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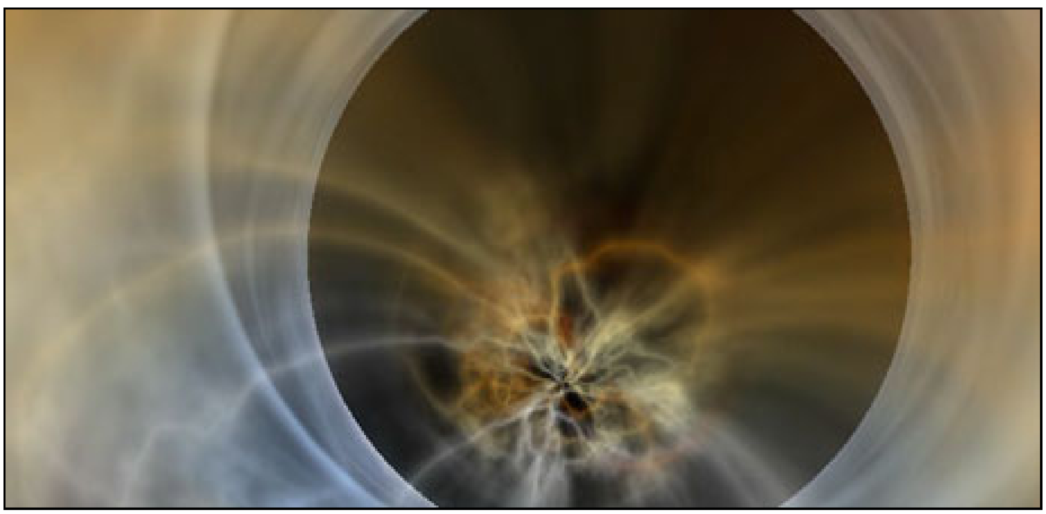
Black Holes: The Other Side of Infinity
Summative Evaluation of Planetarium Show with Students



Report for
Denver Museum of Nature and Science
by
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TABLE OF CONTENTS

EXECUTIVE SUMMARY
SUMMATIVE EVALUATION OF *BLACK HOLES* WITH STUDENTS
MULTIMEDIA RESEARCH, JUNE 5, 2006

With support from the National Science Foundation, Denver Museum of Nature and Science and Thomas Lucas Productions have produced a planetarium show entitled, *Black Holes: The Other Side of Infinity*. The 20-minute full-motion program uses scientific simulations and data-based animations to illustrate the death of stars and the birth and characteristics of black holes.
The summative evaluation focused on appeal to and impact on upper elementary school students.

Method

The participating fourth graders (n = 104) and fifth graders (n = 64) were drawn from four public schools in urban, suburban and rural areas around Denver, CO. Girls made up 61% of each of the grade sub-samples. A researcher administered a pre-viewing questionnaire as part of the regular classroom activity. About one week later, the students took their museum field trip to see *Black Holes: The Other Side of Infinity*. The day after the field trip, the researcher administered the post-viewing questionnaire. Thus, the research design is a one-group pretest-posttest design.

Appeal

The most positive aspect of the show according to most (27%) of students was the experiential "you are there" quality. Another 24% liked best the informative quality of the show, noting some specific piece of information or generally noting that they learned about black holes. Smaller portions of the sample liked everything (13%); liked the 3D look (11%); the kayakers (8%); the screen size (8%); and going inside a black hole (7%). Few students were negative about the show: 14% found the physical experience of the planetarium and the show uncomfortable; 6% were confused by parts of the show; and 5% noted that parts were scary.

Comprehension

Viewing the show significantly increased knowledge about black holes, as measured by two open-ended questions and a 10-point True/False content test. Viewing the planetarium show significantly increased 4^{th} and 5^{th} graders understanding of what a black hole is and how scientists know that black holes exist. Fifth graders gained significantly more knowledge than fourth graders in these content areas. In addition, the true-false test indicates that students learned other specifics about black holes; for example, that black holes are not dark inside; that when stars die, they can form black holes; and that our galaxy has a supermassive black hole at its center.

In conclusion, the summative evaluation shows that *Black Holes: The Other Side of Infinity* successfully both entertains and educates the upper elementary age student.

INTRODUCTION

With support from the National Science Foundation, Denver Museum of Nature and Science and Thomas Lucas Productions have produced a planetarium show entitled, *Black Holes: The Other Side of Infinity*. The 20-minute full-motion program uses scientific simulations and data-based animations to illustrate the death of stars and the birth and characteristics of black holes.

The summative evaluation reported here focuses on the following major outcomes:

- In what ways did the show appeal to elementary school students?
- To what extent did the show achieve its intended viewing goals?

METHOD

Procedure

From a list of 4th and 5th grade greater Denver elementary schools already signed up to attend the show at Gates Planetarium in May, 2006, four were recruited successfully to participate in the summative evaluation. A researcher administered the pre-viewing questionnaire as part of the regular classroom activity. About one week later, the students took their museum field trip to see *Black Holes: The Other Side of Infinity*. The day after the field trip, the researcher administered the post-viewing questionnaire. Thus, the research design is a one-group pretest-posttest design.

Questionnaires

Demographic variables. The pre-viewing questionnaire established respondents' status with respect to three classification variables: gender, grade and age.

Show appeal. Postviewing respondents explained what they liked and did not like about the show and why.

Show knowledge. Both the previewing and postviewing questionnaires included a knowledge test to assess understanding of show content: two open-ended questions (as best you can, explain what a black hole is and how scientists know that black holes exist) and ten "true-false-don't know" questions.

Sample

The participating fourth graders (n = 104) were drawn from two schools: a suburban public school with 18% minority students and a rural public school with 13% minority students.[1] The fifth graders (n = 64) were drawn from an urban public school with 35% minorities and a rural public school with 11% minorities. The largest minority group for these schools is Hispanic. About half of the children are 10 years old, one-quarter are 9 and one-quarter are 11. Girls make up 61% of each of the grade sub-samples.

Data Analysis

Pre-post comparisons are made with parametric tests (paired and two-sample t-tests) and non-parametric statistics[2] (one-tailed paired Wilcoxon signed ranks test). Qualitative responses are sorted and analyzed by keyword and key phrase. All relationships are analyzed for statistical significance, which is reported if p values are less than .05. Variables explored include grade and gender.

[1] Minority statistics from 2000 Census for CO school districts: http://www.dola.state.co.us/demog/SchlDistrict.cfm

[2] Parametric tests assume certain conditions about the population and require measurement at least in an interval scale. Non-parametric statistics are used when the assumptions of parametric tests may not be met and when data are in ordinal or nominal scales.

RESULTS: APPEAL

What was Liked about Show

In an open-ended question, students were asked what they liked about the *Black Holes: The Other Side of Infinity* and why. Table 1 below presents the major categories of what viewers liked most, in order of most to least frequently mentioned categories for the sample.

The majority (27%) of respondents focused on the experiential "you are there" quality as the most positive aspect of the show. Another 24% liked best the informative quality of the show, noting some specific piece of information or generally noting that they learned about black holes. Smaller portions of the sample liked everything (13%), liked that the 3D look (11%), the kayakers (8%), the screen size (8%), and going inside a black hole (7%).

Table 1. What viewers liked about *Black Holes*[3]

Categories	*%*	*Examples of Responses*
Experiential quality	27%	• *How it felt like you were moving and that it looked like they were coming at you. It was like you were in a spaceship.* • *How it makes you feel like you are really there.* • *How it seemed like you were in space.* • *It felt like you were actually there and how everything looked so real.*
Informative quality	24%	• *How dead stars form a black hole because I never knew that.* • *I liked how it showed us how black holes are made.* • *It was very interesting and was filled with information.* • *I learned more about black holes.*
Liked everything	13%	• *I liked all of it because it was so good.*
3D quality	11%	• *I like that it is 3D because that is cool.* • *How the stuff comes popping out at you. It was cool.*
Kayakers	8%	• *When the people were rowing in the water because that really helped me imagine what a black hole was like.* • *I liked when the canoes were in the hole in the water.*
Huge screen	8%	• *I really liked the humongous screen.* • *The huge screen was cool.*
Going inside the black hole	7%	• *When we went inside a black hole because it was really cool to see what it was like.* • *When we went into the black hole because it was fun.*

[3] Percentages have been rounded off and add up to more than 100% because viewers listed more than one category liked.

What was Not Liked about Show

Table 2 presents categories of what viewers did not like about *Black Holes: The Other Side of Infinity*. One-half of viewers like all of the show. Smaller portions of the audience disliked part of the physical experience of the planetarium (14%), found parts of the show confusing (6%) or scary (5%).

Table 2. What viewers did not like about *Black Holes*[4]

Categories	*%*	*Examples of Responses*
Liked it all	48%	
Physical experience	14%	• *It made me dizzy and I almost barfed.* • *I got a headache from spinning and turning.* • *My head having to go all around the screen to find the thing they were showing.* • *The chairs in front were hard to sit in and see.* • *The seats were uncomfortable.*
Confusing	6%	• *They didn't keep the words understandable.* • *It was a little confusing inside the black hole.* • *Some of the stuff I didn't understand.*
Scary	5%	• *It's scary how black holes suck things in them and can't escape.* • *It made me scared of what could happen to our planet.* • *Needed more on how black holes are being studied.* • *Not much new information was given. I already knew a lot of it.* • *Ending very abrupt – leaves a lot of questions open.* • *I didn't like how there was not closure at the end of the show. I felt like in the end it is all still "theory" and a lot is still to be proved.*

RESULTS: COMPREHENSION

Recall of main content points as presented in *Black Holes: The Other Side of Infinity* was assessed via two open-ended questions and a 10-point True-False-Don't Know test.

What is a black hole? Before and after seeing the show, students were asked to explain as best they could what a black hole is. Before viewing the show, 12% of students had a correct idea about a black hole, writing most frequently that it is a dead or exploded star; for example:

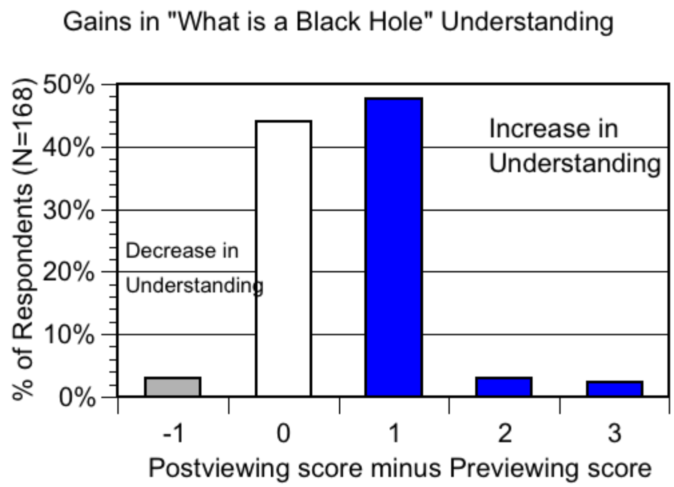
It's the end of a star's life.
Where a star explodes.
A dead star.
The end of life for a star.
Something that happens when a star dies
A star that exploded. The explosion is called a supernova.

[4] Percentages have been rounded off.

After viewing the show, 60% of students had at least one correct idea. The post-viewing ideas were more diverse including the dead/exploded star description as well as massive gravity, light not being able to escape, and a hole in space-time; for example:

A star that has died.
A really old star that blows up and becomes a black hole.
It is the remnants of a star that exploded.
A blown up star that has lots of gravity.
A very big gravatative hole.
Inside a black hole is not dark. Not even light can escape the black hole.
A hole in space where even light can't escape.
A hole that's in space time that's made from a supernova.
A mass so heavy it warps space time so much, it forms a black hole.

Students were given 1 point for one correct idea, 2 points for 2 correct ideas, and 3 points for 2 or more correct ideas only if the response did not include any inaccurate concepts. Post-viewing understanding of what a black hole is was greater than pre-viewing understanding in 53% of the sample (see dark bars in chart to the right). Understanding did not change for 44% of students (see white bar in chart to the right). Understanding decreased for 3% (see gray bars to the left side of chart). Viewing the planetarium show significantly increased student understanding of what a black hole is.[5]



Out of a possible 3 points, the mean achievement score after seeing the show is .71, significantly higher than the mean score of .13 before seeing the show.[6] Both grades and both genders scored significantly higher on their post-viewing response than on their pre-viewing response. There were no significant differences in gain scores between boys and girls; however, fifth graders gained significantly more than fourth graders in their understanding about what a black hole is.[7] (see Table 3 of sub-sample means below).

Table 3. Mean "What is a Black Hole" scores for sub-samples

	Pre	Post	Gain		Pre	Post	Gain
4th	.14	.58	.44	Girls	.09	.69	.60
5th	.11	.92	.81	Boys	.20	.74	.54

[5] One-tailed Wilcoxon matched-pairs signed ranks non-parametric test looks at the direction and relative magnitude of the pre-post differences in scores for individual students; $p \leq .0001$).
[6] Paired t - test, $p < .0001$.
[7] Two sample t-test, $p = .002$.

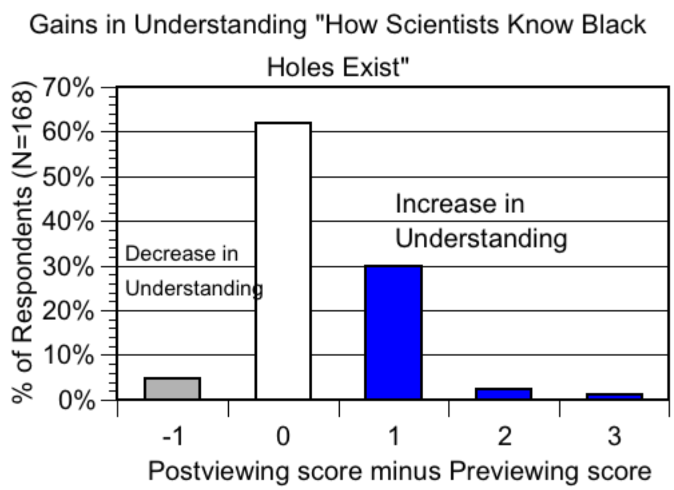
How do scientists know that a black hole exists? Before and after seeing the show, students were asked to explain as best they could how scientists know black holes exist. Before viewing the show, 16% of students had some correct idea about what scientists do, writing most frequently that they use telescopes or satellites; for example:

They see black holes in space with their telescopes.
They use big telescopes that can see in space.
They have satellites that can take pictures of the black holes.

After viewing the show, 63% of students had a correct idea. Most (40%) of the students said that scientists use telescopes or satellites (1 point) or looked for supernovae (1 point); 1% suggested looking for radiation (2 points); and 2% mentioned looking at surrounding stars (3 points); for example:

They use a telescope that has lenses that could see so far in the sky.
Because of a telescope named Swift sent up to study black holes.
By using satellites in space.
They detect the radiation it gives out when it's formed.
They can see stars circling around it.

Post-viewing understanding of how scientists detect black holes was greater than previewing understanding in 33% of the sample (see dark bars in chart to the right). Understanding did not change for 62% of students (see white bar in chart to the right). Understanding decreased for 5% (see gray bars to the left side of chart). Viewing the planetarium show significantly increased student understanding of the methods scientists use to detect black holes.[8]



Out of a possible 3 points, the mean achievement score after seeing the show is .49, significantly higher than the mean score of .16 before seeing the show.[9] Both grades and both genders scored significantly higher on their post-viewing response than on their pre-viewing response. There were no significant differences in gain scores between boys and girls; however, fifth graders gained significantly more than fourth graders in their understanding of how scientists know black holes exist.[10] (see Table 4 of sub-sample means below).

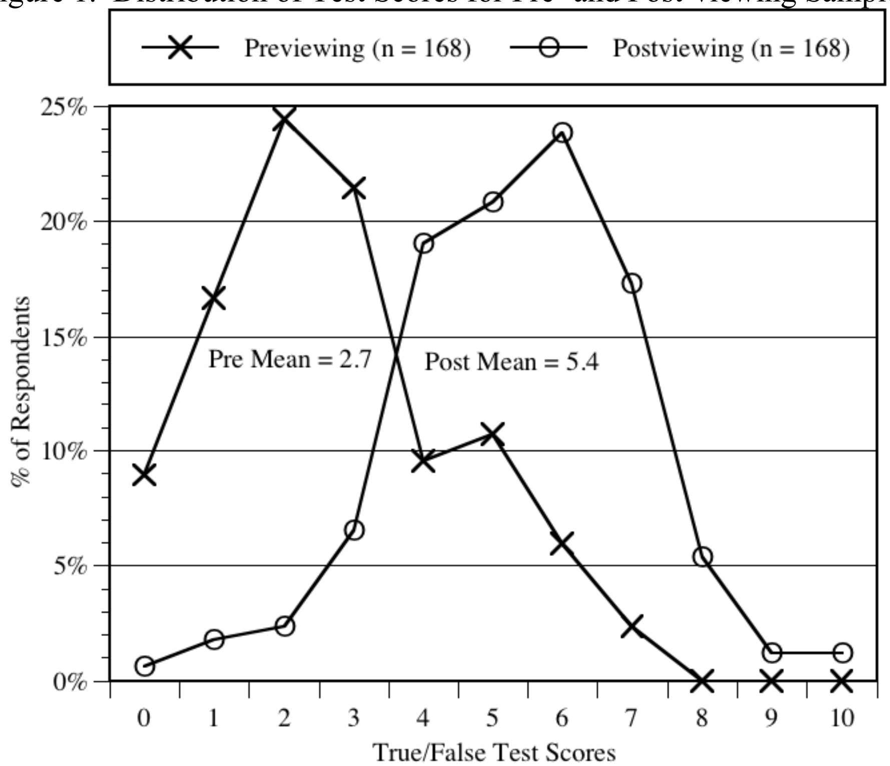
Table 4. Mean "How Scientists Know BHs Exist" scores for sub-samples

	Pre	Post	Gain		Pre	Post	Gain
4th	.22	.37	.15	Girls	.15	.50	.35
5th	.06	.70	.64	Boys	.18	.49	.31

8 One-tailed Wilcoxon matched-pairs signed ranks non-parametric test looks at the direction and relative magnitude of the pre-post differences in scores for individual students; $p \leq .0001$).
9 Paired t - test, $p < .0001$.
10 Two sample t-test, $p = .002$.

True-False Test. In the ten-point True-False-Don't Know test, "Don't Know" was provided as a possible answer but was scored as "incorrect." Figure 1 compares the distribution of test scores for the previewing and postviewing tests.

Figure 1. Distribution of Test Scores for Pre- and Post-viewing Samples



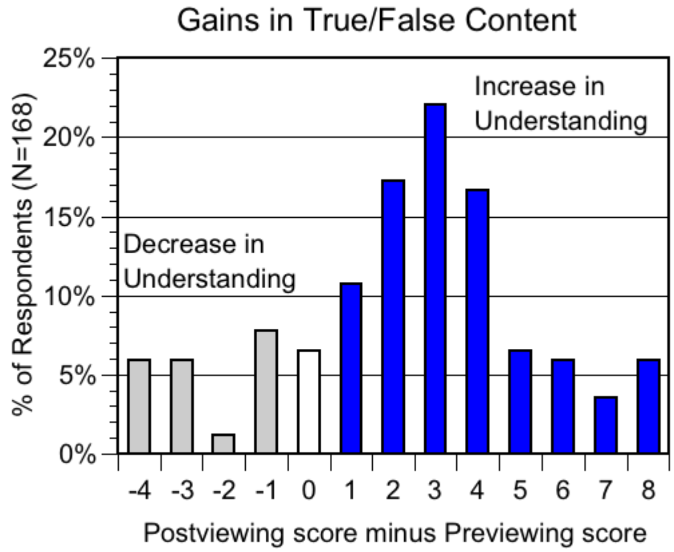
The mean achievement score after seeing the show is 5.4, significantly higher than the mean score of 2.7 before seeing the show.[11] Both grades and both genders scored significantly higher on the posttests than on their pretests, and there were no significant differences in gain scores between 4th graders and 5th graders or between boys and girls (see Table 5 of sub-sample means below):

Table 5. Mean T/F scores for sub-samples

	Pre	Post	Gain		Pre	Post	Gain
4th	2.7	5.1	2.48	Girls	2.5	5.2	2.71
5th	2.9	5.7	2.84	Boys	3.2	5.7	2.48

[11] Paired t - test, p < .0001.

For the true-false test, post-viewing understanding was greater than pre-viewing understanding in 83% of the sample (see dark bars in chart to the right). Understanding did not change for 7% of students (see white bar in chart to the right). Understanding decreased for 10% (see gray bars to the left side of chart). Viewing the planetarium show significantly increased student understanding of content related to black holes.[12]



[12] One-tailed Wilcoxon matched-pairs signed ranks non-parametric test looks at the direction and relative magnitude of the pre-post differences in scores for individual students; $p \leq .0001$).

Figure 2 provides a more detailed presentation for individual test items. Only one of the 10 statements was answered correctly by more than half of the students before seeing the show: 53% correctly said that the statement "Black holes are passageways to other universes" is false, but this correct response rate decreased to 42% after viewing. (Adults also found this content confusing in the show.) Six of the 10 statements were answered correctly by more than half of the students after viewing the show.

Figure 2: Percent correct responses for each true-false statement before and after viewing film