GOODMAN RESEARCH GROUP, INC.
Program Evaluation • Consultation • Market Research

The Black Holes Experiment Gallery

Summative Evaluation

Submitted to
Harvard Smithsonian Center for Astrophysics

Rucha Londhe, Ph.D.
Colleen Manning, M.A.
Laura Houseman
Irene F. Goodman, Ed.D.

August 2010
NSF grant # 0638963

Table of Contents

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.

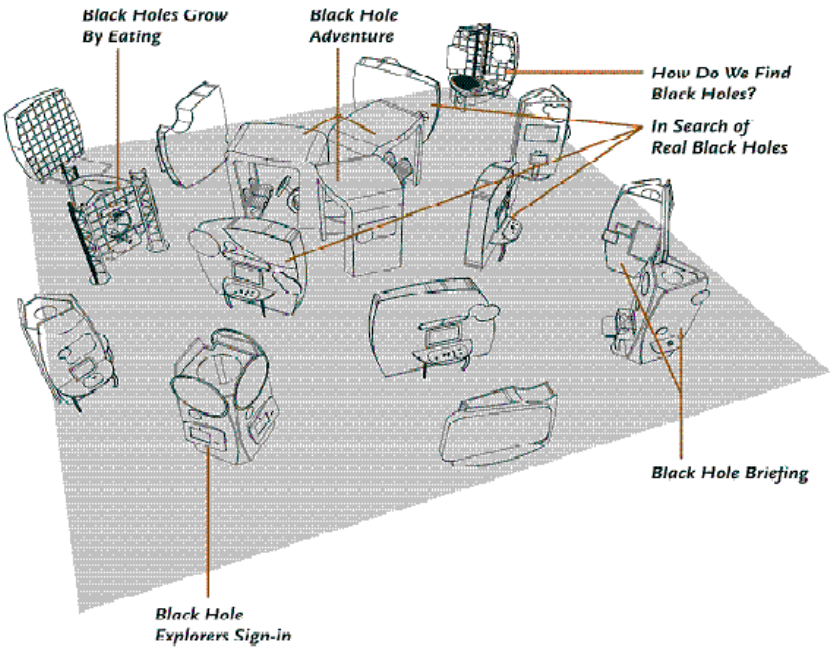
Table 1
BHEG deliverables

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

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 of the technologies of "radio frequency identification tags, 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

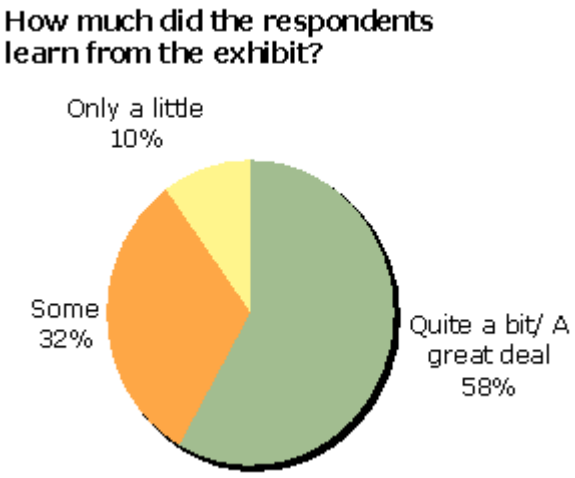
Content question on the pre (sign-in) and post (sign-out) stations[6]	**% of correct pre responses**	**% of correct post responses**
What are black holes?	47%	59%*
How do astronomers determine that black holes exist if they are black and don't emit light?	29%	31%
What evidence for black holes can you 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

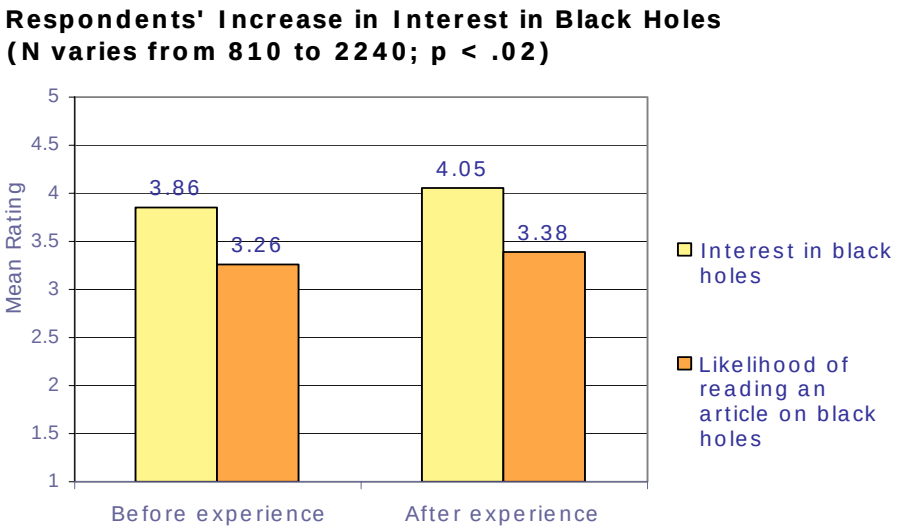
Response category	Examples of actual responses	% of responses
Correct response sophisticated	"By studying light as it bends around a black hole, using telescopes." "By monitoring orbits of objects around BH." "It's hard. Look at paths of stars around black holes, take infrared pictures, and use x-rays."	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

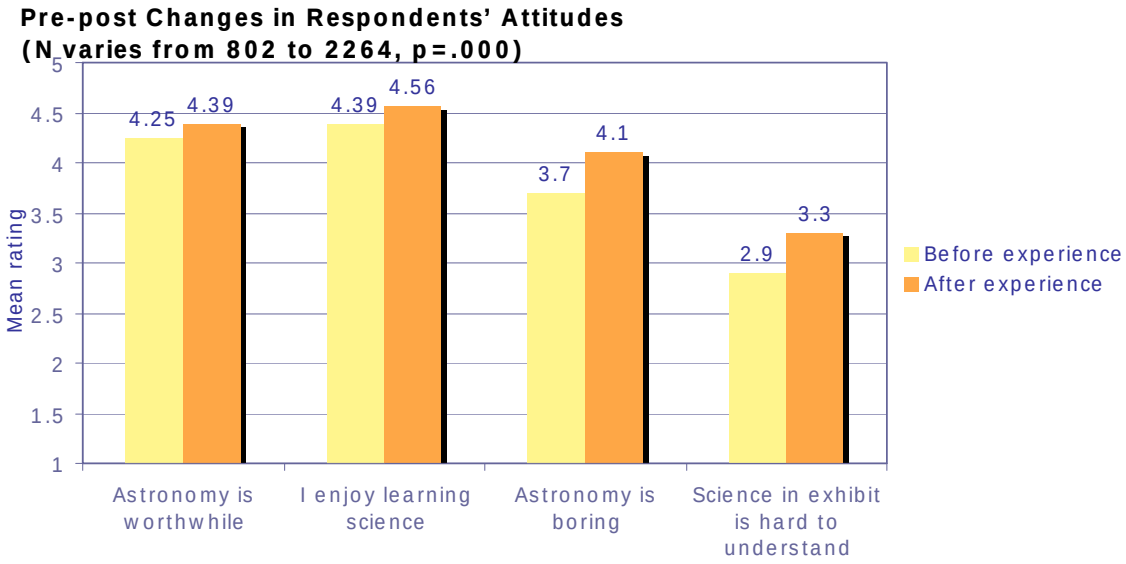
Stations	**Percentage of respondents indicating they enjoyed the station most**
Black Hole Adventure	44%
Got Gravity?	16%
How do we find Black Holes?	13%
Is it True what they say about Black Holes?	7%

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

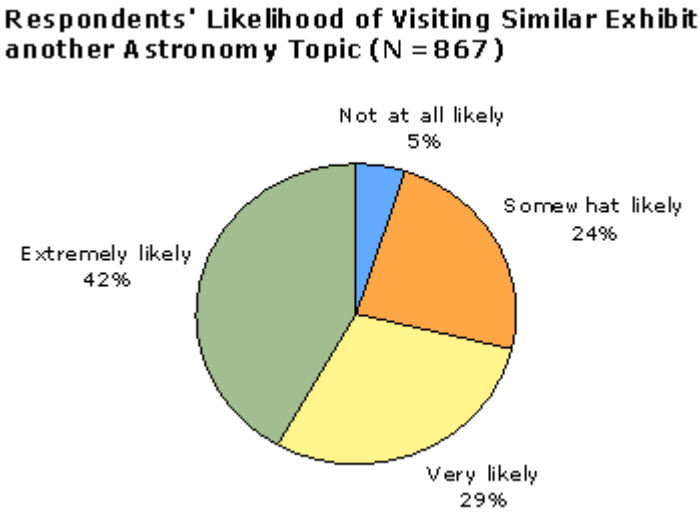


Impact Category D: Behavior

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

Goodman Research Group, Inc.

Main Office
955 Massachusetts Avenue, Suite 201
Cambridge, Massachusetts 02139

Tel: (617) 491-7033
Fax: (617) 864-2399

info@grginc.com
www.grginc.com

© 2010 Goodman Research Group, Inc.