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Program Evaluation • Consultation • Market Research

The Black Holes Experiment Gallery

Summative Evaluation

Submitted to
Harvard Smithsonian Center for Astrophysics

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August 2010
NSF grant # 0638963

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Introduction

The Black Hole Experiment Gallery (BHEG), a project by the Smithsonian Astrophysical Observatory (SAO), included a traveling exhibit and an accompanying website that aimed to engage museum visitors and youth collaborators on the topic of black holes. The project used materials that explore current knowledge and unanswered questions regarding the audience's understanding of black holes.

According to SAO, the intended impacts for exhibit visitors and for youth collaboration teams were:

1) increased engagement, awareness, and interest in current astronomy research among participants who will possess a wide range of incoming experiences, knowledge, and interests; and
2) an increase in participants' factual knowledge, conceptual understanding, and instances of how they understand the ideas of gravity, black holes, tools and techniques of astronomers, and theory and evidence in science.

Goodman Research Group, Inc. (GRG), an evaluation research firm in Cambridge, MA that specializes in the evaluation of educational programs, materials, and services, conducted the summative evaluation of the BHEG project.

BHEG Project Description

Table 1 presents the deliverables that were promised in the BHEG proposal, all of which were delivered between 2007 and 2010.

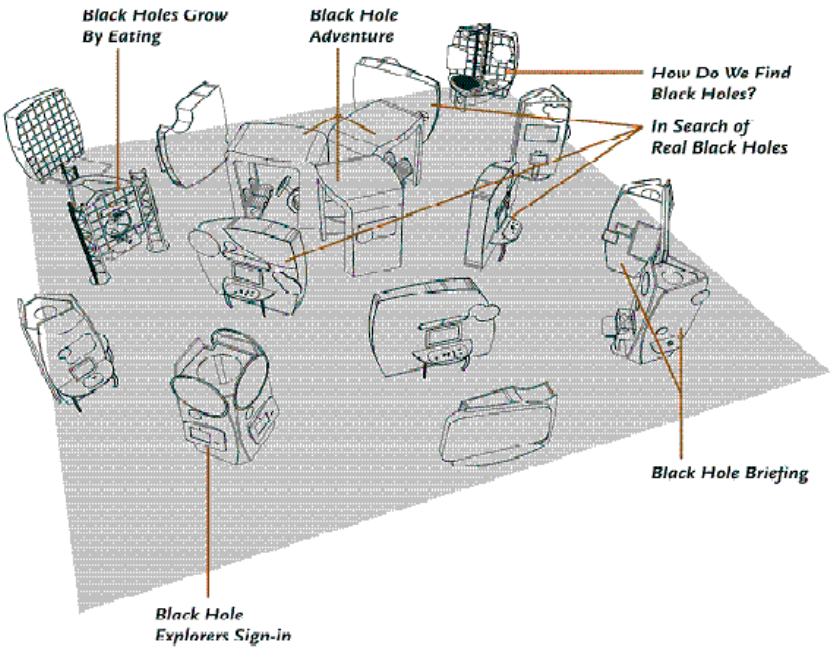
Table 1
BHEG deliverables

Deliverables	
A 2500 sq. ft. traveling exhibition that explored the nature of black holes, gravity, scientific research, and meaning-making	✓
Use of multi-user activity stations and diverse learning modalities at the exhibit stations	✓
Educational materials and programs that supplement the exhibit experience	✓
A web site that consolidates and extends visitors' learning, while personalizing their visit to the exhibit	✓
Innovations	
Youth and adult collaboration during the exhibit design phase that led to the inclusion of youth-designed elements in the exhibit.	✓
Networked technology that would personalize visitors' experiences during the exhibit and help collect useful data on visitor learning.	✓

BHEG exhibit layout and station descriptions[1]

Although the layout of the exhibit differed at the different venues, Figure 1 below portrays one version of the exhibit layout. Below the figure are brief descriptions of all the stations at the BHEG exhibit.

Figure 1: BHEG exhibit layout



Black Holes Explorer Sign-in
At the start of the exhibit, visitors used a touch-screen computer station to choose a nickname and take a digital picture or avatar image to create their own bar-coded *Black Hole Explorer*'s *Card*. Throughout the rest of the exhibit, they could use their Explorer's Card to collect discoveries and generate a personalized website that only they could access (with the PIN number on their card) to share with friends and family.

What's on the Horizon for Black Hole Research?
This component was comprised of a changeable graphic panel and video (updated remotely by Smithsonian Astrophysical Observatory) that highlights a variety of modern black hole research facilities—from the Chandra X-ray Observatory to the CERN Large Hadron Collider.

[1] Source for descriptions and pictures: http://web-bh.cfa.harvard.edu/ATE_walk_through/BH_walk_through.aspx

What is a Black Hole?
This interactive visualization let visitors explore the extremes of gravity near massive objects and the distortions of space and time predicted by Einstein.

Figure 2: *What is a black hole?* Station

Where are Black Holes?
This wall photo of the night sky and Milky Way showed the mapped location of many prominent black holes in our galaxy, using visitor-activated LEDs.

Snapshots in the History of Black Holes
This multi-sided graphic display presented highlights in the historical understanding of how black holes warp space and stretch time.

In Search of Real Black Holes …Weigh a Black Hole!
Visitors used a simple orbital model to determine the actual weight of our galaxy's supermassive black hole, and recorded their results to their online Black Hole Explorer's Journal.

Figure 3: *In Search of Real Black Holes …Weigh a Black Hole!* Station

In Search of Real Black Holes …Take Their Temperature!
Visitors explored infrared, visible-light, and x-ray images of nearby galaxies captured by NASA telescopes that detect warm (Spitzer), hot (Hubble), and superhot (Chandra) objects in space.

In Search of Real Black Holes … Explore a Feeding Black Hole!
At this computer station, astronomer Dr. Elizabeth Blanton guided visitors as they investigated and recorded their thoughts about real astronomical images of these surprising jets created by supermassive black holes at the centers of galaxies.

Do Black Holes Matter? Simulate the Universe!
This component allowed visitors to examine the role black holes play as galaxies collide by investigating a state-of-the-art computer simulation.

How Do We Find Black Holes?
Visitors rolled steel ball bearings across a table with hidden magnets that distorted their paths and tried to figure out where the hidden magnets (representing black holes) are located.

Figure 4: *How Do We Find Black Holes?* Station

Energy from Gravity
This playful ball machine sculpture by kinetic sculpture artist Jeffrey Zachmann explored the physics of falling and the idea that gravity provides the energy that powers the amazing phenomena around black holes.

Got Gravity? (Black Holes Grow by Eating)
At this teen-developed activity, visitors used one of two different-sized spherical nets (representing black hole event horizons) to capture swirling lightweight foam nuggets (representing matter in our galaxy) to "feed" their black holes.

What's Inside a Black Hole?
This video component presented a visualization of a theoretical journey into a black hole created by astrophysicist Andrew Hamilton.

Is It True What They Say About Black Holes?
At this teen-developed media station, visitors selected a video clip related to black holes from a variety of movies and television shows and made a guess as to the scientific accuracy of the clip before receiving a teen guide's explanation of scientists' answers to the same question.

Black Holes Inspire Our Imagination
This display panel explored the role black holes have played in pop culture, as metaphors and as fodder for art, music, and literature.

Black Hole Adventure
Visitors entered one of three "excursion pods" and embarked on an adventure to the black hole at the center of our galaxy. They explored the phenomena around the black hole, including warped space, the slowing of time, and the dangerous magnetic fields and radiation that could leave them stranded on their cosmic adventure.

Black Hole Explorers: Add to Your Journal
At this station, visitors could request images of objects in space that harbor black holes, using a real robotic telescope that will take their image that night. They could also send a black hole-themed e-card, ask a question of that month's featured black hole scientist, or preview their online journals.

Project Innovations

The two innovations of the BHEG project that were explored through evaluation activities are:

1) The inclusion of significant input from youth collaborators in the exhibit's design and development phase in order to achieve improved audience impact. Two separate groups of high school summer interns participated in this collaboration with adults on the SAO team. These were a youth group from the Massachusetts Institute of Technology's Youth Astronomy Apprenticeship (YAA) program in Cambridge, MA, and a summer internship youth group from the Chabot Space and Science Center (CSSC) in Oakland, CA. The collaboration resulted in two of the final exhibit stations titled "Got Gravity" and "Is It True What They Say About Black Holes?," as well as multiple online video projects (http://www.galaxyexplorers.org/blackholes/index.asp)

2) The use of networked exhibit technologies to personalize and enhance the visitor experience of science inquiry, both within and beyond the exhibit gallery. The project was a test-bed for the use, within a traveling exhibition, of laser bar-coded identification cards, networked exhibit stations, and web-content authoring systems to support ongoing visitor engagement beyond the walls of the museum.

   Visitors at the exhibit became black hole explorers. They got an opportunity to make predictions, gather evidence, and draw their own conclusions. Visitors could also extend their learning beyond the exhibit

experience; using the identification tags they could personalize their observations, create a personal journal and website, and access it from home.

Figure 5: Black Holes Explorer Card

Methods

GRG used various sources to collect evaluation data[2]:

- To evaluate the youth-adult collaboration in the project, GRG collected data from the youth and the adults using three different measures:
  - Youth focus groups (which assessed the students' experiences with the exhibit projects and the collaboration with the BHEG project team),
  - Adult interviews (which focused on the adults' impression of how well the collaboration with the students in the exhibit design process worked), and
  - Youth pre and post surveys (which assessed the changes in student knowledge about black holes and attitudes toward learning about them).

- To evaluate visitor outcomes at the exhibition, GRG used a multi method approach:
  - Paper-pencil surveys, observations, and exit interviews conducted with a sample of visitors at the first three museum sites that hosted the exhibit between June 2009 and May 2010.

  - Follow-up online survey to a sample of exhibit users six to nine weeks after their visit to the exhibit.

  - Analyses of data collected through the network technology at the exhibit. As a part of the sign-in process, the visitors answered a question related to their attitude toward, knowledge about, or interest in the concept of black holes. At the end of the

[2] This report's Appendices contain more details on the methods used in the summative evaluation and copies of the instruments.

exhibition at the sign-out station the visitors answered another question from the above pool of questions. The answers to the questions at the sign-in stations provided the pre-experience data and those at the sign-out station provided the post-experience data for analysis.

Data were collected at three different venues that hosted the exhibit between June 2009 and May 2010:

- Museum of Science, Boston, MA (June 21, 2009 – September 7, 2009)
- McAuliffe-Shepard Discovery Center, Concord, NH (September 26, 2009 – January 7, 2010)
- Springfield Science Museum, Springfield, MA (January 30, 2009 – May 9, 2009)

The three venues were very different in terms of their size, scope, focus, and visitorship. The Museum of Science, Boston was the biggest of the three, with maximum visitorship. The Springfield museum was the second largest, and the McAuliffe-Shepard Discovery Center was the smallest with its recent shift from a planetarium to a science center.

Results

The National Science Foundation (NSF) has prepared an evaluation framework that identifies five broad categories of potential project impact. These categories are applied to projects that target *public audiences* by means of an informal STEM education or outreach.[3] The five impact categories are: awareness, knowledge or understanding, engagement or interest, attitude, behavior, and skills.

The findings from the summative evaluation are organized according to the BHEG project's intended public audience impacts. Following these impact categories, tracking and timing results[4] and results related to the two innovations of the project are presented.

Impact Category A: Awareness, Knowledge, Understanding

Visitors demonstrated increased knowledge about the astronomical phenomena of black holes. The use of a Black Holes Explorer Card helped visitors learn about black holes.

The visitors'[5] gain in knowledge related to the phenomenon of black holes was evident from multiple data sources. First, visitors leaving the exhibit ("outgoing visitors") knew more about black holes than visitors entering the exhibit

[3] See http://informalscience.org/researches/EvalGuide_work.pdf for more information on the evaluation framework

[4] Tracking and timing refers to data related to the time spent by the visitors at the exhibit and their behaviors at each exhibit station.

[5] The original BHEG proposal refers to visitors as "Exhibit visitors ages 10 and up."

("incoming visitors"). For each of eight content questions, the outgoing visitors had a higher percentage of correct responses than did the incoming visitors. Four of these differences were statistically significant, indicating visitors learned the most about what black holes are, what x-ray evidence for black holes looks like, the presence of black holes in the universe, and the activity of black holes (See Table 2).

Table 2
Respondents' Increase in Content Knowledge

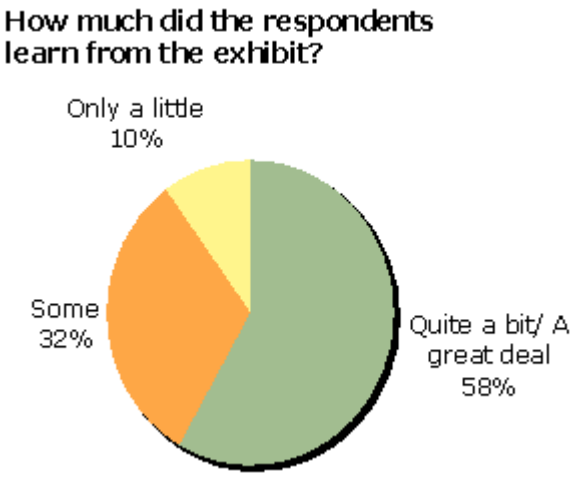
Content question on the pre (sign-in) and post (sign-out) stations[6]	**% of correct pre responses**	**% of correct post responses**
What are black holes?	47%	59%*
How do astronomers determine that black holes exist if they are black and don't emit light?	29%	31%
What evidence for black holes can you notice in this x-ray telescope image of the galaxy Centaurus A?	35%	42%**
What evidence for black holes can you notice in this x-ray telescope image of the Sombrero Galaxy?	15%	18%
What evidence for black holes can you notice in this radio telescope image of a field of galaxies?	25%	27%
Say true or false: Only a few galaxies in the universe have black holes.	49%	62%*
Say true or false: Almost every big galaxy in the universe has a giant black hole at its center.	50%	54%
Say true or false: Black holes have periods of high activity and periods of low activity.	54%	60%***

N varies between 801 and 2320
* p = .000, ** p = .001, *** p = .005

Second, outgoing visitors' ratings of their knowledge of black holes (mean = 3.0, N=905) were significantly higher (p=.000) than those of incoming visitors (mean= 2.7, N = 2279).[7] In other words, sixty-two percent of visitors indicated that they had at least some knowledge about black holes on the post in contrast to fifty-one percent indicating the same on the pre. In addition, 90% of outgoing visitors self-reported learning something new from the exhibit, as shown in Figure 6.

[6] For correct responses to these content questions, refer to Appendices
[7] Ratings based on a 5-point scale where 1 indicated n*othing* and 5 indicated *a lot*.

Figure 6



The visitors' self ratings regarding knowledge gain differed significantly based on at which one of the three museums they saw the exhibit. The percentage of respondents who gave the top two ratings on a five-point scale for knowledge gained at the exhibit was 52% at the Museum of Science, Boston, 56% at the Springfield Science Museum and 72% at McAuliffe-Shepard Discovery Center ($p = .001$).

Finally, one of the project's specific knowledge impact statements was *"After visiting the exhibit, audiences will be more likely to be able to identify properties of black holes such as their location in space and their characteristics."* Of the 262 outgoing visitors who were interviewed, 61% were able to articulate properties of black holes that they learned as a result of their exhibit experience.

Significantly more visitors who had created and used the Black Holes Explorer Card (80%) were able to name the specific characteristics of black holes, compared to those who had not created a card (56%, $p=.000$). The specific black holes characteristics that visitors reported learning from the exhibit are presented in Table 3. (There were no differences in knowledge gains by gender or age.)

Table 3
Black Holes Characteristics Learned by the Respondents

Characteristics of black holes	Examples of respondent responses	Number of respondents
Temperature around a black hole	• How they (black holes) can be hot and cold	38
Black holes do not suck	• That black holes don't suck things like stars in.	38
What's inside a black hole	• What actually goes on deep inside or on the other side of a black hole • What happens at the core of a black hole?	31
How black holes are created and how they grow	• That stars explode and implode. Large stars create black holes. • How they get bigger by devouring stars.	28
Weight or size of a black hole	• That they (black holes) are really big	21
Rules of time around black holes	• What are rules of time and space on interior • If time stops in a black hole. • How fast time moves inside the event horizon.	19
What lies beyond a black hole, beyond the event horizon, or what a black hole leads to	• What happens when you come out the other side (of a black hole)? • Still don't know where they (black holes) lead to.	17
Location of black holes	• They (black holes) are all over our galaxy.	12
Number of black holes	• Learned that there are a lot of them (black holes)	7

N = 262

Visitors increased their knowledge about how scientific discovery relies on evidence and models.

Sixty-three percent of the 260 visitors who were interviewed were able to put into words the methods used by scientists to collect information about black holes (See Table 4)[8]. Fourteen percent of these responses were categorized as sophisticated responses that not only mentioned the scientific methods but also explained them.

[8] Of these 260 visitors, 67% (N=176) had used the Explorer's card and of them 61% (N=107) were able to give correct responses.

Table 4
Respondents' Responses to Indicate Knowledge about Scientific Methods

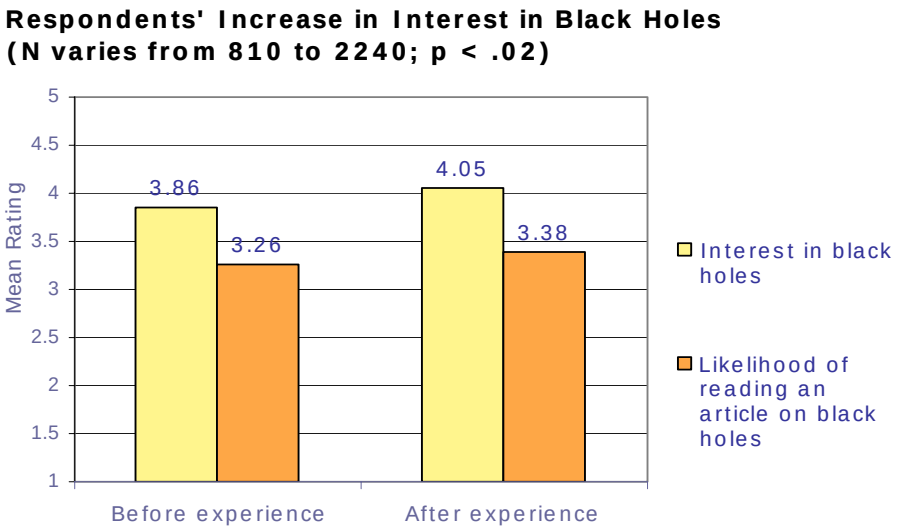
Response category	Examples of actual responses	% of responses
Correct response sophisticated	"By studying light as it bends around a black hole, using telescopes." "By monitoring orbits of objects around BH." "It's hard. Look at paths of stars around black holes, take infrared pictures, and use x-rays."	14%
Correct response unsophisticated	"Using telescopes" "Using satellites"	49%
Incorrect response / I don't know	"Send people into them" "With magnets"	37%

Impact Category B: Engagement, Interest

Exhibit visitors increased their interest about the astronomical phenomena of black holes.

Compared to incoming visitors, outgoing visitors were more interested in black holes and were more likely to say they would read an article about black holes (See Figure 7).

Figure 7



As confirmation of this difference between those entering and exiting the exhibit, 85% of outgoing visitors (N = 728) self-reported that they were either *a little more* (28%) or *a lot more* (57%) interested in black holes as a result of their BHEG experience.

Visitors expressed a sense of personal and social engagement with scientific ideas.

One way of assessing the personal and social engagement of visitors was to measure the extent to which they enjoyed the exhibit. Eighty nine percent of visitors (N = 924) indicated that they enjoyed the exhibit either *quite a bit* (27%) or *a great deal* (61%), the top two ratings on a five-point scale. The younger population of visitors enjoyed the exhibit more than their older counterparts. The data indicated that visitors' self ratings related to enjoyment of the exhibit differed significantly based on the host museum. The percentage of respondents who gave the top two ratings on a five-point scale for enjoyment at the exhibit was 70% at the Museum of Science, Boston, 76% at the Springfield Science Museum and 82% at McAuliffe-Shepard Discovery Center (p = .03).

In terms of specific exhibit components, the centerpiece component entitled *The Black Holes Adventure* was the most popular. *Got Gravity*, an exhibit designed by the project's youth collaborators, stood second in terms of its popularity (See Table 5). We observed that younger visitors (children and teens) were more engaged with *The Black Holes Adventure* exhibit than were older visitors.

It is interesting to note that two out of the four most popular exhibits were card-enabled exhibits that allowed that visitors to collect digital artifacts at the station to add to their electronic journals. Also, the other two exhibits in the top four were products of the adult-youth collaboration - components originally developed and prototyped by teenage exhibit design apprentices.

Table 5
Respondents' Enjoyment of Various Stations

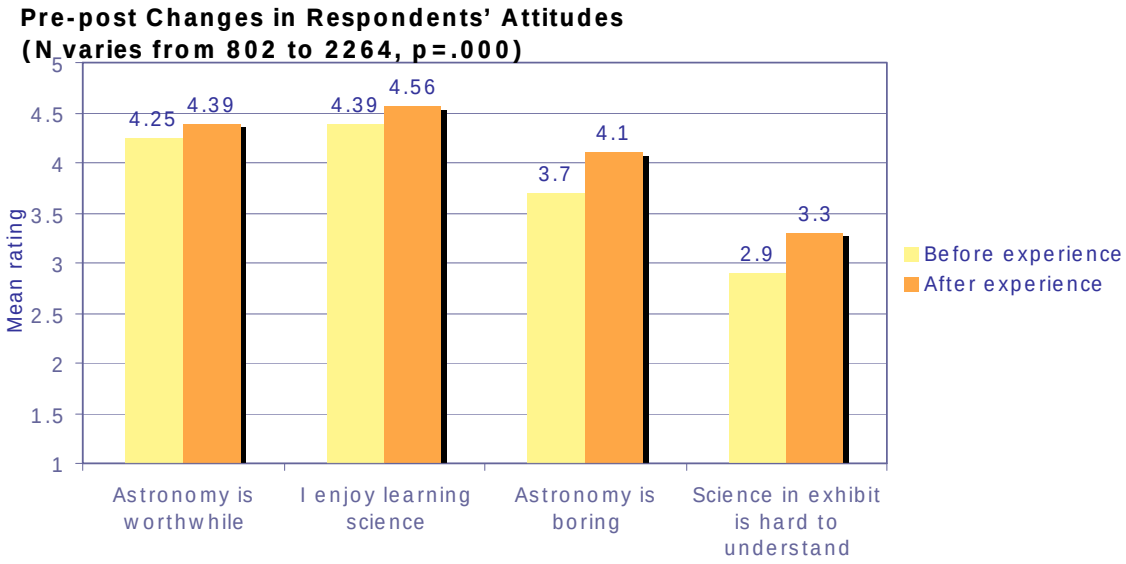
Stations	**Percentage of respondents indicating they enjoyed the station most**
Black Hole Adventure	44%
Got Gravity?	16%
How do we find Black Holes?	13%
Is it True what they say about Black Holes?	7%

N = 223

Another indication of visitors' engagement with scientific ideas was their attitude toward science and scientific fields of study such as astronomy. Outgoing visitors had significantly more positive attitudes about astronomy and science in general than did incoming visitors (See Figure 8[9] for specific statements).

[9] Last two items in the figure are recoded so that higher ratings reflect positive attitude

Figure 8

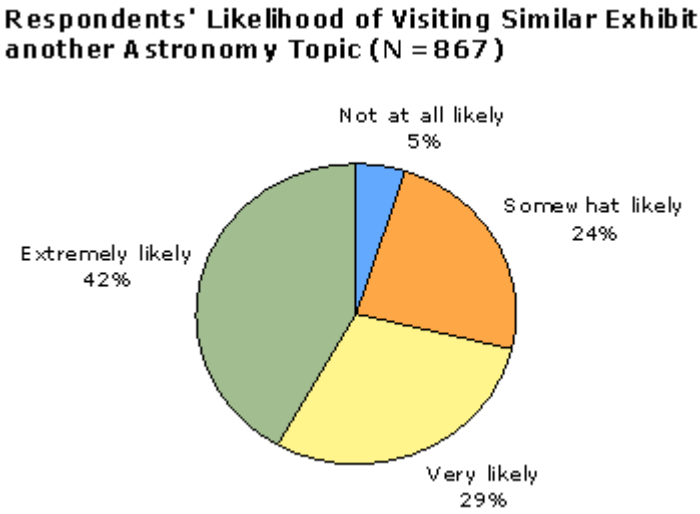


Impact Category D: Behavior

Visitors intended to pursue their interest and learning beyond the museum visit

During the exit interview, 78% of outgoing visitors (N=142) indicated they would visit their personal website after leaving the museum. A considerable number of the visitors also indicated they were likely to visit a similar exhibit on another astronomy topic (See Figure 9).

Figure 9



GRG conducted an online follow-up survey that was hosted on the BHEG website. Because of the low response rate[10] for the follow-up survey, only 65 surveys were collected. Hence, the results obtained cannot be generalized to the population. Data obtained from this small sample indicated that the BHEG motivated the respondents to talk about black holes with others and look up information on black holes on the Internet after having visited the exhibition. The most popular reason for the respondents to browse the BHEG website was to check their online journal created at the exhibit. The respondents very rarely used the multiple resources and "things to do" pages available on the BHEG website.

Impact Category E: Skills

Visitors practiced the scientific skills of making predictions and gathering and comparing evidence.

The hands-on components at the various stations in BHEG offered the visitors opportunities to practice various scientific skills. Observations conducted by the GRG researchers indicated varied use of these hands-on activities by the visitors (see Table 6).

[10] GRG had solicited email addresses through the paper-pencil surveys administered at the exhibit in order to gather follow-up data. Out of the 407 survey respondents, 134 respondents, who gave their email addresses, were invited to participate in the online survey. Out of these, 49 respondents took the survey. In addition, 16 respondents took the survey as they were browsing the BHEG website.

Table 6
Skills Practices by the Respondents through Hands-on Activities

Station	Science skill practiced using the hands-on component	% of respondents
What is a Black Hole?	• Exploring the extremes of gravity near massive objects and the distortions of space and time	47%
In Search of Real Black Holes...Weigh a Black Hole!	• Using a simple orbital model to determine the actual weight of our galaxy's supermassive black hole • Recording results to the online journal.	48%
In Search of Real Black Holes...Take Temperature!	• Discovering and recording evidence for the hot spots produced by feeding black holes in every galaxy.	65%
In Search of Real Black Holes...Explore a Feeding Black Hole!	• Investigating and recording thoughts about real astronomical images of the surprising jets created by supermassive black holes at the centers of galaxies.	64%
Do Black Holes Matter? Simulate the Universe!	• Comparing the scenarios predicted by the computer model to Hubble Space Telescope images of real colliding galaxies.	69%
How Do We Find Black Holes?	• Predicting presence of a black hole in a simulation activity • Recording conclusions on a "map" of the table	77%
Black Hole Adventure	• Exploring the phenomena around the black hole, including warped space, the slowing of time, and the dangerous magnetic fields and radiation	78%

N = 144

Tracking and timing data

Analyses of tracking and timing data indicated that the exhibit was "thoroughly used".

The analyses of tracking and timing data for "thorough use" of an exhibit is often conducted using the following two metrics: the sweep rate index and the percentage of diligent visitors[11]. The sweep rate index (SRI) is calculated by dividing the exhibit's square footage by the average total time spent there for a tracked sample of casual visitors. A lower sweep rate means that visitors spent more time in the exhibit and the assumption is that they were engaged in more learning-related behaviors.

The percentage of diligent visitors (%DV) is the percentage of visitors in the tracked sample who stopped at more than half of the stations in the exhibit. Higher percentages of diligent visitors mean that more people were paying attention to more stations, and fewer exhibit elements were being ignored, skipped, or missed. Based on summary data and cluster patterns from numerous

[11] See http://caise.insci.org/news/96/51/Paying-More-Attention-to-Paying-Attention/d,resources-page-item-detail for more detail on the concept of SRI and %DV.

exhibits, the average value for SRI is set at 300 and the average %DV is set at 26. Using these criteria, the "thorough use" level of an exhibit is established.

In the BHEG exhibit, visitors spent an average of 25 minutes, for an SRI of 100[12] and the %DV was calculated to be 40%. The low SRI and high %DV indicated the BHEG exhibit was "thoroughly used." In other words, visitors spent a relatively long period of time at the exhibit and were engaged with a large proportion of the exhibit elements. In addition, observation data indicated that time spent at the exhibit was positively correlated with overall engagement ($r = .456$, $p = .000$). The longer the time spent at the exhibit, the higher the visitor engagement with the exhibit components.

There were no age or gender related differences in the total time spent at the exhibit. However, it was found that the visitors spent lesser time at the exhibit at the Museum of Science, Boston (22 minutes) than at the other two museums, McAuliffe-Shepard Discovery Center, Concord, NH (28 minutes) and Springfield Science Museum (29 minutes). We speculate that this difference is related to the size and the scope of the museum. The Museum of Science, Boston probably has more to offer to a visitor at any given point in time than the other two museums. These competing demands on the visitors time at the museum may be related to the less time spent at the BHEG.

In terms of the individual stations, the visitors spent the most time at the centerpiece exhibit titled *the Black Holes Adventure* (average time spent = 6 minutes). For each of the other stations, the visitors spent on an average 1 to 3 minutes. This time spent at individual stations is typical behavior at science exhibits.[13]

Success of the BHEG Innovations

The collaboration between the youth and the BHEG adult teams was highly efficient and mutually beneficial.

The BHEG adult-youth collaboration was a unique undertaking that used the skills of youth to assist in the building of science exhibit stations. The two stations inspired by the youth ideas were titled *Is It True What They Say About Black Holes?* and *Got Gravity*. The collaboration was a "win-win" situation that benefited both the youth and the project. On the one hand, the youth enjoyed working on the BHEG project and learned new information about black holes, in particular, and astronomy, in general. Collaborating on the exhibit design helped develop teens' work force skills, such as teamwork, creativity, communication, and time-management. Their work on creating the exhibits and multi-media components for the BHEG website gave them real-world job experience.

On the other hand, the collaboration was beneficial to the development of the exhibit. The exhibit components and the multi-media components of the Black

[12] Square footage of BHEG was 2500 sq. ft.
[13] http://onlinelibrary.wiley.com/doi/10.1002/%28SICI%291098-237X%28199711%2981:6%3C689::AID-SCE6%3E3.0.CO;2-E/abstract

Holes website created by the youth were direct contributions to the BHEG project. As mentioned earlier, the station "Got Gravity," which was inspired by the youth, was the second most popular station.

There were certain lessons learned through this collaboration:

- There was some ambiguity about the autonomy and decision making power offered to the youth, with youth expecting more of that power than what was offered.

- The two youth programs that participated in the youth-adult collaboration were structured differently. The collaboration worked better when the youth component was devoted completely to the collaboration (not piggybacking off an existing program). When the youth program was a part of another bigger program, the teens were often overworked and uncertain of their definite roles in the collaboration.

- Although communication between the adults and youth during the BHEG collaboration was open, it needed to be more frequent. Constant contact and exchange of information among all the teams was deemed essential for the success of the collaboration. This was especially true because one team of youth was working long distance in California.

The network technology used at the BHEG helped optimize the exhibit experience for the visitors.

Sixty-six percent of visitors surveyed (N=397) created and used a Black Holes Explorer Card. Moreover, 95% of these visitors said they would recommend that other visitors create and use a card.

The data gathered through traditional evaluation methods (observations, interviews, and surveys) allowed for comparisons between the experiences of the card users and the non-card users. These data indicated that, in addition to its appeal, the Black Holes Explorer Card also enhanced visitor outcomes in the following way:

- First, as shown in Table 7, visitors who created and used the card at the exhibit gave higher enjoyment and learning outcome ratings compared to those who did not create a card. In addition, limited data also indicated that the visitors who created a card were not differently motivated than those who did not create the card, thus increasing the credibility of these differences.

What did the visitors like about using the Explorer's card?

- *that you could get all the information without writing it*
- *that you can log-in from home, go back and look at things*
- *that you could create an online journal [and] take pictures*
- *that we can go online and see what we accomplished and learned.*
- *that I could do things with it that I couldn't do without the card.*
- *It gave a personal effect. You [could] take part of your experience with you.*

Table 7
Differences in Visitor Outcomes by Use of an Explorer Card

	% of respondents giving the top two ratings on a five-point scale	
	Created card	**Did not create card**
How much did you enjoy the Black Holes Exhibit?	79%	63%*
How much did you learn from the Black Holes Exhibit?	61%	50%*

N = 396-397
* p = .000

- Second, observation data collected by trained GRG researchers indicated that visitors who created and used Explorer cards were significantly more engaged with the exhibits overall, as well as specifically with the centerpiece exhibit *the Black Holes Adventure* (See Table 8).

Table 8
Differences in Visitor Engagement based on the Use of the Explorer Card

	% of respondents giving the top two engagement ratings on a five-point scale	
	Created card	**Did not create card**
Overall exhibition	50%	17%*
The Black Holes Adventure	54%	12%*

N=99-136
* p = .000

- Third, card-using visitors learned significantly more about the characteristics of black holes than did visitors who did not use cards; 80% of card-using visitors versus 56% of non-card visitors were able to name the characteristics of black holes (p=.000).

- Finally, visitors who created and used Explorer cards spent significantly more time (almost twice as much, p=.000) at the exhibit (29 minutes) compared to those who did not create cards (16 minutes).

Conclusions and Recommendations

Based on our findings from the evaluation study, we conclude that the BHEG project was successful at achieving the potential project impacts based on the NSF evaluation framework and at implementing the two project innovations. The following paragraphs elaborate on these successes as well present our recommendations for future projects.

The BHEG was associated with multiple positive visitor outcomes such as visitors' enjoyment of the exhibition, gain in their knowledge about black holes and the scientific methods used to understand black holes, an increase in their interest in the phenomenon of black holes, and positive changes in their attitudes toward science and scientific fields of study such as astronomy.

> ***Given these successes in visitor outcomes, GRG recommends that SAO consider the BHEG as a benchmark in terms of deciding the format, presentation, difficulty level, and such other factors of future exhibits. GRG also recommends the dissemination of information about the BHEG at appropriate venues (professional conferences and journals) in the field of astronomy and museum studies.***

The use of innovative network technology proved to be the highlight of the BHEG project. Not only did the Black Holes Explorer's Card have a novelty appeal, it also enhanced visitors' outcomes. The use of the card made a difference in visitors' time spent, their interest, and their learning at the exhibit. It helped optimize the exhibit experience for the visitors and at the same time provided them the opportunity to personalize the experience**.**

> ***GRG highly recommends future use of this technology for similar exhibits on science topics. The Explorer's Card could be adapted and used in various types of exhibit. The look of the card would vary depending upon the topic at hand. Given the positive outcomes associated with the use of the technology, in the future, GRG recommends that SAO explicitly promote the use of card as the visitors enter the exhibit and provide repeated reminders during and at the end of the exhibit.***

The network technology also proved to be an extremely useful evaluation tool, providing an opportunity for the embedded assessment of visitor outcomes at the exhibit.

> ***The continued use of technology at the future SAO exhibits will ensure more opportunities for embedded evaluation data on visitor behavior and outcomes. This can prove to be a rich contribution to the professional field of visitor studies in a variety of museum types.***

The second innovation of the BHEG project, namely the collaboration with the youth during the exhibit planning phase, was also successful. The collaboration was mutually beneficial, such that the youths' ideas helped the creation of two actual exhibit stations and multiple online resources, and the participation in the program provided the youth with an enriching experience.

> ***GRG recommends the involvement of youth in future exhibit planning and creation. Based on certain lesson learned through the current collaboration experience, GRG recommends that the youth be given more autonomy in the future; adults can make the youth feel empowered if they seek youth input, while setting deadlines and creating schedules and giving them frequent, detailed information about the progress of the project.***
>
> ***GRG also recommends that, in the future, open and frequent communication channels be established among all the teams participating in the collaboration. There needs to be constant contact and exchange of information among all teams, so as to keep everyone connected to the project.***

Although the visitors intended to visit their personal website after leaving the museum, very few actually did so. In addition, there is a lot of information on the black holes website that most visitors did not access.

> ***GRG recommends that, in the future, more efforts need to be taken by SAO to encourage visitors to pursue their learning beyond the museum visit. For instance, this can take the form of raising visitor awareness of the myriad resources about Black Holes, including promotion of the related BHEG Website and ancillary materials.***

Based on the survey data, GRG concluded that the characteristics of the host museum played a role in the visitors' exhibit experience. Visitors spent more time at the BHEG when they were visiting a smaller museum such as the McAuliffe-Shepard Discovery Center, Concord, NH or the Springfield Science Museum than at a bigger museum such as the Museum of Science, Boston. Their ratings also indicated higher enjoyment and more learning at the smaller venue, variables that are typically related to more time spent.

At smaller museums, there typically are fewer concurrent exhibits and so BHEG did not face competition from other exhibits than it did at Museum of Science. It appears that the larger the museum and the more visitors it draws, the more likely it is that visitors feel crowded and rushed at the travelling exhibit. This can lead to lesser time spent at the featured exhibit.

> ***Hence, GRG recommends that SAO take the size and scope of the museum into consideration as it plans the future venues for the travelling exhibit. Although this may not always be a SAO decision, SAO can make the partner organizations aware of this finding so as to make an informed decision regarding hosting the exhibit.***

APPENDICES

Appendix A

Protocol for Black Holes Youth Collaborators Focus Groups

A Research Associate from GRG will conduct a half-hour, semi-structured focus group with the youths participating in the Black Holes project. If conditions allow, the discussion will be tape-recorded. Name tags will be used to identify participants.

The main objectives of the focus group are to gather information from the students on the following topics:

- Youths' experiences with the Black Holes project
- Youths' process of working on their individual projects
- Youths' perceptions about the collaboration with the Black Holes team
- Youths' perceived benefits from the collaboration

The moderator of the group will use this protocol to introduce herself to the group, and to elicit information on the above mentioned themes.

I. Welcome/Overview/Survey

- **GRG Introduction:** *My name is …. I am with Goodman Research Group, an education research group in Cambridge, Massachusetts. We are the evaluators of the Black Holes project.*

- **Participant Introduction:** *Could we go around the room/table and have everyone say their name? I'd also like you to put on a nametag so that I can use your names during our discussion.*

- **Statement of Purpose:** *The purpose of the discussion today is for us to hear about your experiences while working on the Black Holes project. What you say will be used to help improve the program for future. I want you to know that what you say in this discussion is confidential; we'll summarize what we hear and we will not use your individual names in our evaluation report.*

- **Request to Tape-record:** *I'd like to tape this discussion so that I can listen to what you say and remember it without taking lots of notes. The evaluation team at Goodman Research Group are the only ones who would listen to the tape. Does anyone object to taping?*

- **Ground Rules:** *Okay, a few ground rules before we get started. First, in some ways your experiences might be the same, but in other ways they might be different. I want to hear everyone's perspective, so please speak up if your experience is different than someone else's. Also, I want to hear from everyone, so if some people are talking a lot and other people aren't talking much, I might ask you if you have something to say.*

Let's get started!

Date and time of focus group:
Name of interviewee:

Researcher comments (if any):

II. Feedback on the Black Holes projects

- Tell me a little bit about your experiences working on your individual project.
  Probe for information about what the individual projects were related to, why those particular projects were chosen, etc.

- How did you work on the project?
  Probe for information about baseline research, collaboration with Erika, Irene, Mary, and other adult members, teamwork, how they made decisions, and the various other stages of the process.

- What did you like best about working on these projects? Why?

- What did you like least about working on these projects? Why?

III. Feedback on the collaboration process

- How was your experience working with the adults in the Black Holes project?
  Probe for how they worked together, interacted with adults, and whether they had ever worked with adults in this way before (e.g., on a project).
    - What was the highlight about working with the group of adults from CfA?
    - What were the challenges of working with the group?
      Probe for any disagreements, etc.

- What was your role in the Black Holes exhibit design process?
  Probe for what they were trying to do together with the adults, what they think they contributed to the process of designing the Black Holes exhibit, what they think they added to the exhibit design process that wouldn't have possible without their involvement.

- What were the adults' roles in the Black Holes exhibit design process?

- Any suggestions about more ways in which you could have contributed?
  Probe for information about changes to the collaboration process.

IV. Feedback on benefits of the collaboration to the youths

- Thinking about your experience with the Black Holes project, what do you think has been the most significant change in your knowledge or understanding about science?
  Probe for what they learned or better understood about Black Holes or astronomy.

- How do you see yourself making use of this experience in the future?

V. Concluding remarks

- Before we end, do you have any suggestions for improving the experience that teens would get through such a program in future?

- That covers all my questions. Is there anything else you would like to tell me about your experiences and opinions that we haven't already talked about?

Your feedback is very valuable to Black Holes Project. Thanks so much for taking the time to talk with me.

Appendix B

Protocol for Black Holes interviews

A Research Associate from GRG will conduct semi-structured interviews with the adults involved in the adult-youth collaboration of the Black Holes project. If conditions allow, the interviews will be tape-recorded.

The main objective of the interviews is to gather information from the adult on his/her perceptions about the adult-youth collaboration.

The interviewer will use this protocol to introduce herself/himself to the adult. The questions listed in the following sections will be used as prompts.

I. Welcome/Background information

- **GRG Introduction:** *My name is _____. I am with Goodman Research Group, an education research group in Cambridge, Massachusetts. We are the evaluators of the Black Holes program.*

- **Statement of Purpose:** *The purpose of the interview today is for us to hear about your collaboration with the youth. I want you to know that what you say in this interview is confidential; we will not use your individual name in our report. The information you provide will be used to help improve the program.*

- **Request to Tape-record (if applicable):** *I'd like to tape this interview so that I can listen to what you say and remember it without taking lots of notes. The evaluation team at GRG are the only ones who would listen to the tape. Do you object to taping?*

- **Questions:** *Do you have any questions before we begin?*

Let's get started!

Date and time of interview:
Name of interviewee:

Researcher comments (if any):

II. Feedback on the Black Holes projects and collaboration

- Tell me a little bit about your experiences working with the youth on their individual projects. What was your role in the youth projects?

  Probe for how the adult helped the process of project selection and execution.

- Tell me about your interactions with the youth (how you worked with them);

- Have you ever been a part of such adult-youth collaboration before (e.g., on a project).

- What was the highlight of working with the youth group?

- What were the some of the challenges of working with them?
  Probe for any disagreements, issues etc.

- How did the collaboration benefit the exhibit design process?

  Probe for how they think the youth contributed to the process of designing the Black Holes exhibit, what they think the youth added to the exhibit design process that wouldn't have possible without their involvement.

- How do you think the collaboration benefited the youth?

- Do you have any ideas about more ways in which the youth could have contributed?
  Probe for suggestions about changes to the collaboration process.

- Before we end, do you have any suggestions for improving the experience that teens would get through such a collaboration in future?

- That covers all my questions. Is there anything else you would like to tell me about your experiences and opinions that we haven't already talked about?

Your feedback is very valuable to Black Holes Project. Thanks so much for taking the time to talk with me.

Appendix C

The Black Holes Experiment Gallery
Chabot Space and Science Center Youth Pre-survey

1. **Your Full Name:** _____

2. **Are you**:
   ❑ Male ❑ Female

3. **How old are you?** _____

4. **What grade did you most recently complete?**
   ❑ 9th ❑ 10th ❑ 11th ❑ 12th ❑ Other: _____

5. **What is your race/ethnicity?** *(Check all that apply.)*
   ❑ American Indian or Alaska Native
   ❑ Asian
   ❑ African American
   ❑ Native Hawaiian or Other Pacific Islander
   ❑ Spanish/Hispanic or Latino
   ❑ White
   ❑ Other
   If other, please specify: _____

6. **In the last 12 months have you participated in any of these activities?** *(Check one box for each.)*
   Science fair ❒ Yes ❒ No
   Science club ❒ Yes ❒ No
   After-school academic club ❒ Yes ❒ No
   Which one(s)? _____
   Any other club/ program / activity ❒ Yes ❒ No
   Describe: _____

7. **In the last 12 months have you done any of the following?** *(Check one box for each.)*
   Took a class on astronomy ❒ Yes ❒ No
   Read a book or a magazine article about astronomy ❒ Yes ❒ No
   Watched a TV show about astronomy ❒ Yes ❒ No
   Visited a website on astronomy ❒ Yes ❒ No
   Participated in an astronomy club ❒ Yes ❒ No
   Any other astronomy-related activity ❒ Yes ❒ No
   Which one? _____

8. **How much do you know about …?**

	A great deal	**Quite a bit**	**Some**	**A little**	**Nothing**
Astronomy	❒	❒	❒	❒	❒
Black Holes	❒	❒	❒	❒	❒

9. How strongly do you agree or disagree with each of the following statements about science and astronomy? *(Check one box for each.)*

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
I like science.	❒	❒	❒	❒	❒
I enjoy learning science.	❒	❒	❒	❒	❒
Science is boring.	❒	❒	❒	❒	❒
Science is important to everyone's life.	❒	❒	❒	❒	❒
I would like a job that involved using science.	❒	❒	❒	❒	❒
Learning about astronomy is worthwhile and necessary.	❒	❒	❒	❒	❒
I like learning about astronomy.	❒	❒	❒	❒	❒
Activities related to astronomy are interesting.	❒	❒	❒	❒	❒
I want to find out more about Black Holes.	❒	❒	❒	❒	❒

10. How interested are you in learning more about …?

	Extremely Interested	Very interested	Somewhat interested	A little interested	Not at all interested
Astronomy	❑	❑	❑	❑	❑
Black Holes	❑	❑	❑	❑	❑

Below are some questions about astronomy and Black Holes. You will be learning about some of these things in the next few weeks. We want to see how much you already know about these topics. Answer each question as best you can – if you don't know an answer to a question, just take your best guess.

11. For each of the following statements about black holes, please indicate whether it is *True* or *False*. If unsure of the answer please choose *Don't Know*.

Black holes are…	True	False	Don't know
… are typically found in the center of planets like Earth or Mars.	❒	❒	❒
… are invisible.	❒	❒	❒
… were described by the theories of Albert Einstein.	❒	❒	❒
… are like cosmic vacuum cleaners that clean the dust and debris that accumulates in outer space.	❒	❒	❒
… are the remnants of collapsed/dead stars.	❒	❒	❒
… have not yet been located in our galaxy.	❒	❒	❒
… swallow everything that falls toward them.	❒	❒	❒
… have periods of high activity and periods of low activity.	❒	❒	❒

12. **Do scientists think that the black hole at the center of the Milky Way Galaxy is generally active or inactive at present?** *(Please check one box.)*

❒ Active
❒ Inactive
❒ Not applicable — The Milky Way doesn't have a black hole at the center.
❒ Don't know

13. **How can scientists determine whether there's a black hole in a certain part of a galaxy? What method(s) can they use to demonstrate that it exists?** *(Check all that apply.)*

❒ Look for sudden flare ups of radiation.
❒ Look for an accumulation of stars released from the other side of the black hole.
❒ Clock the speed of stars moving around its suspected location.
❒ Look for areas of extreme darkness.
❒ Look for a jet of high energy particles.
❒ Measure for higher concentrations of dust and debris particles.
❒ None of the above
❒ Don't know

14. **For each of the following statements, please indicate whether it is *True* or *False*. If unsure of the answer please choose *Don't Know*.**

	True	False	Don't know
Only a few galaxies in the universe have black holes.	❒	❒	❒
When matter falls toward a black hole it gets sucked straight in.	❒	❒	❒
Black holes form in the death of large stars.	❒	❒	❒
Scientists believe that our sun will one day turn into a black hole.	❒	❒	❒
All the big galaxies in the universe have a black hole at their center.	❒	❒	❒
When something falls into a black hole, it eventually comes back out.	❒	❒	❒
Black holes have a region beyond which nothing can escape, not even light.	❒	❒	❒

15. **What are black holes?** *(Please check one box.)*

❒ The remains of burned-out stars
❒ High-gravity objects that distort space and time
❒ Causes of x-ray radiation
❒ All of the above

16. **How do astronomers determine black holes exist if they are black and don't emit light?** *(Please check one box.)*

❒ They send space probes to objects in space suspected to be black holes
❒ They use telescopes to observe material outside the black hole
❒ Both of the above
❒ There is no evidence that black holes really exist - black holes are theoretical

17. **What shape is a black hole and its "event horizon"?** *(Please check one box.)*

❒ A sphere, ball-shaped
❒ Funnel-shaped
❒ Round like a hole in the ground
❒ It has no shape

18. **What would change if our Sun were suddenly replaced by a black hole of the same mass?** *(Please check one box.)*

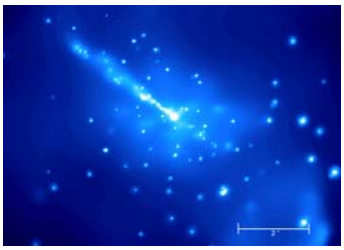
❒ Earth would be pulled into the black hole
❒ The planets would no longer have the same orbits
❒ The temperature on Earth would change
❒ All of the above

19. **Which of these four telescope images of galaxies do you think shows the best evidence for BOTH a supermassive black hole at that galaxy's center AND multiple smaller black holes within the galaxy?** *(Please check one box.)*

❒ Combined x-ray and optical image of Galaxy M74

❒ Combined x-ray/optical/infrared image of Sombrero Galaxy

❒ X-ray image of Galaxy Centaurus A



❒ Optical image of Galaxy Centaurus A

Why did you choose that image?

_____
_____
_____
_____
_____
_____

Thank you for taking this survey!

The Black Holes Experiment Gallery
Chabot Space and Science Center Youth Post-survey

1. **Your Full Name:** _____

2. **Please describe briefly the project you have worked on for the past couple of weeks.**

_____
_____
_____
_____
_____
_____

3. **What was the most interesting thing you did or learned about Black Holes in the last couple of weeks?**

_____
_____
_____
_____
_____

4. **How much do you know about …?**

	A great deal	**Quite a bit**	**Some**	**A little**	**Nothing**
Astronomy	❒	❒	❒	❒	❒
Black Holes	❒	❒	❒	❒	❒

5. **How strongly do you agree or disagree with each of the following statements about science and astronomy?** *(Check one box for each.)*

	Strongly Agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly Disagree**
I like science.	❒	❒	❒	❒	❒
I enjoy learning science.	❒	❒	❒	❒	❒
Science is boring.	❒	❒	❒	❒	❒
Science is important to everyone's life.	❒	❒	❒	❒	❒
I would like a job that involved using science.	❒	❒	❒	❒	❒
Learning about astronomy is worthwhile and necessary.	❒	❒	❒	❒	❒
I like learning about astronomy.	❒	❒	❒	❒	❒
Activities related to astronomy are interesting.	❒	❒	❒	❒	❒
I want to find out more about Black Holes.	❒	❒	❒	❒	❒

6. How interested are you in learning more about …?

	Extremely Interested	Very interested	Somewhat interested	A little interested	Not at all interested
Astronomy	❑	❑	❑	❑	❑
Black Holes	❑	❑	❑	❑	❑

Below are some questions about astronomy and Black Holes. Answer each question as best you can – if you don't know an answer to a question, just take your best guess.

7. For each of the following statements about black holes, please indicate whether it is *True* or *False*. If unsure of the answer please choose *Don't Know*.

Black holes are…	True	False	Don't know
… are typically found in the center of planets like Earth or Mars.	❒	❒	❒
… are invisible.	❒	❒	❒
… were described by the theories of Albert Einstein.	❒	❒	❒
… are like cosmic vacuum cleaners that clean the dust and debris that accumulates in outer space.	❒	❒	❒
… are the remnants of collapsed/dead stars.	❒	❒	❒
… have not yet been located in our galaxy.	❒	❒	❒
… swallow everything that falls toward them.	❒	❒	❒
… have periods of high activity and periods of low activity.	❒	❒	❒

8. Do scientists think that the black hole at the center of the Milky Way Galaxy is generally active or inactive at present? *(Please check one box.)*

❒ Active
❒ Inactive
❒ Not applicable — The Milky Way doesn't have a black hole at the center.
❒ Don't know

9. How can scientists determine whether there's a black hole in a certain part of a galaxy? What method(s) can they use to demonstrate that it exists? *(Check all that apply.)*

❒ Look for sudden flare ups of radiation.
❒ Look for an accumulation of stars released from the other side of the black hole.
❒ Clock the speed of stars moving around its suspected location.
❒ Look for areas of extreme darkness.
❒ Look for a jet of high energy particles.
❒ Measure for higher concentrations of dust and debris particles.
❒ None of the above
❒ Don't know

10. For each of the following statements, please indicate whether it is *True* or *False*. If unsure of the answer please choose *Don't Know*.

	True	False	Don't know
Only a few galaxies in the universe have black holes.	❒	❒	❒
When matter falls toward a black hole it gets sucked straight in.	❒	❒	❒
Black holes form in the death of large stars.	❒	❒	❒
Scientists believe that our sun will one day turn into a black hole.	❒	❒	❒
All the big galaxies in the universe have a black hole at their center.	❒	❒	❒
When something falls into a black hole, it eventually comes back out.	❒	❒	❒
Black holes have a region beyond which nothing can escape, not even light.	❒	❒	❒

11. What are black holes? *(Please check one box.)*

❒ The remains of burned-out stars
❒ High-gravity objects that distort space and time
❒ Causes of x-ray radiation
❒ All of the above

12. How do astronomers determine black holes exist if they are black and don't emit light? *(Please check one box.)*

❒ They send space probes to objects in space suspected to be black holes
❒ They use telescopes to observe material outside the black hole
❒ Both of the above
❒ There is no evidence that black holes really exist - black holes are theoretical

13. What shape is a black hole and its "event horizon"? *(Please check one box.)*

❒ A sphere, ball-shaped
❒ Funnel-shaped
❒ Round like a hole in the ground
❒ It has no shape

14. What would change if our Sun were suddenly replaced by a black hole of the same mass? *(Please check one box.)*

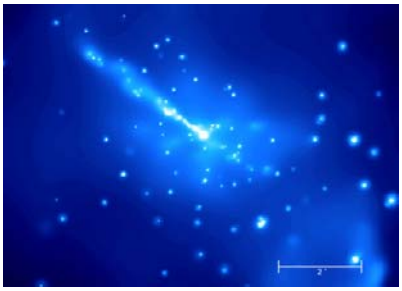
❒ Earth would be pulled into the black hole
❒ The planets would no longer have the same orbits
❒ The temperature on Earth would change
❒ All of the above

15. **Which of these telescope images of galaxies do you think shows the best evidence for BOTH a supermassive black hole at that galaxy's center AND multiple smaller black holes within the galaxy?** *(Please check one box.)*

❒ Combined x-ray and optical image of Galaxy M74

❒ Combined x-ray/optical/infrared image of Sombrero Galaxy

❒ X-ray image of Galaxy Centaurus A



❒ Optical image of Galaxy Centaurus A

Why did you choose that image?

_____
_____
_____
_____
_____
_____

Thank you for taking this survey!

Appendix D

Date: _____

Black Holes: Space Warps & Time Twists
Visitor Survey

1. With whom did you visit the Black Holes exhibit?

❑ Alone ❑ Friend(s) ❑ Family
❑ Colleagues ❑ Classmates ❑ Other

2. How much did you enjoy the Black Holes exhibit?

❑ Not at all ❑ Only a little ❑ Some ❑ Quite a bit ❑ A great deal

3. How much did you learn about black holes from the exhibit?

❑ Nothing ❑ Only a little ❑ Some ❑ Quite a bit ❑ A great deal

4. What was the most interesting or surprising thing you learned about black holes today?

_____

_____

5. What are one or two things that scientists still *don't know* about black holes?

_____

_____

6. Please rate the success of the Black Holes exhibit in each of the following areas:
(Check one box for each item.)

	Not at all successful	Only a little successful	Somewhat successful	Very successful	Extremely successful
Helping you see how science impacts your everyday life	❑	❑	❑	❑	❑
Increasing your curiosity about black holes	❑	❑	❑	❑	❑
Helping you feel more confident talking about black holes	❑	❑	❑	❑	❑
Increasing your understanding of where black holes "fit in" in the universe	❑	❑	❑	❑	❑
Increasing your knowledge about the relationship between gravity and black holes	❑	❑	❑	❑	❑

7. Did you create a *Black Holes Explorer's Card* at the sign-in station?

❑ Yes
❑ No (SKIP TO QUESTION 12)

Please turn page over ☛

8. Did you use the card?
❑ Yes
❑ No (SKIP TO QUESTION 12)

9. Did you experience any problems trying to use the card?
❑ Yes
❑ No

10. Would you recommend to other visitors that they use a *Black Holes Explorer's Card*?

❑ No; why not? _____

❑ Yes; why? _____

11. Do you plan to visit your personal Black Holes web site after leaving the museum today?
❑ Definitely not
❑ Probably not
❑ Probably
❑ Definitely

12. Are you interested in participating in an online follow-up survey about the exhibit and receiving a $20.00 stipend (an online gift certificate)? If yes, please provide your email address in the space below.

A few final questions about you:

13. Are you: ❑ Female ❑ Male

14. Your age group:

❑ Less than 14	❑ 25-34	❑ 55-64
❑ 15-17	❑ 35-44	❑ 65 or older
❑ 18-24	❑ 45-54	

15. Do you and/or anyone in your family work in a science- or astronomy-based field?
❑ Yes , Please explain: _____
❑ No

16. Primary reason for visiting the museum today (Please check one)
❑ To visit the Omni Theatre
❑ To visit the museum in general
❑ To visit specifically the black holes exhibit
❑ To visit another specific exhibit; which? _____

17. Please write any additional comments you have about the Black Holes exhibit or about the survey:

Thank you for participating in this survey!

Appendix E

BLACK HOLES: SPACE WARPS & TIME TWISTS
OBSERVATION PROTOCOL

Observer: _____ **Start time:** _____ *Circle* AM PM

Date: _____ **Stop time:** _____ *Circle* AM PM

Gender: *Circle* Female Male **Age:** *Circle* Child Teen Adult

Group: _____ # adults _____ # children

Created Black Hole Explorer's Card: *Circle* Yes No

Others in group created card: *Circle* All One Some None Alone

Level of engagement:

Black Hole Explorer's Card	Not engaged	Only a little engaged	Somewhat engaged	Very engaged	Extremely engaged	N/A
Black Hole Adventure	Not engaged	Only a little engaged	Somewhat engaged	Very engaged	Extremely engaged	N/A
Exhibit Overall	Not engaged	Only a little engaged	Somewhat engaged	Very engaged	Extremely engaged	N/A

Behavior:

Discussed exhibit/experience with group	Yes	No	N/A
Discussed exhibit/experience with other visitors	Yes	No	N/A
Discussed exhibit/experience with museum staff	Yes	No	N/A
Encountered non-working component	Yes	No	
Revisited component	Yes	No	

Tag line – phrase or brief sentence that captures the story of this visit:

Tracking & Timing:

Stop #		Entry time	Exit time	Read/watch	View video	Hands-on	Take/use card	Talk
	Black Hole Explorers: Start Here							
	What's on the Horizon for Black Hole Research?							
	What is a Black Hole?							
	Where are Black Holes?							
	Snapshots in the Exploration of Black Holes							
	In Search of Real Black Holes...Weigh a Black Hole!							
	In Search of Real Black Holes...Take Their Temperature!							
	In Search of Real Black Holes...Explore a Feeding Black Hole!							
	Do Black Holes Matter? Simulate the Universe!							
	How Do We Find Black Holes?							
	Energy from Gravity							
	Got Gravity? (Black Holes Grow by Eating)							
	What's Inside a Black Hole?							
	Is It True What They Say About Black Holes?							
	Black Holes Inspire Our Imagination							
	Black Hole Adventure							
	Black Hole Explorers: Add to Your Journal!							
	Images on the back wall							

Appendix F

BLACK HOLES: SPACE WARPS & TIME TWISTS
EXIT INTERVIEW

Interviewer: _____ **Date:** _____

Visitor Gender: *Circle* Female Male **Visitor Age:** *Circle* Child Teen Adult

Did you create a Black Hole Explorer's Card in the exhibit today? *Circle* Yes No
If no, why did you decide not to create a card?

If yes, did you use the card? *Circle* Yes No

If yes, what did you like or not like about using the card?

Do you plan on visiting your personal web site after leaving the museum today (back home or wherever you access the Internet)? *Circle* Yes No
If no, why not?

What is the most interesting or surprising thing you learned about black holes today?

How do scientists collect information about black holes?
Probe: How scientists collect evidence for the existence of a black hole? Can you give some examples?

Did you enjoy any particular station more in comparison to other stations? If yes, which station and why?
Probe: Look for experiences at stations created by teens vs. other stations

What more would *you* like to learn about black holes?
Probe: What questions do you still have about Black Holes?

Appendix G

Black Holes: Space Warps & Time Twists
Follow Up Visitor Web Survey

1. How many times have you visited this *Black Holes: Space Warps & Time Twists* website?
Today is my first time on the website
2-3 times before
4 or more times

2. For what reason(s) did you visit the website today? (*Check all that apply.*)
To learn more about black holes in general
To check my online journal
To check my telescope image of a black hole
To get a scientist's answer to a specific black hole question
To share information about the exhibit with a friend
To see my e-card
To look for activities to do
Other; *please describe:* _____

3. While at the Black Holes website, did you sign in with your card and view your Explorer's Journal?
❑ Yes
❑ No (skip to Question # 5)

4. Which pages did you look at in your journal?
❑ My Models
Modeling Lab
Finding black Holes
Supernova Model
Simulate the Universe
❑ My Evidence
Black hole's Temperature
Feeding a black hole
Weigh a black hole
Youth Media Connections
Black hole Adventure
Black holes in Pop Culture

5. Did you visit the Black Holes exhibit at the:
Museum of Science, Boston
McAuliffe-Shepard Discovery Center
Springfield Science Museum
No, did not visit (skip to Question # 16)

6. How many times did you visit the Black Holes exhibit?
Once
2-3 times
4 or more times

7. While you were at the Black Holes exhibit, did you get a Black Holes Explorer's Card?

❑ Yes
❑ No (skip to Question # 10)

8. Which types of data did you collect in your Explorer's Journal at the exhibit?

Predictions about black holes
Images of stars, galaxies and black hole evidence
Voice recordings of my conclusions
Photographs taken during my Black Hole Adventure
Video postcard recorded during my Black Hole Adventure
I did not use my Explorer's card to collect data
Other; please explain:_____

9. Please describe how having your online Explorer's Journal has affected your interest in black holes since visiting the exhibit:

I'm a lot more interested now.
I'm a little more interested now.
My interest is the same.
I'm a little less interested now.
I'm a lot less interested now.

10. How much do you remember about what you learned about black holes at the exhibit?

A great deal
Quite a bit
Some
Only a little
Not at all
I didn't learn anything at the exhibit; *please explain:* _____

11. Was there any part of the exhibit that stood out for you?

❑ Yes; *which part or parts?* _____
❑ No

12. In your opinion, how successful was the Black Holes exhibit in each of the following areas?
(Check one box for each item.)

	Extremely successful	**Very successful**	**Somewhat successful**	**Only a little successful**	**Not at all successful**
Helping you see how science impacts your everyday life	❑	❑	❑	❑	❑
Increasing your curiosity about black holes	❑	❑	❑	❑	❑
Helping you feel more confident talking about black holes	❑	❑	❑	❑	❑
Increasing your understanding of where black holes "fit in" in the universe	❑	❑	❑	❑	❑
Increasing your knowledge about the relationship between gravity and black holes	❑	❑	❑	❑	❑
Helping you understand how scientists study black holes	❑	❑	❑	❑	❑

13. What have you done in relation to black holes <u>since</u> attending the exhibit? *(Check all that apply.)*
Looked up information on black holes on the internet
Talked about black holes with others
Taught others about black holes
Noticed the mention of black holes in the media
Visited the Black Holes Exhibit website
Other; *please explain:* _____

14. Please describe your level of interest in black holes <u>since</u> your visit to the Black Holes exhibit.
I'm a lot more interested now.
I'm a little more interested now.
My interest is the same.
I'm a little less interested now.
I'm a lot less interested now.

15. Please describe your level of interest in astronomy <u>since</u> your visit to the Black Holes exhibit.
❑ I'm a lot more interested now
❑ I'm a little more interested now
❑ My interest is the same
❑ I'm a little less interested now
❑ I'm a lot less interested now

16. How much have you enjoyed the Black Holes website?
A great deal
Quite a bit
Some
Only a little
Not at all

17. How much did you learn about black holes from the website?

❑ A great deal
❑ Quite a bit
❑ Some
❑ Only a little
❑ Nothing

18. Which of the following resources on the website have you visited? *(Check all that apply.)*

RSS feeds (e.g. portal to the universe)
Blogs
Podcasts
Black holes E-Cards
Do black holes really exist?
Audio files (e.g. sound of colliding black holes)
Video files (e.g. seeing a hidden monster)
Live GRB Map (Gamma-ray Bursts Real Time Sky Map)
Chandra Press Releases
Images from Chandra X-ray Image Gallery
Black holes Wallpaper
What are black holes?
What are we trying to find out?
Other
None of the above

19. Which of the following activities on the "Things to do" page have you carried out? *(Check all that apply.)*

Interactive Flash Galleries
Printable activities, games, and interactive games
Sky Tours with WorldWide Telescope and Google Earth
MicroObservatory Robotic Telescope Network
Astronomy dialog
None of the above

20. Did you ask a scientist a question via the website?

❑ Yes
❑ No (skip to question # 24)

21. What question did you ask? _____

22. Did the scientist get back to you?

❑ Yes
❑ No (skip to question # 24)

23. How satisfied were you with the scientist's answer?

Extremely satisfied
Very satisfied
Somewhat satisfied
Only a little satisfied
Not at all satisfied

24. What was the most interesting or surprising thing you learned about black holes on the website?

_____

Finally, a few final questions about you:

25. Are you: ❑ Female ❑ Male

26. Your age group:

Less than 14 years
15-17 years
18-24 years
25-34 years
35-44 years
45-54 years
55-64 years
65 or older

27. Do you and/or anyone in your family work in a science- or astronomy-based field?

❑ Yes; *please explain:* _____
❑ No

28. Please write any additional comments you have:

_____
_____

Appendix H

Pre-test survey questions[1]

Questions on self-perception of knowledge (4)

1. How much do you know about astronomy?
   - ❑ A great deal
   - ❑ Quite a bit
   - ❑ Some
   - ❑ A little
   - ❑ Nothing

2. How much do you know about black holes?
   - ❑ A great deal
   - ❑ Quite a bit
   - ❑ Some
   - ❑ A little
   - ❑ Nothing

3. How much do you agree or disagree with the following statement?
   "The science in the Black Holes exhibit will be hard for me to understand"
   - ❑ Agree strongly
   - ❑ Agree somewhat
   - ❑ Neither agree nor disagree
   - ❑ Disagree somewhat
   - ❑ Strongly disagree

4. How much do you agree or disagree with the following statement?
   "Ordinary people can understand black holes"
   - ❑ Agree strongly
   - ❑ Agree somewhat
   - ❑ Neither agree nor disagree
   - ❑ Disagree somewhat
   - ❑ Strongly disagree

Black hole content questions (8)

5. What are black holes?
   - ❑ The remains of collapsed/dead stars
   - ❑ High-gravity objects that distort space and time
   - ❑ Causes of x-ray radiation
   - ❑ *All of the above*

6. How do astronomers determine black holes exist if they are black and don't emit light?
   - ❑ They send space probes to objects in space suspected to be black holes
   - ❑ *They use telescopes to observe material outside the black hole*
   - ❑ Both of the above

[1] Correct answers to content questions are italicized and highlighted.

❑ There is no evidence that black holes really exist - black holes are theoretical

7. What evidence of black holes can you notice in this x-ray telescope image of the galaxy Centaurus A?

❑ A feeding supermassive black hole at the galaxy's center
❑ Multiple smaller black holes within the galaxy
❑ *Both A and B*
❑ There is no evidence for black holes in this image

8. What evidence of black holes can you notice in this x-ray telescope image of the Sombrero Galaxy?

❑ A feeding supermassive black hole at the galaxy's center
❑ *Multiple smaller black holes within the galaxy*
❑ Both A and B
❑ There is no evidence for black holes in this image

9. What evidence of black holes can you notice in this radio telescope image of a field of galaxies?

❑ *A feeding supermassive black hole at one galaxy's center*
❑ Multiple smaller black holes within the galaxies
❑ Both A and B
❑ There is no evidence for black holes in this image

10. Is this statement true or false?
"Only a few galaxies in the universe have black holes."
❑ True
❑ *False*
❑ Don't know

11. Is this statement true or false?
"All the big galaxies in the universe have a black hole at their centers."
❑ *True*
❑ False
❑ Don't know

12. Is this statement true or false?
"Black holes have periods of high activity and periods of low activity."
❑ *True*
❑ False
❑ Don't know

Attitudes (science questions 1, astronomy questions 3, BH questions 3)

13. How much do you agree or disagree with the following statement?
"I enjoy learning science."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

14. How much do you agree with the following statement?
"I would feel confident talking about black holes with friends."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

15. How much do you agree or disagree with the following statement?
"Astronomy is boring."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

16. How interested are you in learning about astronomy?
❑ Extremely interested
❑ Very interested
❑ Somewhat interested
❑ A little interested
❑ Not at all interested

17. How much do you agree or disagree with the following statement?
"Learning about astronomy is worthwhile and necessary."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

18. How interested are you in learning about black holes?
    - ❑ Extremely interested
    - ❑ Very interested
    - ❑ Somewhat interested
    - ❑ A little interested
    - ❑ Not at all interested

19. How likely are you to read an article about black holes in a newspaper, magazine, or on the Web?
    - ❑ Extremely likely
    - ❑ Very likely
    - ❑ Somewhat likely
    - ❑ A little likely
    - ❑ Not at all likely

Questions related to their visit (5)

20. With whom are you visiting the Black Holes exhibit today? (Please select one.)
    - ❑ I am here alone
    - ❑ With my family
    - ❑ With friend(s)
    - ❑ With a group (school, club, etc)

21. How many people are in your group visiting the Black Holes exhibition today? (Please select one.)
    - ❑ I am here alone
    - ❑ There are 2 of us
    - ❑ There are 3-5 of us
    - ❑ I am here with a larger group

22. How did you FIRST hear about the Black Holes exhibition? (Please select one.)
    - ❑ Word of mouth
    - ❑ Radio commercial
    - ❑ Street banner
    - ❑ Museum website
    - ❑ Newspaper
    - ❑ Flyer / Poster
    - ❑ Dropped in
    - ❑ Other

23. What is your PRIMARY reason for attending this exhibition? (Please select one.)
    - ❑ Brought along by someone else
    - ❑ Interested in science in general
    - ❑ Interested specifically in Black Holes
    - ❑ Wanted to learn more about the topic
    - ❑ Entertainment
    - ❑ School trip
    - ❑ Just passing by

❑ Other

24. What do you MOST expect to gain out of your experience at the exhibition today? (Please select one.)
    ❑ I expect to have fun
    ❑ I expect to learn about astronomy in general
    ❑ I expect to learn about Black Holes in particular
    ❑ I expect to learn about the role of Black Holes in my life
    ❑ Other

Post-test survey questions

Questions on self-perception of knowledge (4)

1. How much do you know about astronomy?
    ❑ A great deal
    ❑ Quite a bit
    ❑ Some
    ❑ A little
    ❑ Nothing

2. How much do you know about black holes?
    ❑ A great deal
    ❑ Quite a bit
    ❑ Some
    ❑ A little
    ❑ Nothing

3. Please indicate the extent to which you agree or disagree with the following statement. "The science in the Black Holes exhibit is hard for me to understand"
    ❑ Agree strongly
    ❑ Agree somewhat
    ❑ Neither agree nor disagree
    ❑ Disagree somewhat
    ❑ Strongly disagree

4. Please indicate the extent to which you agree or disagree with the following statement. "Ordinary people can understand black holes"
    ❑ Agree strongly
    ❑ Agree somewhat
    ❑ Neither agree nor disagree
    ❑ Disagree somewhat
    ❑ Strongly disagree

Black hole content questions (8)

5. What are black holes?
    ❑ The remains of collapsed/dead stars
    ❑ High-gravity objects that distort space and time
    ❑ Causes of x-ray radiation

❑ *All of the above*

6. How do astronomers determine black holes exist if they are black and don't emit light?
   ❑ They send space probes to objects in space suspected to be black holes
   ❑ *They use telescopes to observe material outside the black hole*
   ❑ Both of the above
   ❑ There is no evidence that black holes really exist - black holes are theoretical

7. What evidence of black holes can you notice in this x-ray telescope image of the galaxy Centaurus A?

   ❑ A feeding supermassive black hole at the galaxy's center
   ❑ Multiple smaller black holes within the galaxy
   ❑ *Both A and B*
   ❑ There is no evidence for black holes in this image

8. What evidence of black holes can you notice in this x-ray telescope image of the Sombrero Galaxy?

   ❑ A feeding supermassive black hole at the galaxy's center
   ❑ *Multiple smaller black holes within the galaxy*
   ❑ Both A and B
   ❑ There is no evidence for black holes in this image

9. What evidence of black holes can you notice in this radio telescope image of a field of galaxies?

   ❑ *A feeding supermassive black hole at one galaxy's center*
   ❑ Multiple smaller black holes within the galaxies
   ❑ Both A and B
   ❑ There is no evidence for black holes in this image

10. Is this statement true or false?
    "Only a few galaxies in the universe have black holes."
    ❑ True
    ❑ *False*
    ❑ Don't know

11. Is this statement true or false?
"All the big galaxies in the universe have a black hole at their centers."
❑ *True*
❑ False
❑ Don't know

12. Is this statement true or false?
"Black holes have periods of high activity and periods of low activity."
❑ *True*
❑ False
❑ Don't know

Attitudes (science questions 1, astronomy questions 3, BH questions 3)

13. How much do you agree or disagree with the following statement?
"I enjoy learning science."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

14. How much do you agree with the following statement?
"I would feel confident talking about black holes with friends."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

15. How much do you agree or disagree with the following statement?
"Astronomy is boring."
❑ Strongly agree
❑ Agree
❑ Neither agree not disagree
❑ Disagree
❑ Strongly disagree

16. How interested are you in learning about astronomy?
❑ Extremely interested
❑ Very interested
❑ Somewhat interested
❑ A little interested
❑ Not at all interested

17. How much do you agree or disagree with the following statement?
"Learning about astronomy is worthwhile and necessary."
- ❑ Strongly agree
- ❑ Agree
- ❑ Neither agree not disagree
- ❑ Disagree
- ❑ Strongly disagree

18. How interested are you in learning about black holes?
- ❑ Extremely interested
- ❑ Very interested
- ❑ Somewhat interested
- ❑ A little interested
- ❑ Not at all interested

19. How likely are you to read an article about black holes in a newspaper, magazine, or on the Web?
- ❑ Extremely likely
- ❑ Very likely
- ❑ Somewhat likely
- ❑ A little likely
- ❑ Not at all likely

<u>Questions related to their visit (5)</u>

20. Please rate your enjoyment of this exhibition
- ❑ I enjoyed the exhibition a great deal
- ❑ I enjoyed the exhibition quite a bit
- ❑ I enjoyed the exhibition to some extent
- ❑ I enjoyed the exhibition a little
- ❑ I did not enjoy the exhibition

21. How likely are you to visit a similar exhibition, on another topic in astronomy, in the future?
- ❑ Extremely likely
- ❑ Very likely
- ❑ Somewhat likely
- ❑ A little likely
- ❑ Not at all likely

22. Has this exhibit increased or decreased your interest in black holes?
- ❑ I'm a lot more interested now
- ❑ I'm a little more interested now
- ❑ My interest is the same
- ❑ I'm a little less interested now
- ❑ I'm a lot less interested now

23. How much do you agree or disagree with the following statement?
"I learned something new from the Black Holes exhibition"
- ❑ Strongly agree
- ❑ Agree
- ❑ Neither agree not disagree
- ❑ Disagree
- ❑ Strongly disagree

24. How much do you agree or disagree with the following statement?
"The Black Holes exhibits showed everyday applications of science"
- ❑ Strongly agree
- ❑ Agree
- ❑ Neither agree not disagree
- ❑ Disagree
- ❑ Strongly disagree

Appendix I

Black Holes: Space Warps & Time Twists
Annotated Visitor Survey

1. With whom did you visit the Black Holes exhibit?

	Percentage of Respondents
Alone	3%
Colleagues	--
Friend(s)	25%
Classmates	2%
Family	70%
Other	4%

N=406

2. How much did you enjoy the Black Holes exhibit?

	Percentage of Respondents
Not at all	--
Only a little	5%
Some	21%
Quite a bit	42%
A great deal	32%

N=406

3. How much did you learn about black holes from the exhibit?

	Percentage of Respondents
Nothing	1%
Only a little	10%
Some	32%
Quite a bit	42%
A great deal	15%

N=405

4. What was the most interesting or surprising thing you learned about black holes today?

	Percentage of Respondents
General: that they exist	12%
Characteristics of Black Holes	63%
How Black Holes grow	7%
Learned how to use/navigate museum components	8%
Research facts about Black Holes	4%
Nothing	4%
I don't know/remember: I wasn't paying attention.	2%

N=325

5. What are one or two things that scientists still *don't know* about black holes?

	Percentage of Respondents
General information about Black Holes	20%
Nothing/not sure	20%
What do Black Holes lead to?	19%
What's inside a Black Hole	16%
Characteristics of Black Holes	14%
Rules of time around Black Holes	10%
Information about wormholes	2%

N=226

6. Please rate the success of the Black Holes exhibit in each of the following areas:
(Check one box for each item.)

	Not at all successful	Only a little successful	Somewhat successful	Very successful	Extremely successful
Helping you see how science impacts your everyday life	6%	14%	40%	31%	9%
Increasing your curiosity about black holes	1%	6%	22%	44%	27%
Helping you feel more confident talking about black holes	4%	17%	36%	30%	13%
Increasing your understanding of where black holes "fit in" in the universe	3%	14%	35%	36%	12%
Increasing your knowledge about the relationship between gravity and black holes	3%	12%	28%	40%	17%

N=397

7. Did you create a *Black Holes Explorer's Card* at the sign-in station?

	Percentage of Respondents
Yes	67%
No	33%
N=397	

8. Did you use the card?

	Percentage of Respondents
Yes	93%
No	7%
N=269	

9. Did you experience any problems trying to use the card?

	Percentage of Respondents
Yes	25%
No	75%
N=255	

10. Would you recommend to other visitors that they use a *Black Holes Explorer's Card*?

	Percentage of Respondents
Yes	96%
No	4%
N=246	

11. Do you plan to visit your personal Black Holes web site after leaving the museum today?

	Percentage of Respondents
Definitely not	5%
Probably not	12%
Probably	45%
Definitely	38%
N=253	

A few final questions about you:

12. Are you:

	Percentage of Respondents
Female	52%
Male	48%

N=389

13. Your age group:

	Percentage of Respondents
Less than 14	25%
15-17	8%
18-24	16%
25-34	13%
35-44	18%
45-54	13%
55-64	5%
65 or older	2%

N=389

14. Do you and/or anyone in your family work in a science- or astronomy-based field?

	Percentage of Respondents
Yes	15%
No	85%

N=385

15. Primary reason for visiting the museum today (Please check one)

	Percentage of Respondents
To visit the Omni Theatre/Planetarium/Other Museums in the Complex	14%
To visit the museum in general	68%
To visit specifically the black holes exhibit	13%
To visit another specific exhibit	5%

N=381

16. Please write any additional comments you have about the Black Holes exhibit or about the survey:

Appendix J

Follow-up Visitor Annotated Survey

1. Did you visit the Black Holes exhibit at the:

	Percentage of Respondents
Museum of Science, Boston	74%
McAuliffe-Shepard Discovery Center	14%
Springfield Science Museum	12%

N=49

2. How many times did you visit the Black Holes exhibit?

	Percentage of Respondents
Once	86%
2-3 times	14%

N=49

3. While you were at the Black Holes exhibit, did you get a Black Holes Explorer's Card?

	Percentage of Respondents
Yes	90%
No	10%

N=49

4. Which types of data did you collect in your Explorer's Journal at the exhibit?

	Percentage of Respondents
Photographs taken during my Black Hole Adventure	63%
Images of stars, galaxies and black hole evidence	56%
Predictions about black holes	47%
Video postcard recorded during my Black Hole Adventure	33%
I did not use my Explorer's card to collect data	19%
Voice recordings of my conclusions	16%
Other	9%

N=43; Note: Total exceeds 100% as respondents were able to select multiple options.

5. Please describe how having your online Explorer's Journal has affected your interest in Black Holes since visiting the exhibit:

	Percentage of Respondents
I'm a lot more interested now	16%
I'm a little more interested now	39%
My interest is the same	43%
I'm a little less interested now	--
I'm a lot less interested now	2%

N=44

6. How much do you remember about what you learned about Black Holes at the exhibit?

	Percentage of Respondents
A great deal	6%
Quite a bit	29%
Some	41%
Only a little	22%
Nothing	2%
I didn't learn anything at the exhibit	--

N=49

7. Was there any part of the exhibit that stood out for you?

	Percentage of Respondents
Yes	59%
No	41%

N=49

8. In your opinion, how successful was the Black Holes exhibit in each of the following areas? *(Check one box for each item.)*

	Extremely successful	Very successful	Somewhat successful	Only a little successful	Not at all successful
Helping you see how science impacts your everyday life	6%	42%	33%	17%	2%
Increasing your curiosity about black holes	19%	53%	28%	--	--
Helping you feel more confident talking about black holes	10%	29%	44%	10%	7%
Increasing your understanding of where black holes "fit in" in the universe	21%	44%	31%	--	4%
Increasing your knowledge about the relationship between gravity and black holes	17%	46%	29%	6%	2%
Helping you understand how scientists study black holes	13%	55%	21%	11%	--

N=48

9. What have you done in relation to black holes <u>since</u> attending the exhibit? *(Check all that apply.)*

	Percentage of Respondents
Talked about black holes with others	57%
Noticed the mention of black holes in the media	34%
Looked up information on black holes on the internet	32%
Visited the Black Holes Exhibit website	19%
Other	15%
Taught others about black holes	13%

N=47; Note: Total exceeds 100% as respondents were able to select multiple options.

10. Please describe your level of interest in black holes <u>since</u> your visit to the Black Holes exhibit.

	Percentage of Respondents
I'm a lot more interested now.	15%
I'm a little more interested now.	46%
My interest is the same.	37%
I'm a little less interested now.	--
I'm a lot less interested now.	2%

N=48

11. Please describe your level of interest in astronomy <u>since</u> your visit to the Black Holes exhibit.

	Percentage of Respondents
I'm a lot more interested now.	16%
I'm a little more interested now.	55%
My interest is the same.	27%
I'm a little less interested now.	2%
I'm a lot less interested now.	--

N=49

12. Have you visited the Black Holes: Space Warps & Time Twists website since your visit to the exhibit?

	Percentage of Respondents
Yes	24%
No	76%

N=49

Note: The frequencies for questions 13-25 are presented as numbers instead of percentages because the number of participants who responded is N=12.

13. How many times have you visited this *Black Holes: Space Warps & Time Twists* website?

	Percentage of Respondents
Once	9
2-3 times before	3

N=12

14. For what reason(s) have you visited the Black Holes website? *(Check all that apply.)*

	Percentage of Respondents
To learn more about black holes in general	5
To check my online journal	6
To check my telescope image of a black hole	6
To get a scientist's answer to a specific black hole question	--
To share information about the exhibit with a friend	2
To see my e-card	4
To look for activities to do	1
Other	1

N=12

15. How much have you enjoyed the Black Holes website?

	Percentage of Respondents
A great deal	2
Quite a bit	7
Some	2
Only a little	1
Not at all	--

N=12

16. How much did you learn about black holes from the website?

	Percentage of Respondents
A great deal	--
Quite a bit	6
Some	4
Only a little	2
Not at all	--

N=12

17. Which of the following resources on the website have you visited? *(Check all that apply.)*

	Percentage of Respondents
RSS feeds (e.g. portal to the universe)	2
Blogs	--
Podcasts	--
Black holes E-Cards	--
Do black holes really exist?	--
Audio files (e.g. sound of colliding black holes)	2
Video files (e.g. seeing a hidden monster)	2
Live GRB Map (Gamma-ray Bursts Real Time Sky Map)	2
Chandra Press Releases	5
Images from Chandra X-ray Image Gallery	6
Black holes Wallpaper	3
What are black holes?	4
What are we trying to find out?	--
Other	--
None of the above	2

N=12; Note: Total exceeds N as respondents were able to select multiple options.

18. Which of the following activities on the "Things to do" page have you carried out? *(Check all that apply.)*

	Percentage of Respondents
Interactive Flash Galleries	1
Printable activities, games, and interactive games	1
Sky Tours with WorldWide Telescope and Google Earth	3
MicroObservatory Robotic Telescope Network	2
Astronomy dialog	2
None of the above	5

N=12; Note: Total exceeds N as respondents were able to select multiple options.

19. Did you ask a scientist a question via the website?

	Percentage of Respondents
Yes	0
No	12

N=12

20. What question did you ask?
N/A

21. Did the scientist get back to you?
N/A

22. How satisfied were you with the scientist's answer?
N/A

23. What was the most interesting or surprising thing you learned about black holes on the website?

The whole exhibit was very interesting. We wanted to go back again to make cards for myself and husband but we ran out of time. Would love to see this come back to the museum again. There is so much that is still to be seen and taken in.
That Black Holes have an incredible amount of energy but yet they have no mass.
I enjoyed how black holes are portrayed by the media in movies and TV shows.
I already knew quite a bit about black holes. I also subscribe to Astronomy magazine. It was great to see my kids faces when they were able to see what I was talking about.
How prevalent they are
About gravity and temperature in the Black Hole.

N=6

24. While at the Black Holes website, did you sign in with your card and view your Explorer's Journal?

	Percentage of Respondents
Yes	8
No	4
I did not create a card	--

N=12

25. Which pages did you look at in your journal?

	Percentage of Respondents
My Models	2
Modeling Lab	1
Finding black Holes	3
Supernova Model	2
Simulate the Universe	2
My Evidence	2
Black hole's Temperature	3
Feeding a black hole	2
Weigh a black hole	2
Youth Media Connections	--
Black hole Adventure	4
Black holes in Pop Culture	4

N=7

Finally, a few final questions about you:

26. Are you:

	Percentage of Respondents
Female	53%
Male	47%

N=49

27. Your age group:

	Percentage of Respondents
Less than 14 years	10%
15-17 years	6%
18-24 years	18%
25-34 years	14%
35-44 years	23%
45-54 years	21%
55-64 years	6%
65 or older	2%

N=49

28. Do you and/or anyone in your family work in a science- or astronomy-based field?

	Percentage of Respondents
Yes	8
No	41

N=49

29. Please write any additional comments you have:

Appendix K

GRG'S SAMPLE

Summer 2007

- Focus Group conducted with youth from MIT's Youth Astronomy Apprenticeship (YAA) program.

Summer 2008

- Interviews with adults from MIT: Erika Reinfeld, Mary Dussault, and Vesal Dini.
- Interviews with adults from the Chabot Space and Science Center (CSSC): Tamara Schwarz and Lisa Hoover.
- Pre and post surveys from CSSC youth (N=11).
- Focus Group conducted through video conference with youth from CSSC.

Summer 2009-Spring 2010

Museum Exhibit Data Collection Sample

	Museum of Science, Boston, MA Summer 2009	**McAuliffe-Shepard Discovery Center, Concord, NH** Fall 2009	**Springfield Science Museum, Springfield, MA** Spring 2010	**Total**
Visitor Surveys	228	87	92	407
Observations	81	21	42	144
Exit Interviews	145	46	72	263
Follow-up Survey	36	7	6	49
Total	490	161	212	**863**

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