the permanent exhibition**

  The level of sophistication the exhibit employed is a watermark. It leaves you looking at everything else in your permanent exhibit and realizing you need to update. (MCFTA staff)

DISCUSSION OF FINDINGS

CONTEXT AND GOALS FOR VISITORS

While the *Cosmic Questions* exhibition presents viewers with extensive amounts of scientific information, it also asks visitors to personally connect with their experience of the exhibition—to construct their own meaning from the content; to reflect on their own, personal relationship to what it portrays; and to ask their own often unanswerable questions about the universe. In fact, the developers placed as great or greater importance on visitors' abilities to make personal connections with the content as on the learning of facts, although the latter is also a very important aspect of *CQ*.

In this context, the exhibition had four major goals for its viewers, as described in project literature:

1. Learn about key astronomical and scientific concepts, including:
    a. The composition of the universe and its vast scales of space and time
    b. The physical and analytical tools of the astronomer; learning from light
    c. The interplay of models, evidence and explanation in forming our understanding of the universe
2. Increase their understanding of the nature of scientific inquiry by engaging in activities that explore "how we know" about the universe.
3. Encounter various human perspectives (historical, personal, cultural, artistic, etc.) on age-old cosmic questions.
4. Reflect upon their own ideas about the universe and the meaning and relevancy of the ongoing human search for answers to cosmic questions.

Although it is difficult to attribute causality, visitor statements indicate that the *Cosmic Questions* exhibition succeeded in meeting these goals, usually to a high degree. *CQ* definitely contributed to visitor curiosity, reflection, and learning about the topics presented. The exhibition stimulated many visitors to think, to ask questions, and to develop a greater sense of their personal connections to the universe. Some respondents, including many staff and volunteers who worked with or around the exhibit at the two museum sites, were touched quite deeply by their interaction with *CQ*.

According to visitor responses, a majority of those who experienced the exhibition developed new understandings and learned new information about a wide range of topics. This new knowledge included information about the tools of the astronomer. However, visitors were often left unaware of the significance of these tools, or how they were actually used in scientific exploration. It appeared that visitors also needed more help in identifying the methods scientists use in forming their understandings of the universe, but limited data was collected on that topic.

The exhibition succeeded in providing multiple pathways for visitors to connect with the experience of space science. Visitors mentioned a variety of components while talking about the exhibition. Each of the related components—the play, demonstration, and planetarium show—reached different audiences and offered overlapping but unique experiences to visitors. Also, for those who were interested in or who spent enough time at the exhibition to explore it thoroughly, *CQ* succeeded in conveying a variety of historical, personal, cultural, and artistic perspectives on the universe.

Cosmic Questions also had a wide appeal—across age ranges, level of prior scientific background, and religious/spiritual beliefs. Young visitors frequently expressed a similar level of curiosity and learning as older visitors, revealing a high level of reflection about the topics and issues presented. Experts in the field often found particular information that was new and of interest to them, while novices found much of the exhibition to be quite accessible.

Most of those who talked about spiritual or religious topics were comfortable with the content of the exhibition. Of those who expressed strong religious beliefs, the majority found no contradiction between their beliefs and *CQ*'s presentation about the universe and its creation; in fact, many felt that the exhibition supported their beliefs. Others felt that the exhibition did differ from at least some religious beliefs, and often shared their uncertainty as to what to believe. A small minority of visitors disagreed with information presented about the big bang and challenged the scientific evidence supporting it.

PROJECT IMPLEMENTATION

Cosmic Questions is an innovative traveling exhibition that has brought extensive benefits to the sponsoring institutions and has also posed some logistical and implementation challenges. Both MOS and MCFTA felt the exhibition enhanced their reputations, advanced their main missions, and helped them to establish new working relationships, along with other benefits. Both also experienced several challenges, including some related to the training, technology, and space needs of the exhibition. While implementation varied somewhat at the two sites, both museums were extremely pleased with their overall experience with the exhibition. Staff and volunteers who worked with *CQ* made

important suggestions about improvements to the exhibition and its implementation (which can be found in Part Three of this report.)

The interactive nature of the *Cosmic Questions* exhibition led to extensive and sometimes extended technological problems with some of the components, which created frustrations for both visitors and staff. Also, installation difficulties created unexpected and unwelcome hurdles, especially in Midland. These issues marred what was otherwise considered an excellent experience for the institutions and their visitors. Hopefully these issues will be resolved.

Another important aspect of the implementation of *CQ* concerns educator involvement. While available data showed that the educator symposium and teachers' guide could be quite useful to teachers, recruiting teachers for the symposium proved problematic. Reaching more educators will enable *CQ* to have an even greater impact.

Finally, communicating the full scope of the exhibition and capturing the imagination of potential visitors is key for bringing in an even larger and broader range of attendees. Since the exhibition developers are most able to accomplish this, they may want to consider preparing promotional materials to travel with the exhibition.

DIFFERENCES BETWEEN THE SITES

While all of the components of the main exhibition traveled from Boston to Midland, there were also numerous significant differences between the two museums and their implementation of the exhibition. However, data indicate that visitors at the traveling site, MCFTA, expressed generally similar responses and experienced similar positive outcomes as those at the pilot site, MOS. The only significant differences in the findings were in the follow-up phone interviews—MCFTA visitors reported far fewer lingering questions as a result of viewing the exhibition than MOS visitors; they also cited a much smaller variety of components when asked what they remembered most, and almost exclusively the most interactive components. (Approximately half as many follow-up interviews were conducted with MCFTA visitors.)

The differences at the two museums include:

- Identity of museum
- Size and structure of museum
- Relationship to other exhibits
- Visitor population
- Organization of *CQ* exhibition within the museum

- Difference in interpreter/docent roles
- Use of related activities (play, demonstration, planetarium show)
- Relationship to exhibit developers
- Promotion and publicity of *CQ*

TYPE OF MUSEUM AND VISITOR POPULATION

The Boston Museum of Science and the Midland Center for the Arts are two extremely different institutions. The MOS, a large, well-known and well-respected urban science museum, presents multiple permanent and traveling exhibitions simultaneously. It supports a large, expert staff and houses a planetarium and Omni theater on site.

The MCFTA is a much smaller institution than the MOS, is just beginning to present large traveling exhibitions, and hopes to host more. It is a very unique and remarkable institution located in a community of less than 50,000 people, which gives it tremendous support. The MCFTA is comprised of eight collaborating arts organizations with a mission to integrate science and the arts. The building includes two state-of-the-art theaters as well as the exhibition halls. Despite the differences, the permanent collections of both institutions include a wide variety of learning possibilities including many high-level interactive, hands-on components geared to visitors of all ages.

Because of its small size and open-style of architecture, it was rare for a MCFTA visitor to bypass *CQ* (all building exhibits could be experienced in a single visit). It appeared that more Michigan visitors took the time to fully explore the content of those computer stations most dense with information, such as *Explore Mauna Kea, Explore Chandra,* and *What's Up in Space?* Although the exact cause is unknown, those at the MCFTA may have had more time to spend in the exhibition, or found this type of presentation to be more unusual than MOS visitors. At the MOS, with its large number of exhibits and activities (it is not possible to see everything in one visit), some visitors reported that they were already overwhelmed by information and input by the time they reached *Cosmic Questions*, and many others never reached *CQ*'s back corner location.

The two museums' identities and communities also affected the types of visitors who experienced the exhibition. Boston visitors included many tourists from around the country and around the world, along with local and regional residents; at MCFTA, the majority of visitors were from Midland, with very few from further than fifty miles away. Boston visitors attended in a wide variety of configurations, including singles, adult groups, and family groups. Midland visitors attended primarily in family groups, with a small number in adult groups. At both sites, the experience of adults with children, especially younger children, was usually limited by the needs of these children. This had a

greater impact on Midland visitors because of the greater number of families in our sample.

Because of their locations, the MOS hosted more visitors from the northeastern US, while the MCFTA hosted almost entirely Midwestern visitors. Without trying to identify differences in those populations, these geographic groups often represent different cultural groups as well. One possible related difference in visitor responses concerned religion—Midland visitors were more likely to talk about religious topics, especially creationism, than visitors in Boston.

ORGANIZATION AND IMPLEMENTATION OF *CQ*

Layout and Installation

The layout of the exhibition varied greatly at the two sites, and it appeared that these variations likely resulted in slightly different visitor experiences. Both sites had to make compromises because neither had one area large enough to accommodate the entire exhibition.

In Boston, the *Black Hole* and *Dark Matter/Dark Energy* components were placed in two rooms just outside the main gallery. It appeared that over half the visitors either visited one or two of these rooms or the main exhibition hall, but not both areas. Largely due to the lack of signage, there was no assistance to help visitors realize the connection between the exhibition gallery and *Black Hole/Dark Matter* areas. The play, demonstration, and planetarium show were located on the opposite end of the museum, and visitors to the main gallery were not notified of these activities, although visitors to the related activities were encouraged to attend the *CQ* exhibition.

In Midland, for the first several months, *CQ* was divided into two sections, with other exhibitions separating *CQ*. For some of this period, signage (illuminated stars on the floor) guided visitors to the back part of the exhibition, and museum guards and volunteers played an active role in assisting visitors to the complete experience. Thus, most, but not all, visitors to Midland were aware of the entire exhibition.

Secondly, exhibition components were organized, laid out, and lighted in different ways at each site. The organization and layout of *CQ* appeared to have some influence on visitor interaction with particular components. The most striking example was the position and lighting of the *Cosmic Calendar*. In Boston, this component was centrally located and well-lit; it was often mentioned in exit interviews and both interactive and casual observations revealed frequent visitor interest. However, in Midland, this component was in a dimly-lit back room and required a visitor to get close to it to see what it was; it was rarely mentioned in visitor interviews. Thus, the layout and design decisions for *CQ* at future sites can have important implications for the visitor experience.

A third factor concerning layout was the entrance to *CQ*. In Boston, the large opening panel seemed to obscure the exhibition from some potential visitors. Midland visitors first encountered the large Milky Way mural as they entered the floor with the exhibition, which appeared to immediately draw them into *CQ*.

Another feature of the MCFTA's role as a traveling site concerned installation problems. While the exhibition developers were found to be extremely responsive and easy to work with, those in charge of the installation were not. In fact, MCFTA administrators found that the involvement of the developers was essential in resolving differences and making the implementation process acceptable.

Supporting Features and Promotion

Boston and Midland also implemented supporting features of the exhibition differently. MOS performed the demonstration and play daily, offering visitors a chance to more fully understand and interact with the ideas of *CQ* and museum staff. The on-site planetarium provided easy access to a related show, for which Midland visitors had to travel ten miles. (In Michigan, the museum and the planetarium advertised each other's presentations and offered dollar-off coupons.) With less resources, Midland decided not to include the play or regular demonstrations with *CQ*, but rather to sponsor evening programs and *Science Sunday* lectures. One of the Sunday programs consisted of a demonstration presented by a MOS staff member. Some visitors at both sites were eager to engage personally with knowledgeable staff, especially about some of the more challenging concepts covered by *CQ*.

Volunteer docents in Midland primarily offered assistance to visitors with exhibition components, while in Boston, volunteers also presented supplemental interpretations designed especially for *CQ*. These interpretations, although often bypassed, gave Boston visitors additional access to *CQ* content and more openings to learn from volunteers. While at least some volunteers at both sites brought extensive prior knowledge to their work, those in Boston received more training and more support to delve deeply into the material and expand their own learning.

MCFTA's approach is likely a function of the size and nature of the institution, but also may be related to being a traveling site. MOS, because it developed the educational materials for *CQ*, provided an intense learning environment for anyone working with the exhibition. MOS staff and volunteers alike benefited from the need and challenge of thoroughly understanding the scientific concepts, which they greatly enjoyed. Those Midland volunteers who also independently explored these concepts (in addition to reading training materials that accompanied the exhibition), experienced similar benefits.

Finally, promotion of *CQ* was handled very differently at the two sites. MOS devoted most of their extra publicity resources to a general-interest traveling exhibit (*Quest for Immortality*) that arrived at the museum at about the same time, due to scheduling changes. Administrators felt that *CQ* would primarily be of interest to current museum-goers, and focused instead on expanding their visitor base by publicizing the other program. MCFTA, however, undertook an extensive publicity campaign with the goal of bringing in new visitors, which they felt they did, although not as many as they had hoped. MCFTA also promoted the exhibition heavily within the museum itself, including a special section in their museum shop, which MOS did not. This may have resulted in a somewhat broader visitor population with a different level of prior scientific interest and understanding.

Despite all the differences between the two sites, the *Cosmic Questions* exhibition offered generally positive experiences for visitors at both locations. Most visitors left with more knowledge and more thoughtful reflections, and they were more curious than when they had entered. In addition, many staff and volunteers at both sites felt personally and professionally enriched through their experience with the exhibition.

APPENDICES